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Field investigation of thermal comfort level of patients and surgical staff in operating rooms at St Olavs hospital

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PREFACE

This present study is written during my exhange studies in Norwegian University of Science and Technology at Department of Energy and Process Engineering. The study was completed with good collaboraton with St. Olavs hospital and the research infrastructure The Operating Room of the Future (FOR). Thanks to these institutes, I get the best experience in Norway. There have been many days around this study and following persons have a good part of this. Firstly, I thank my supervisor Guangyu Cao, who have been a good advisor for this half year and gave me a lot of necessary tips to improve my study. My co-supervisor Anna Bogdan has given me a lot good support and ideas, to reach to the best result of my thesis. My supervisor in Estonia, Martin Thalfeldt, has been good helping hand to get my study here started and gave me good tips. Also, thanks for all workers in St. Olavs hospital and in NTNU, with who I have had the honor to meet and who have been helping me a lot during this semester.

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And last, but not least, thanks for my family giving me good support during that time. To be in abroad and work for the master thesis is not the easiest thing to do. Also, I am so grateful that I had three nice roommates, who have been so supportive for all this semester.

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ABSTRACT

In healthcare facilities and hospital environments, it is essential to be able to predict thermal comfort as a parameter of indoor air quality. Unstable thermal conditions are critical in the operating room environment and may reduce the work efficiency and increase the possibility of surgical errors. At the same time, the main purpose of ventilation systems in operating rooms is to enable clean and comfort indoor environment. Although, there is an increasing number of studies covering the area of thermal comfort, there have been few literature reports written on the comfort of healthcare staff and patients in hospitals and in the operating room environment.

Therefore, the purpose of this study is to investigate and estimate the thermal comfort leve of patient and surgical staff at St. Olavs hospital operating rooms with two ventilation solution. This study is going to base on PMV-PPD level and to deduce the thermal sensation from environmental conditions (temperature, humidity and airflow), and from personal conditions (their metabolic rate and clothing insulation).

The research methods include the thermal environment measurements in hospital operating room after mock surgeries, a survey among surgical staff and patients, to get information about real sensation. There has been also conducted the observation, where the mean focus has been put to the estimation of the activity level of every occupant. Also, the clothing thermal resistance of every occupants in operating room has been estimated by literature review. Furthermore, the skin temperature of surgeons has been investigated with thermal camera.

As a result, the PMV-PPD level of four occupant group in operating room has been calculated from measurements and the thermal sensation of real surgical staff has been deduced from survey.

SAMMENDRAG

I helsetjenester og sykehusmiljøer er det viktig å kunne forutsi termisk komfort som en parameter for inneluftkvalitet. Ustabile termiske forhold er kritiske i operasjonsrommet og kan redusere arbeidseffektiviteten og øke muligheten for kirurgiske feil. Samtidig er hovedformålet med ventilasjonssystemer i operasjonsrommet å muliggjøre et rent og komfortabelt innemiljø. Selv om det er stadig flere studier som dekker termisk komfort, har det vært få litteraturrapporter skrevet om komforten til helsepersonell og pasienter på sykehus og i operasjonsrommet.

Derfor er formålet med denne undersøkelsen å undersøke og anslå den termiske komforten til pasient- og kirurgisk personale i to operasjonsrom med ulike ventilasjonsløsninger, på St. Olavs sykehus. Denne studien skal basere seg på PMV-PPD-nivå og å utlede den termiske sensasjonen fra miljøforhold (temperatur, fuktighet og luftstrøm) og fra personlige forhold (deres metabolske varmeproduksjon og isolasjonsnivå på klærne de bruker).

Forskningsmetodene inkluderer termiske miljømålinger i operasjonsrommet etter simulerte operasjoner, en undersøkelse blant operasjonspersonell og pasienter, for å få informasjon om ekte sensasjon. Det har også blitt gjennomført observasjonen, der det er lagt vekt på estimeringen av aktivitetsnivået for hver personell. Dessuten har den termiske motstanden til operasjonspersonellets klær blitt estimert ved litteraturgjennomgang. Videre har hudtemperaturen hos kirurger blitt undersøkt med termisk kamera.

Som et resultat har PMV-PPD-nivået på fire occupant-lag i operasjonsrommet blitt beregnet ut fra målinger, og den termiske sensasjonen til et reelt kirurgisk personale blitt utledet fra undersøkelsen.

CONTENTS

ABBREVIATIONS

DV – dilution ventilation or dilution ventilation solution

EXP – experiment (EXP1-4 are the experiments in dilution ventilation operating room and EXP5-6 are the experiments in laminar air flow operating room)

LAF – laminar air flow or laminar air flow ventilation solution

MET – metabolic rate

OR – operating room

PMV – predicted mean vote

SD – standard deviation

Distribution nurse – the nurse, who is not in sterile zone and delivers the objects to clean zone nurse.

Mock surgery – simulated surgery, what is mostly used to imitate the real surgery as same as possible (sterilization and movements)

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1 INTRODUCTION

1.1 Motivation: thermal comfort in OR is challenging

Operating room conditions are very clarified conditions. It is named cleanroom technology, what is ,,a matter of maintaining an indoor environment clean enought to avoid contaminating operating wounds, drugs, food and beverages, microelectronic components, micromechanic components and optical components." (1) The requirements to reach these conditions are therefore demanding, that there is difficult to reach to thermal comfort of all occupants in operating room.

Nevertheless, this is essential to have a good thermal environment in operating room - ,,Whereas productivity, as the ability to perform mentally and physically demanded tasks, is influenced by the thermal environment, therefore unsatisfied thermal environment will cause low productivity, of surgical staff work." (1) Clear is that, the thermal comfort is not the first aspect to control in operating room, but it is very essential also in patient perspective to assess patient thermal comfort level before, during and after operation. (2)

R. Van Gaever et al. brings out in their study, that ,,it is not possible to achieve thermal comfort for each member of the surgical staff by only revising the HVAC standard." It is essential to adapt the ventilation system to meet thermal needs of the surgical staff without losing the protective properties to prevent SSI (surgical site infection) – there is need of future research (3)

There have been made several studies about thermal comfort in operating rooms, but still too less to have a good overview. Therefore, the idea of this study to collect more information for making the better overview about thermal comfort in operating rooms.

1.2 Objective

The overall objective of this thesis is to get an overview of thermal comfort of surgical staff and patient in various operating rooms with two different ventilation solutions at St. Olavs Hospital. Under main investigation are four occupant groups (surgeons, anesthetists, distribution nurses and patient). To clarify the objective, the following three research questions are formulated:

Research question: What is the thermal comfort level of four occupant group in operating room with LAF and dilution ventilation solution?

> **Subquestion 1**: What is the predicted thermal comfort of four occupant group in OR with LAF and dilution ventilation solution?

Subquestion 2: What is the real thermal comfort of four occupant group in OR with LAF and dilution ventilation solution?

1.3 Methodology and structure of study

To achieve the objective of this studi, there is going to be used three methods:

1. Field measurements of indoor thermal environment to calculate the thermal comfort level of surgical surgical staff in mock surgery
2. Observation of real surgical process to estimate thermal comfort levels of surgical staff and patient
3. Survey – using questionnaires to collect direct thermal comfort feedback from surgical staff

In first chapter, the author has been collected the literature about all aspects, what will concern the thermal comfort in operating room. There has been brought out earlier studies and suggestions.

In methodology part, the author will describe these three methods in detail and bring out the devices, what have been used in this study.

In third part, the results are divided by method and will be described in occupant level.

In discussion part, there can meet the discussion over the investigations, the suggestions how to improve the thermal environment in operating room and also ideas for future work.

In conclusion, there can see the good overview of all the results and in the end of the document are also some appenicies to complete this study.

2 LITERATURE REVIEW

2.1 Thermal comfort in operating room

ASHRAE Standard 55-2017 defines thermal comfort as a ,,condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation‟ (4).

The first condition necessary for thermal comfort for a person under long exposure to a given environment is the existence of a heat balance, but it is also a condition which is naturally far from sufficient, because for human body it is possible to create heat balance without meeting thermal comfort. (5) ,,Insufficient heat loss leads to overheating (hyperthermia), and excessive heat loss results in body cooling (hypothermia). (6)

If in common HVAC systems principal purpose is to provide conditions for human thermal comfort (6), then in hospital operating rooms, the main aim is to prevent the infection of the surgical wound by airborne infectious microorganisms. (7) As a supplement, the technical HVAC standards state that to prevent SSI (surgical site infection), the thermal comfort must be achieved for the patient and all members of the surgical staff in the operating room. (3) One general reason is that the thermal satisfaction influences productivity and health of surgical staff. (8) Other reason is in patient perspective - the American Society of PeriAnesthesia Nursing standard recommend to put an effort to control patient thermal comfort level regularly before, during and after operation, because it will decisively influence the wellbeing of patient – hazard of hypothermia. (2)

Due to biological variance of people, it is not possible to satisfy everyone at the same time. Therefore, it is essential to achieve the environment conditions where the highest possible percentage of the people will meet the thermal comfort. (5) To reach to that state in operating room, Wyon et al. concluded, that the only way seem to be for the anaesthetists and nurses to wear rather warmer clothing in operating rooms. (9)

2.1.1 Main variables influencing the thermal comfort

The most important variables which influence the condition of thermal comfort are the environmental parameters (air temperature, mean radiant temperature, relative air velocity and water vapour pressure in ambient air) and individual parameters (as activity level and thermal insulation of clothing). (5) Furthermore, according to ISO 7726:1998, for the analyzis of the thermal balance between man and the thermal environment, the evaporative resistance of clothing and external work (for most activities it is nil) are also decisive quantities. First one determines the heat losses throught the evaporation. (10)

2.1.1.1 Air temperature

The body responds to many illnesses or infections with a rise in temperature. The ability of the body to regulate its own temperature is impaired during these periods of "fever". An environment that is either too hot or too cold may delay recovery. Too warm environment may even lead to heat stroke and death. Cool conditions can result in impaired mobility due to joint stiffness in the extremities; under extreme cold stress, hypothermia and potentially death may occur. For the ill persons, have increased sensitivity to the environment." (1)

Air temperature is mostly used indicator to determine indoor climate, but what comes with thermal comfort, it is just one of six parameters and should always be considered in conjunction with other factors. (8) ,,Generally, there are thermal non-uniformities in OR air movement and air temperature that have a local effect on skin temperatures, and that can further influence the overall thermal sensation and comfort of the occupants." (8)

Different standards recommend the air temperature adjustable between 19°C to 26°C. Mainly 20°C to 24°C (ASHRAE 170:2013), because use of lower or higher temperature is acceptable only, when patient comfort and/or medical conditions require those conditions. (11) The American Society of PeriAnesthesia Nurses (ASPAN) Standard recommends that the ambient room temperature should be at or above 24°C before operation (preoperative) and between 20°C to 25°C during the operation (hereby, limitation of patient skin exposure to lower ambient environmental temperatures is recommended). (2) However, ,,Johnston and Hunter (1984) stated, that in order to prevent the patient from becoming hypothermic during surgery, a temperature between 24°C and 26°C is required." (11)

Finally, ,,Balaras et al. concluded in their study that a constant temperature within the recommended range would produce maximal comfort." (8) And, to overcome the heat production of occupants, lights and other medical equipments the recommendation is to design the supply air temperature lower than the room air temperature. (3)

2.1.1.2 Relative humidity and water vapour pressure

ISO 7726 says that the absolute humidity of the air is taken into account when determining the transfer of heat by evaporation from a subject. A high air humidity reduces evaporation of sweat and thus constitutes a thermal stress for the subject.

Human body uses sweating to control the heat balance and cool the body, also named as evaporative heat loss. The relative air humidity has strong impact on that – the smaller is the vapour pressure in ambient air (as relative humidity), the bigger is the heat loss throught the skin by vapour diffusion. (5) In conclusion, body needs to produce more vapour by itself to allocate the heat. In addition, humidity also affects the concentrations of allergens, bacteria and contaminants. High humidity levels may result growth of airborne bacteria that are attached to the water molecules. In contrast, low humidity levels are conducive to blood coagulation, will contribute towards skin and nose drying, throat irritation and respiratory problems. (8)

There are also few earlier studies, who have been investigated the impact of relative humidity. Balaras et al. concluded in their study, that in investigated operating rooms there were lack of humidity control, what in most cases resulted to significant variations and overall very low levels. (11) Also, San Jose-Alonso et al. took out the problem that due to lack of humidity control in the installations, the PMV level varies widely (-0,7 to 0,6) over a day. (12) ASHRAE Standard 170 recommends to design relative humidity between 30-60%.

2.1.1.3 Relative air velocity

Air velocity is defined by EN ISO 13731:2001 as the magnitude of the velocity vector of the flow at the measuring point considered, over an interval of time (measuring period).

,,The air velocity in a space can influence the convective heat exchange between a person and the environment. This influences the general thermal comfort of the body (heat loss) and the local thermal discomfort due to draught." (13)

Zhang Rui et al. stated in their study on biological contaminent control strategies in hospital operating rooms, that air velocities, in the case of diffusers with laminar flow are higher than in the case of mixed flow difusers. Also, they pointed out, that DIN 1946-4:2008 requires that, the local velocity should stay within the range of 0,23 – 0,45 m/s and the average velocity should be at least 0,25 m/s, or stay within the range of 0,23 – 0,25 m/s. In case, to use the higher air velocities are desirable for contaminant control, but will lower the thermal comfort of users. (14) ASHRAE 170-2013 recommends to use air velocity in LAF ventilation operating room between 0.15-0.18 m/s. Furthermore, the ASHRAE Standard 55-2017 recommends that for operative temperatures below 23,0 °C, the limit of average air speed v_a shall be 0,2 m/s.

2.1.1.4 Mean radiant temperature

ISO 13731:2001 defines the mean radiant temperature as ,,uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform enclosure". It is often calculated to determine the influence of thermal radiation on a person's heat balance. (Nilsson, 2003)

Barbara E. Tredre stated that ,,the MRT at a point in a room will vary with the proximity of that point to the boundary surfaces radiating with high or low intensity, and it will be affected by the radiation received from occupants, furniture or equipment." (Tredre, 1964)

Uscinowicz et al. studies calculations shows that medical staff is not exposed to high radiant temperatures, but the mean radiant temperature was in some locations considerably higher than the ambient temperature – mainly vicinity of shadowless operating lamps or medical appliances. (15) For confirmation, Wyon et al. stated that surgeons and assistant surgeons are exposed to thermal radiation from the operating lamps. (9) Likewise, Gaever et al. found out, that surgeons feel uncomfortably warm mainly due to the influence of the surgical lamps on the mean radiant temperature and also on air velocity. (3)

In addition, Uscinowicz et al. also stated, that the work area of particular groups of operating staff is different. Surgeons area is heavily influenced by surgery lamps, the patient temperature control system and others appliances generating high heat gains. As a result of their operation the air temperature and mean radiant temperature increases. Other areas, where medical staff will be located, is also influenced by heat gains, however this is smaller than in the case of surgeons. (15)

,,Estimating the MRT is rather difficult and time-consuming since it depends on the individual surface areas and their temperatures, the distance and angle factors between those surfaces and the occupants, and whether those persons are seated or standing." (8)

2.1.1.5 Metabolic rate

Human requires energy to perform work and produce heat to maintain an internal body temperature of around 37 °C. Heat production depends on activity level. If the activity level is high, they produce too much heat and the body will sweat – that will cause discomfort. If activity level is low, then too little heat is produced. It may cause blood withdrawn from the hands and feet, skin temperature will fall and the person will feel cold and uncomfortable. ,,Environmental conditions and clothing required for comfort will therefore directly depend upon metabolic production." (16) In confirmation, Gauthier and Shipworth showed that in the PMV-PPD calculations the most influential parameter are the metabolic activity and also, the clothing insulation. (17)

In operating room, every occupant have different metabolic rate. From literature, there have been found some conditions, what have been investigated before (Table 1).

Reference	Conditions	Surgeon	Distribution nurse	Anesthetist	Patient	Method
(18)	t_a = 24,5 °C, RH = 50%	MET = 139,7 W/m^2; CLO = 0,22 m^{2}k /w,	MET = 98,9 W/m^2; CLO = 0,14 m^{2}k /w	MET = 110,6 W/m^2; CLO = 0,14 m^{2}k /w	MET = 46,6 W/m^2; CLO = 0,2 m^{2}k /w	From room model (CFD)
(15)	Many different	MET = 120 W/m^2	MET = 100 W/m^2	MET = 70 W/m^2	MET = -	From authors earlier studies
(7)	t_a = 19.5-25 °C, RH = 43%	MET = 93,12 W/m^2; CLO = 0,133 m^{2}k /w,	MET = 81,5 W/m^2; CLO = 0,065-0,121 m^{2}k /w,	MET = 81,5 W/m^2; CLO = 0,065 m^{2}k /w,	MET = 40,2 W/m^2; CLO = 0,093-0,171 m^{2}k /w,	From ASHRAE Handbook – Fundamentals 1997

Table 1 Metabolic rate and clothing insulation from earlier studies

2.1.1.6 Clothing in operating rooms and its thermal and vapour resistance

The main idea of clothing in operating room is to ,,minimize the spread of infective agents to and from patients' operating wounds." For personnel working in an operating room, the medical clothing must be made of materials resistant to the permeation of blood and other body liquids. (19) Standard EN 13795:2013 set requirements for materials used to produce medical clothing. As indicated by Anna Bogdan et al. (19), that in Annex D the standard brings out the variables what will impact the overall comfort of surgical gowns and clean air suits, but any requirements and concrete parameters regarding thermal comfort are not given. About surgical drapes the standard says that it ,,should provide reasonable physiological comfort to support the physical condition of the patient." (20)

Clothing, what are used or tested in earlier study (19), are:

a) Surgical underwear, also known as clean air suit, is made of polyester cloth with carbon fibre, which, in theory was supposed to be characterised by high humidity absorption;
b) Cotton surgical gown for single use
c) ,,*barrier* surgical gown for multiple use, worn during standard risk operations, made of polyester cloth with the addition of carbon fibre. The gown's critical area (front and sleeves) is made of liquid proof fabric of higher resistance (weight 300 g)";
d) ,,*barrier* surgical gown for multiple use, worn during high risk operations, made of polyester cloth with the addition of carbon fibre on the back. The gown's critical

area (front and sleeves) is made of laminate with a PTFE (polytetrafluorethylene) membrane‟;

e) ,,lead surgical apron, Pb 0.5 mm, used to make x-ray pictures (mass 3.349 kg).‟;

Mora, English & Athienitis (2001) have a good conclusion of their study, that since the surgical staff cannot reduce their clothing level (0,86 clo), for the thermal comfort the air temperature should be about 19°C. ,,At this themperature, the patient would require at least 1,6 clo and the dilution nurses and anesthetists at least 0,9 clo (add t-shirt and jackets to their uniform).‟ (7)

,,Thermal insulation tests performed at the Central Institute of Labour Protection – National Research Institute on surgical clothing ensembles in the past years, selected in accordance with WHO recommendations and the requirements of EN ISO 9001 [7], showed that their thermal insulation lies within the limits: 0.54 ± 0.01 clo - 0.95 ± 0.01 clo [8]. At the same time, it was determined that surgeons will experience thermal comfort when the temperature in an operating theatre amounts to 20 - 24 °C and their clothing is composed of shoes, cotton socks and a surgical ensemble made of nonwoven fabric, similar to cotton, containing viscose fibres of good air and water steam permeability. Likewise, thermal comfort can also be achieved in the temperature range of 16 - 20 °C, when the surgical outfit includes the above mentioned garment in combination with a thermoplastic 2-layered hygienic surgical gown, a made of nonwoven fabric and polypropylene foil, which is liquid-proof.‟ (19)

,,Furthermore, the results have shown weak points in the clothing structure e.g. a considerable increase in the mean skin temperature by almost 2 °C and in the humidity between the skin and clothing by 40%.‟ (19)

In Table 1, exposed above, has been brought out some clothing insulations from earlier studies for comparison.

2.1.2 Other variables to characterize thermal comfort

2.1.2.1 Operative temperature

The combined effects of air and mean radiant temperature can be combined into a single index, the operative temperature. The operative temperature have to be defined as the uniform temperature (i.e. equal values of t_{mr} and t_o) of an imaginary enclosure in which man would exchange the same dry heat by radiation and convection as in the actual environment.‟ (21)

Wyon et al. (1968) investigated, that the operative temperature, that at which the highest proportion of operating room staff in Britain are comfortable, is 20,5 °C (9)

2.1.2.2 Skin temperature and sweating

P.O. Fangers experimental investigations showed, that mean skin temperature and sweat secretion at a given activity level are closely connected with the sensation of thermal comfort. He says, as both will be as functions of the activity level, they will be used as basic conditions for thermal comfort. Also, there is connection between skin temperature and activity level – Fanger investigated, that the mean skin temperature decreases with increasing activity. (5)

It is often stated earlier, that it was a condition for thermal comfort that the mean skin temperature was 33-34 °C, and that sweating did not occur. This is true only for sedentary persons, but Fanger showed, that at higher activities the skin temperature necessary for comfort falls, and moderate sweating takes place. (22) Also, he brings out that ,,in experiments at the Techn. Univ. Of Denmark (Andersen and Olesen), where a subject in 32 three-hour tests was exposed to different combinations of the variables (2 activities, 2 clo-values, 2 mean radiant temperatures, 2 velocities), it was found that in a state of thermal comfort no significant differences exist between the observed skin temperatures and sweat rates at a given activity, no matter whether the subject was exposed to a high t_{mrt} and a low t_a or vice versa, a velocity of 0,8 m/s or „still air", a clo-value 0,6 or nude." (5)

Previous studies have been found out, that in Knee prothesis operation the surgeons have way higher skin temperature than nurses. Surgeons temperature may increase from 32 °C (clothing is a cotton overall with a non transpiring overall) to 34 ° C (clothing is a a paper transpiring overall, lead long overall, gloves and protective cap). Also, there have been found out, how the lead waistcoat will increase the skin temperature of assistant surgeon – from 30,5°C (cotton overall) to 32,5 °C (lead waistcoat). (23)

2.2 Patient thermal comfort

The thermal comfort of patient is mainly described using body temperature, because it impacts directly the wellbeing of patient. The American Society of PeriAnesthesia Nurses sets a core temperature of normothermia (normal body temperature) between 36°C to 38°C (2). However, hypothermia is a body status, where the temperature is below 36°C and it has adverse effects that range from patient thermal discomfort to increased morbidity and mortality. Hypothermia may directly impair white blood cell function or trigger constriction of blood vessels under the skin, what will cause an increased incidence of surgical wound infection. To keep the patient body temperature at normal level, they use prewarming. Prewarming is defined as warming of peripheral tissues or surface skin before induction of anesthesia. It is decreasing the core-to-peripheral temperature gradient and cause the dilatation of blood vessels. Without pre-warming, a period of hypothermia is typical even if active warming is instituted after induction of anesthesia. (2).

Further, earlier studies have been found out, that during total hip arthroplasty, the patient, who have less than 2° C perioperative core hypothermia increased blood loss about 500 mL and un-warmed patients needed more allogeneic blood transfusions. (24)

Another study says, that at or above a "critical ambient temperature" 21°C esophageal and nasopharyngeal temperatures of patient remained essentially stable in the normal range of 36,0-37,5°C. Body temperatures of patient in rooms cooler than 21°C were less than 36,0°C 45 minutes postinduction of anesthesia, and progressively declined at a mean rate of 0.3 degrees C/hour in the ensuing two to three hours. (25)

2.3 Surveys on thermal comfort of surgical staff in operating room

Mora, English & Athienitis (2001) have been conducted a survey among surgical staff in several operating rooms (majority of them were with laminar airflow solution). OR conditions were in following range: temperature between 19°C and 25°C; relative humidity between 24% and 63,5%; operative temperature in range 19,5°C-27°C and air velocity between 0,07 m/s (near nurses area) and 0,30 m/s (near surgeons area). They devided the operating toom into 3 zones. From questionnaires, they get the outcome, that a „slightly warm" to „warm" thermal sensation is always felt by the surgical staff (surgeons, scrub nurses in zone 1), no matter, what the air temperature is. But the service staff (anesthetists, nurses in zone 2 and 3) experiences a „slightly cold" thermal sensation. The comfortable air temperature of nurses and anesthetists ranges from 23.0°C to 24°C. The air temperature for surgeons thermal comfort should be between 18°C to 19°C and if the patient is well covered (1,1 clo), the required room air temperature for thermal comfort should be around 24.5-25.5°C. To comparison, they pointed out, that Johnston and Hunter stated in 1984, that for the staff the air temperatures should be between 20°C and 22°C. (7)

Sante Mazzacane et al. have been investigated the overall sensation on the orthopedics theatre thermal sensation through a survey. They found out, that the nurses claim to be comfortable 75% of the times and only to feel slight discomfort 25% of the times; the assistants feel slight discomfort 90% and comfort only 10% of the times, while the first surgeon feels discomfort 25% and slight discomfort 75% of the times. (23)

Also, there have been asked an judgment of thermal environment on the operating theatre. In this study there have been found out, that ,,surgeon was very hot 25% of the times and hot the remaining 75%; the second surgeon was hot 50%, slightly hot 33% of the times and had a neutral sensation the remaining 17%. The surgical assistants were hot 67%, slightly hot 23% and neutral the remaining 10% of the times. Finally the nurses felt good 75% of the times while the remaining 20% were cold.‟ (23)

Finally, there have been found out, that ,,in particular surgeons and assistants for a percentage between 70% and 100% would like it to be colder while nurses do not ask for any microclimatic environmental changes in about 70% of the requests, they even ask for heating in the surgical theatre in 23% their requests.‟ (23)

2.4 Standards and requirements.

The thermal conditions in operating room are clearly determined in different standards and guidelines. There is brought out the overview:

Room air temperature T_r °C	**Supply air temperature T_a °C**	**Relative humidity %**	**Supply air velocity [m/s]**	**Standards and guidelines**
a	19 or $T_r - T_a$ = 1 - 2	55-65	0,3 ≤ v < 0,35	Beheersplan luchtbehandeling[1]
19 – 26	$T_a < T_r$	N/A	v ≥ 0.23	DIN 1946[1]
22	$T_a < T_r$	30 - 50	v ≥ 0.23	VDI 2167[1]
20 - 24	N/A	30 - 60	0.13 - 0.18	ASHRAE 170
$T_{if\ normothermic}$ ≥ 24°C or $t_{intraop}$ 20-25°C	N/A	N/A	N/A	ASPAN's Evidence-Based Clinical Practice Guideline
N/A – not applicable; 1 – from R. Van Gaever et. el. study				

Table 2 Thermal conditions determined in different standards

ANSI/ÁSHRAE/ASHE Standard 170-2013 says, that In Class B and C operating rooms, the airflow needs to be unidirectional, downwards, and the average velocity of the diffusers shall be 25 to 35 cfm/ft2 (127 L/s·m2 to 178 L/s·m2) and minimum total air changes per minut should be 20 or ,,suites with a large amount of electronic equipment have been reported to require 30 to 35 air changes per hour using conventional air-conditioning systems with 10 to 11 K supply temperature differentials‟.

2.5 PMV-PPD level for operating rooms

2.5.1 Fangers model

Mora, English & Athienitis (2001) compared their studies with P.O. Fanger and concluded, that the Fanger PMV model does not include effect of draft on uncovered arms and necks of nurses and anesthetists. Also, Fanger model do not include asymmetric thermal radiation from surgical lights (what was between 6°C and 7°C) and from heated ceiling (between 10°C and 12°C) on the surgical staff, what may cause 21% to 23% dissatisfaction. In addition, ASHRAE Standard 55 specified a maximum asymmetric thermal radiation as 5°C. Also, this model do not include sweating.

2.5.2 Suggested parameters

R. Van Gaever et al. stated recommended environmental parameters, clothing and activity level to obtain thermal comfort. They point out, that the PMV level differs for each member of the surgical staff and the air temperature should be locally encreased up to 21.5°C above the anesthetist. Table 3 from their study summarizes the personal comfort parameters to achieve thermal comfort for the surgical staff by including the measurements as suggested by the authors. (3)

	Suggested by R. Van Gaever et al.				
Variable	**Surgeon with lead apron**	**Surgeon**	**Surgery assistant**	**Nurse**	**Anesthetist**
Air temperature (°C)	19	19	19	19	21.5
mean radiant temperature (°C)	19	19	19	19	19
relative humidity (%)	55	55	55	55	55
air velocity (m/s)	0.3	0.3	0.3	0.3	0.3
clothing (clo)	1.5	1.1	1.1	1	1.1
activity level (W/m2)	120	100	80	80	60
pmv (-)	0.9	0.21	-0.3	-0.46	-0.5
ppd (%)	22	6	7	9	10

Table 3 Suggested environmental conditions in OR by R. Van Gaever et al.

2.5.3 Determination of PMV level in operating room

ISO 7730:2005 application chapter says, that the PMV can be used to check wether a given thermal environment complies with comfort criteria and to establish requirements for different level of acceptability. By setting PMV=0, an equation is established which predicts combinations of activity, clothing and environmental parameters which on average will provide a thermally neutral sensation.

Fanger reminds that his comfort equation is deduced on the basis of experiments performed during winter with American college-age subjects under steady-state conditions and it it cannot be taken for granted that the equation can be used for other groups without corrections. (5)

Furthermore, ergonomics standard ISO/TS 14415:2005 says, that ,,the PMV and PPD indices are statistically derived from a theoretical comfort equation and experimental data from a large number of subjects, mainly healthy young adults, and although some older persons were considered, generally the aged were not. The method given in ISO 7730 may not therefore be able to adequately predict the thermal sensation or the dissatisfaction of the disabled and the aged with thermoregulatory impairments without modification. The method is not intended for predicting the thermal sensation of persons, but more for predicting which thermal conditions (temperature, humidity, air velocity, clothing, activity) are acceptable or preferred."

In the heat balance equation, the mechanical work done by the muscles for a given task is often assumed as zero, because the mechanical work produced is small compared to metabolic rate. (6)

R. Gaever et al. investigated thermal comfort in operating rooms and they found out, that the surgeon feels uncomfortably warm (+0.74) due to their higher clothing insulation, but mainly due to the influence of the surgical luminaire on the mean radiant temperature and air velocity. They added also, that if the air temperature is 19 °C, then it requires an increase of air velocity to 0.3 m/s beneath the surgical lights. If the velocity will be 0.1 m/s beneath the luminaire, then it requires a temperature decrease to 16 °C. They added, that a surgeon wearing a lead apron feels even more uncomfortably warm (PMV +1.25; PPD 38%), so they does not achieve thermal comfort for the design air temperature of 19 °C, not even at higher air velocities (v = 1 m/s). The suggested comfort levels for surgical staff are brought out in Table 3 (3) It is essential to maintain, that in general, the thermal comfort ranges within the limits -0.5 < PMV < +0.5, where 90% of occupants are satisfied. (4)

2.5.4 PPD

ISO 7730:2005 defines that ,,the PPD is an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people who feel too cool or too warm. For the purposes of this International Standard, thermally dissatisfied people those who will vote hot, warm, cool or cold on the 7-point thermal sensation scale."

With the PMV value determined, calculate the PPD using following equation:

$$PPD = 100 - 95\ x\ \exp(-0{,}03353 * PMV^4 - 0{,}2179\ x\ PMV^2)$$

3 RESEARCH METHODOLOGY

In this chapter author describes field experiments, the survey among surgical staff and observations what have been conducted in St. Olavs hospital. The used measuring equipments will also be described.

3.1 Summary of methodology

3.1.1 Surgical facilities

The nucleus of this master thesis are St.Olavs hospitals two operating rooms with LAF ventilated ("Stue 8" at "Bevegelsessenteret") and in dilution ventilation ("Stue 1" at "AHL-senteret") solution. The hospitals ventilation system is mainly controlled by servicecenter and can be adjusted by surgical staff via three different scenarios with three different condition settings: operasjon pågår (operation is ongoing), infeksjonsfare/rengjøring (Infection risk / cleaning), operasjonstue klargjort (operating room prepared). The humidity of airflow is not controlled due to hazard of bacterial distribution. In following chapters these two operating rooms are described.

3.1.1.1 Operating room with dilution ventilation solution

Figure 1 Dilution ventilation solution operating room

Dilution ventilation operating room is showed on Figure 1. The area of this room is 59.1 m^2 and volume 170.7 m^3. There are four supply diffusers and four wall mounted exhaust outlets. During the measurements, the scenario was operasjon pågår (operation is ongoing) and temperature set point were 23°C. General boundary conditions in operating room during measurements and observations are in Table 4.

The results from experiment will base on location, what is marked black in Figure 2. The location of occupants was the same in every experiment. Occupants location in real operation (red marking) will be different from occupants location during experiments.

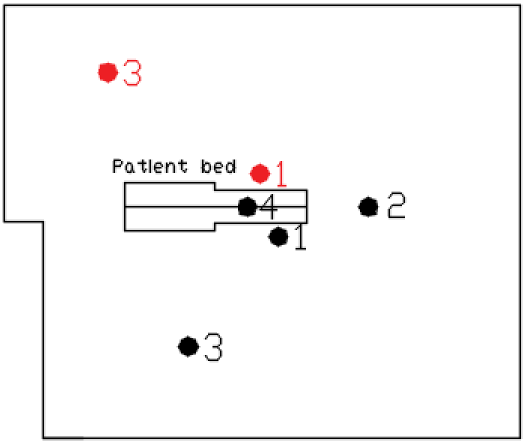

Figure 2 Occupants location in dilution ventilation OR (1 – Surgeon; 2 – Anesthetist; 3 – Distribution nurse; 4 – Patient)

3.1.1.2 Operating room with LAF ventilation solution

Figure 3 Laminar air flow ventilation solution operating room

Laminar air flow ventilation solution operating room is showed on Figure 3. The area of this room is 56.1 m^2 and volume 168.3 m^3. It has a 4mx4m area LAF zone in the ceiling, what is surrounded with ca 110 cm long walls, two wall mounted exhaust outlets near floor and six exhaust outlets in the ceiling around LAF area. In the measurements in LAF solution OR, the scenario was operasjon pågår (operation is ongoing) and temperature set point 23°C. General boundary conditions in laminar air flow operating room during measurements and observations are in Table 4.

The results from experiment will base on location, what is marked black in Figure 4. The location of occupants was the same in every experiment. Occupants location in real operation (red marking) will be different from occupants location during experiments.

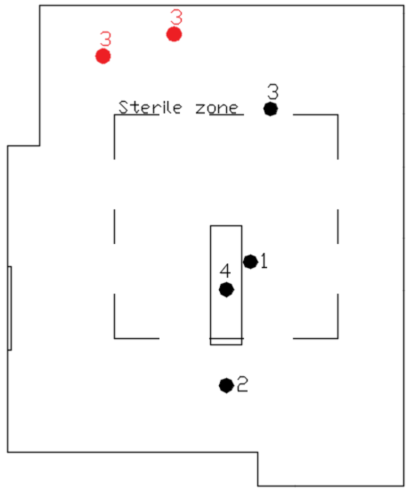

Figure 4 Occupants location in LAF OR (1 – Surgeon; 2 – Anesthetist; 3 – Distribution nurse; 4 – Patient)

Variables	**DILUTION VENTILATION OR**					**LAF VENTILATION OR**		
	Field experiment			**Observation and survey**		**Field experiment**		**Observ. and survey**
	4.03.19 at 13:00	**8.3.19 at 13:00**	**15.3.19 at 13:00**	**27.03.19 at 13:00**	**2.04.19 at 13:00**	**23.03.19 at 13:00**	**29.3.19 at 13:00**	**21.3.19 at 13:00**
	EXP2	EXP3	EXP4	OBS1&2	OBS3	EXP5	EXP6	OBS4
outdoor air temp, °C (1)	-1.8	0.6	2.7	5.3	4.7	0.6	1.6	6
outdoor air RH, % (1)	78	54	49	82	44	92	93	54
indoor air Temp, °C (2)	23.5	23.7	24.2	NM		23.7	22.3	NM
indoor air RH, % (2)	15	13	12.1			20.9	24.3	
Vap. partial pressure kPa (3)	**0.43**	**0.38**	**0.37**	**0.74**	**0.37**	**0.61**	**0.65**	**0.49**
RH, %	15	12.80	12.1	26.39	13.30	20.86	24.26	17.34
pas, kPa	2.90	2.93	3.03	2.81	2.81	2.93	2.70	2.81
ta, °C	23.5	23.7	24.2	22.99	23.00	23.70	22.32	23.02
Room area, m2	59.1					56.1		
Room volume, m3	170.7					168.3		
Exhaust air temp, °C (4)	22.8	x	**23.00**	22.99	23	22	21.7	23.02
indoor air RH, % (4)	13	x	12.50	26.39	13.3	20	22.4	17.34
Supply airflow, m3/h	3700					12850.00		
Air change rate, ACH	21.7					76.35		

(1) Forecast data from YR.no; (2) Measured with Pegasor AQ Indoor device near wound area; (3) Calculated with (2) or (4); (4) data from servicecenter of St.Olavs hospital for comparison

Table 4 Boundary conditions in LAF and DV OR at St.Olavs hospital

3.2 Field experiments at St. Olavs Hospital during and after mock-up surgery

This study includes measurements during and after 15 min intensive mock surgeries, what were taking place in two above mentioned real operating rooms at St. Olavs hospital during March (boundary conditions brought out above, in Table 4). The field experiments in dilution ventilation operating room has been taken in three weekdays at 1st, 4th, 8th and 15th of March, but calculation has been done for the last three days, due to inadequate measurement on 1th of March. In laminar air flow operating room, the measurements have been taken in two weekdays at 23rd and 29th of March.

During measurements surgical lamps were turned on and operating room doors were closed. The height of operating bed was 84.5 cm, the height of surgical lights from floor was in dilution ventilation room 2.1 m and in LAF ventilated room 2.15 m.

There have been taken measurements of thermal comfort variables. In the vicinity of human body, the air temperature and air relative velocity has been taken. For mean radiant temperature, there has been measured the dimensions of room and the surface temperature of surfaces. Finally, there have been measured overall conditions during mesurements for calculation of vapour partial pressure. Following chapters are describing the measurements particulatly.

3.2.1 Instruments used in experimental measurements

3.2.1.1 VelociCalc plus (Model 8388 and Models 8382)

The air velocity measurements have been done with VelociCalc Plus Model 8388, what is hot-wire anemometer (indicate velocities with reference to a set of standard conditions: 21.1° C and 101.4 kPa), it has uni-directional probe and does not respond to flows in all directions. The air temperature measuements have been done with VelociCalc Plus Model 8382. The accuracy data of these devices are on Table 5. Furthermore, the device have function as time constant, store and average, what have been used in this study. Detailed description of these functions is in Appendix B.

Velocity	Model 8388	Model 8382
Measurement Range	0.15 to 50 m/s	0.15 to 50 m/s
Accuracy[2)]	3% of reading or 0.02 m/s, whichever is greater	3% of reading or 0.02 m/s, whichever is greater
Response time	200 milliseconds	200 milliseconds
Temperature		
Measurement Range	-10 to 60°C	-17.8 to 93.3°C
Resolution	0.1°C	0.1°C
Accuracy	±0.3°C[2]	±0.3°C[2]
Response time	8 seconds	8 seconds
Relative Humidity		
Measurement range	0 to 95%	N/A
Accuracy[3)]	±3% rh	N/A
2) Accuracy with instrument case at 25°C. Add uncertainty of 0.03°C/°C for change in instrument temperature. 3) Accuracy with probe at 25°C. Add uncertainty of 0.2%rh/°C for change in probe temperature. Includes 1% hysteresis.		

Table 5 Technical data of VelociCalc Plus

The temperature calibration data is at Appendix A in Table 25. The relative humidity has been correlated with Pegasor AQ Indoor™, which accuracy is in Table 8. The correlation data is at Appendix A in Table 26.

3.2.1.2 Bosch PTD 1

Surface temperature of clothing and room surfaces have been measured by contact free measuring tool Bosch PTD 1. The technical data is on Table 6.

	Surface temperature [1) 2)]	Ambient temperature	Relative humidity [2)]
Measuring range	-20…+200 °C	-10…+40°C	10…90%
Accuracy	+10…+30°C: ±1 °C	Typically ±1 °C	<20°C: ±3%; 20…60%: ±2 %
1) At a measuring distance of 0.75-1.25 m to the surface 2) At an ambient temperature of 22 ° C			

Table 6 Technical data of Bosch PTD 1

3.2.1.3 Infrared thermograph camera FLIR E60

The measurements of surface temperature as well have been done with infrared camera FLIR E60. The video has been recorded with FLIR Tools+ software and the data has been analyzed with FLIR Tools software. The technical data of FLIR E60 is on Table 7.

Surface temperature	
Measuring range	−20°C to +120°C; 0°C to +650°C
Accuracy	±2°C or ±2% of reading, for ambient temperature 10°C to 35°C

Table 7 Technical data of FLIR E60

3.2.1.4 Pegasor AQ Indoor

The measurements for boundary conditions (as temperature and relative humidity) in mock surgeries have been done with Pegasor AQ Indoor device. The technical data is on Table 8.

Relative humidity	Sensor Vaisala HUMICAP® 180R
Measurement range	0…100 %
Accuracy[1)]	0…90%RH: ±1,5 %RH
Temperature	Sensor Pt1000 RTD Class F0.1 IEC 60751
Measurement range	-40 ... +80 °C
Accuracy[1)]	±0.2 °C
1) Accuracy at 0 ... +40 °C	

Table 8 Technical data of Pegasor AQ Indoor

3.2.1.5 TinyTag Plus 2 datalogger used for observation

The boundary conditions over one week in both operating room has been logged by TinyTag Plus 2 TGP-4500 datalogger. It is logging the air temperature and relative humidity. The location of dataloggers in each operating room has been brought out in Appendix D. Technical data has been brought out in Table 9

	Temperature	**Relative humidity [2)]**
Measuring range	-25…+85°C	0…100%
Accuracy	Around 20°C: ±0.45°C	At 25°C: ±3

Table 9 Technical data of TinyTag Plus 2 TGP-4500

3.2.1.6 Required accuracy

Regarding to ISO 7726 the recuired accuracies of measurements are in Table 10.

Class	Measuring range	Class C (comfort)
Air temperature	10 °C to 40 °C	± 0.5 °C
Air velocity	0,05 m/s to 1 m/s	± (0.05+0.05*v_a) m/s
Surface temperature	0 °C to 50 °C	± 1 °C
Absolute humidity expressed as partial pressure of water vapour	0,5 kPa to 3,0 kPa	± 0.15 kPa

Table 10 The accuracy of measurements (ISO 7726)

3.2.2 Measurements in vicinity of occupants

The measurements have been done according to ISO 7726. In this study the environment is heterogeneous, due to air movement and radiation from equipments. The standard says, ,,when the environment is too heterogeneous, the physical quantities shall be mesured at several locations at or around the subject" (10). According to that, the variables as air temperature and air relative velocity have been measured in the vicinity of every four occupants (surgeon, anesthetist, distribution nurse and patient). Table 11 from ISO 7726 shows the suggested and used heights in experiments for measuring the basic quantities. The sensors are placed in the vicinity (on the one side) of every four occupants (also suggested in ISO 7726). The sensor tip distance from human body center is 0.4 m, because of thermal plume of occupant. (26) Variables near patient are measured at height 0.9 m from floor and probe tip is on the surgeon side, distance from patient table is 0.1 m.

Location of the sensors	Sitting person	Standing person	Patient
Head level	1,1 m	1,7 m	0.9 m
Abdomen level	0,6 m	1,1 m	0.9 m
Ankle level	0,1 m	0,1 m	0.9 m

Table 11 Measuring heights from floor for the physical quantities of an environment (ISO 7726) enclosed with patient measurepoints

Figure 5 Air temperature and relative velocity measurements in OR

3.2.2.1 Air temperature measurement

ASHRAE 55 defines the average air temperature as ,,the average air temperature surrounding a representative occupant. The average is with respect to location and time. The spartial average is the numerical average of the air temperature at the ankle level, the waist level and the head level (mentioned above)." This standard recommends that the time averaging is over a period not less than three and not more than 15 minutes. In this study, the temperature has been marked down 3 times during 2 minutes, because the temperature is constant most of time. Even, if the technical data says, that the response time of temperature sensor is 8 minutes, the correction with Pegasor shows, that the response time may be even 1 minute. Due to that, before the measurement, there has been waited 1 minute. These results has been averaged and used in estimation of thermal comfort and PMV calculations.

3.2.2.2 Air velocity measurement

Due to that, the VelociCalc Plus anemometer has uni-directional probe and does not respond to flows in all directions, the results deviations may differ from -5% to +4%. Velocity measurements in dilution ventilation operating room has been taken as probe tip measuring the airflow vertically from ceiling to floor, because the airflow direction is not known, due to air mixing distribution. In laminar air flow operating room, the distribution is fixed and the probe tip has been located in corporate of airflow. The probe tip measuring directions in LAF OR is described in Table 12.

Measuring point	Probe tip measuring direction
1 - Surgeon	Under the LAF area: airflow vertically from ceiling to floor
2 - Anesthetist	Outside of LAF area: airflow horizontal from LAF area to person
3 – Distribution nurse	Outside of LAF area: airflow horizontal from LAF area to person
4 - Patient	Under the LAF area: airflow vertically from ceiling to floor

Table 12 Probe tip measuring direction in LAF operating room

The measurement have been taken with using the VelociCalc functions: averaging time constant is 10 seconds; this reading is stored after every 10 seconds 6 times (>6o sec); these 6 values has been averaged and marked down as averaged velocity. This velocity has been used to estimate the thermal comfort and calculate the PMV level.

3.2.2.3 Overall room measurements

In this study, the humidity is simplified to overall room humidity, because it is usually the same around the room (5). The surface temperature and relative humidity has been measured approximately at the centre height of standing human (1,1 m).

Air humidity

The air humidity has been logged by Pegasor device. Also, the humidity has been measured with VelociCalc – in cases, when the Pegasor will show inclined result – and later correlated with correlation in Table 26 in Appendix A. The humidity is used to calculate the vapour partial pressure, using following equations from ISO 7726 (10).

$$p_a = 0{,}01\ x\ p_{as}\ x\ RH$$

Equation 1 Vapour partial pressure

Where:

$$p_{as} = 0{,}611\ x\ \exp\left(\frac{17{,}27 t_a}{t_a + 237{,}3}\right)$$

t_a - air temperature

RH – air relative humidity

P_{as} – vapour saturation pressure

3.2.3 Mean radiant temperature calculation from the temperature of surrounding surfaces

The mean radiant temperature is going to be calculated with following equation 2 using surface area and measured surface temperature of surroundings.

Equation 2 Mean radiant temperature

$$T_{mrt} = \frac{T_1 A_1 + T_2 A_2 + T_3 A_3 + \cdots + T_N A_N}{A_1 + A_2 + A_3 + \cdots + A_N}$$

3.2.3.1 Surface area

The dimensions of every wall, floor and ceilings have been measured with Bosch Zamo II digital laser, whats accuracy is ±3 mm degree of precision. The dimensions are in Appendix E.

3.2.3.2 Surface temperature of surroundings

The surface temperature has been measured every day from every walls, ceiling, floor, doors and windows in three different places with Bosch PTD 1 device. Regarding to the standard ISO 7726:1998, that ,,most building materials have a high emissivity, it is possible to disregard the reflection i.e. to assume that all the surfaces in the room are black" (10), the emissivity has been taken near to 1 - specifically, 0.95.

Although, there are many equipments (lights, LCD screen, anaesthetic devices, x-ray device) in operating room and due to their higher surface temperature have significant influence to MRT, they nevertheless are not included to MRT calculation. This is as well because of complicated calculation of angle factor. However, the surface area method can not be used, because this will cause false results due to distance difference between walls and equipments (in calculation with surface area, the walls will influence more due to their bigger surface area than equipment, what is unlikely). Therefore, it is very significant to use angle factor in calculation of MRT from equipments and is strongly recommended by the author for the future studies. However, the thermal camera pictures of surgical lights are taken, analyzed and the influence of luminaire will be discussed later.

3.2.4 PMV calculation for estimation of thermal comfort

The PMV level for estimation of thermal comfort has been calculated by using the following equation 3 from ISO 7726:200. The calculations has been done first to local body parts and then, the final mean PMV level has been correlated and the standard deviation has been calculated by IBM SPSS software. The variables used in equation are described above and the metabolic rate and clothing thermal insulation are explained in observation chapter.

Equation 3 Predicted mean vote

$$PMV = [0{,}303 * \exp(-0{,}036 * M) + 0{,}028] * \begin{cases} (M-W) - 3{,}05 * 10^{-3} * [5\,733 - 6{,}99 * (M-W) - p_a] - 0{,}42 * [(M-W) - 58{,}15] \\ -1{,}7 * 10^{-5} * M * (5\,867 - p_a) - 0{,}0014 * M * (34 - t_a) \\ -3{,}96 * 10^{-8} * f_{cl} * [(t_{cl} + 273)^4 - (\bar{t_r} + 273)^4] - f_{cl} * h_c * (t_{cl} - t_a) \end{cases}$$

$$t_{cl} = 35{,}7 - 0{,}028 * (M-W) - I_{cl} * \{3{,}96 * 10^{-8} * f_{cl} * [(t_{cl} + 237)^4 - (\bar{t_r} + 237)^4] + f_{cl} * h_c * (t_{cl} - t_a)\}$$

$$h_c = \begin{cases} 2{,}38 * |t_{cl} - t_a|^{0{,}25} & for\ 2{,}38 * |t_{cl} - t_a|^{0{,}25} > 12{,}1 * \sqrt{v_{ar}} \\ 12{,}1 * \sqrt{v_{ar}} & for\ 2{,}38 * |t_{cl} - t_a|^{0{,}25} < 12{,}1 * \sqrt{v_{ar}} \end{cases}$$

$$f_{cl} = \begin{cases} 1{,}00 + 1{,}290 * I_{cl}, & for\ I_{cl} \leq 0{,}078\ m^2 * K/W \\ 1{,}00 + 0{,}645 * I_{cl}, & for\ I_{cl} > 0{,}078\ m^2 * K/W \end{cases}$$

M is the metabolic rate, in watts per square metre (W/m^2)

W is the effective mechanical power (usually as nil), in watts per square metre (W/m^2)

I_{cl} is the lothing insulation, in square metres kelvin per watt (m^2*K/W);

f_{cl} is the clothing surface area factor;

t_a is the air temperature, in degrees Celsius (°C);

v_{ar} is the relative air velocity, in metres per second (m/s);

p_a is the water vapour partial pressure, in pascals (Pa);

h_c is the convective heat transfer coefficent, in watts per square metre kelvin [W/(m^2*K)];

t_{cl} is the clothing surface temperature, in degrees Celsius (°C).

The clothing temperature has been calculated by using Excel Solver function.

3.2.5 Other measurements and calculations for estimation of thermal comfort

3.2.5.1 Operative temperature

To compare the environments vicinity every occupant and also with other studies, the operative temperature has been calculated by air temperature, air velocity and mean radiant temperature at the abdomen level of occupants.

The standard ISO 7726:1998 present the equation 4 for operative temperature.

Equation 4 Operative temperature

$$t_o = \frac{t_a\, x\, \sqrt{10\, x\, v_a} + \overline{t_r}}{1 + \sqrt{10\, x\, v_a}}$$

Where,

t_a – air temperature

v_a – air relative velocity

t_r – mean radiant temperature

3.3 Observation

In present study, the observation of several variables has been conducted. Firstly, the metabolic rate of occupants has been observed from recorded video. Video has been recorded in LAF OR by St.Olavs research group and in DV OR by author. The estimation from the video is according to ISO 8996:2004. NS-ISO 7730:2005 suggests to estimate the metabolic rate using ISO 8996 or Annex B, taking into account the type of work during the previous 1 h period, but in this study, the recording and observing duration was 1.5 to 2h for each operation. The observations in dilution ventilation operating room took place in two days – 27. of March and 2. of April, and in laminar air flow operating room at 21. of March. Furthermore, the patient real thermal comfort is going to be observed. Also, in this chapter the estimation of thermal resistance of clothing in St. Olavs hospital has been done by literature review.

3.3.1 Estimation of the metabolic rate of surgical staff

The MET level estimation has been taking place for mock surgery and also for real surgery. The occupant under estimation is surgical staff and patient. The estimation is based on EN ISO 8996:2004 Level 2: observation. For anesthetic nurse in DV OR, whose activity is more standing and resting than moving, the estimation is based on Level 1B: Classification according to activity. Regarding to standard, the metabolic rate is estimated from the following observations:

- The body segment involved in the work: both hands, one arm, two arms, the entire body;
- The workload for that body segment: light, medium, heavy, as judged subjectively by the observer;
- The body posture: sitting, kneeling, crouching, stnading, standing stooped;
- The work speed.

The observation duration was approximately over two hour and after every movement end, the body segment work together with mean value of metabolic rate and time has been stated.

The mean value of metabolic rate has been taken from Table B.1 (or from Table A.2) in Annex B at ISO 8996. If the body posture is different from seated, the correction for the body posture has been taken from Table B.2 in the same annex. Also, if there has been difficult to observate or the mean value from Table B.1 was not correct, then the mean value for metabolic rate has been taken from Table B.3 in Annex B at ISO 8996.

In the observation of real surgery, there has been taking into account, that surgeons are used to these movements and experienced, so their met level is not increasing that much, as it will do in case the unexperienced person will do the surgery.

In mock surgery, there is fixed movement description together with fixed duration, what has been used. Activity level is going to be estimated over two hours.

There is significant to indicate, that the tabulated values presented in ISO 8996:2004 are generalized and concern an „average" individual:

- A man 30 years old weighing 70 kg and 1.75 m tall (body surface area 1,8 m^2)
- A woman 30 years old weighing 60 kg and 1.70 m tall (body surface area 1.6 m^2)

3.3.2 Estimation of the metabolic rate of patient

Malcolm A. Holliday et al. have been investigated the hospital patient metabolic rate and brought out that the metabolic rate of patients resting in bed is correlated with weight, as >20 kg person have metabolic rate 1500 cal + 20 cal/kg for each kg over 20 kg. Therefore, a man 30 years old weighing 70 kg (body surface area 1,8 m2) metabolic rate is 2500 kcal/day and a woman 30 years old weighing 60 kg (body surface area 1,6 m^2) metabolic rate is 2300 kcal/day. The rate in W/m^2 is respectively 67.3 W/m^2 and 69.6 W/m^2. For calculation of thermal comfort of patient, there have been taken averaged person between man and woman, who have averaged weight of 65 kg and body surface area 1,7 m^2, due to this, the metabolic rate is 2400 kcal/day, what is 68,4 W/m^2.

3.3.3 The observation of thermal comfort of patient

To investigate the thermal comfort of real patient in dilution ventilation operating room, the body temperature, environment temperature and relative humidity has been analyzed. The body temperature is measured by St. Olavs hospital surgery team anesthetists during surgery as bladder temperature. The surgeries under observation, are endovascular aneurysm repair (EVAR) and endovascular thrombectomy (last one as emergency operation). First measuring time is right after the patient has been entered the room. The measuring period is after every 0.5 hour over one surgery, what will last from 1.5 to 4.5h. The environment conditions has been logged with TinyTag datalogger after every 5 minutes near surgical area.

The body temperature is not logged in laminar air flow operating room. There, the thermal comfort of patient will be proceed by air temperature, what is measured with TinyTag datalogger. There has been observed 3 operations: two knee and one hip operation.

3.3.4 Clothing at St. Olavs hospital and the estimation of thermal resistance

The clothing in St.Olavs hospital is mainly produced by manufacturer Mölnlycke. It is made with polypropylene film and polyester/polyethylene nonowen comfort layer what should be breathable matherial for thermal comfort. Also, it is tested regarding to EN13795 Standard/High Performance and is at AAMI Level 3. (27). ,,The single-use scrubs consisted of non-woven spun-bonded polypropylene (Mölnlycke Health Care AB, Göteborg, Sweden); weight 35 g/m2, antistatic-treated. The material fulfils the requirements for clean air suit according to the standard EN 13795:2011." (28)

In St.Olavs hospital, the surgeons are mostly wearing surgical underwear, hat, cap, mask, socks, shoes, sterilized surgical gown and gloves (in dilution ventilation OR also lead apron for x-ray). Distribution nurses and anesthetists are mostly using surgical underwear, cap, hat, mask, socks, shoes and gloves (in dilution ventilation OR also lead apron for x-ray). In operations, the surgical underwear is most of times reusable green scrub (50% polyester, 50% cotton), but the single use clean air suit is also used. In this study, only the single use clean air suit is under investigation in calculation of PMV.

In real operation, patients are most of times naked and covered with warm blanket, surgical drape and polyethylene film. In some operations also the bair hugger is used – forced-air warming blanket system. The surgical drape is made with same material as surgical gowns – polyester. The warm blanket is non-woven material made with polypropylene and polyester by OneMed. The blanket provides a uniform heat distribution and is usually prewarmed in warming cabinet to 40 °C.

During the mock surgery in dilution ventilation room, patient was wearing the clean air suite and covered with surgical drape. In LAF ventilated OR, the warm blanket has been added to these two.

3.3.4.1 Observation of thermal insulation of clothing from literature review

Thermal resistance of clothing is taken from Anna Bogdan et al. study (19), because these clothings are in similar material (also manufactured by barrier according to the requirements of EN ISO 9001 and EN 13795), as the clothings in St. Olavs hospital. The clothing thermal insulation, what is used in analyze, is brought out in Table 13. To calculate the individual garments thermal insulation, there has been used the equation 5 from NE ISO 9920:2009.

Equation 5 Thermal resistance of clothing

$$I_{cl} = 0{,}161 + 0{,}835x \sum I_{clu}$$

I_{clu} – effective thermal insulation of the individual garments, m^2K/W

I_{cl} – thermal insulation of ensemble, m^2K/W

Clothing type in St.Olavs	**Description from reference** (19)	**Thermal insulation**
Surgical underwear Clean air suite BARRIER	made of polyester cloth with coal fibre, ensuring humidity absorption from the skin's surface	0,154 m^2*K/W
Standard surgical gown + clean air suite	barrier surgical gown for multiple use, worn during standard risk operations, made of polyester cloth with the addition of carbon fibre	0,202 m^2*K/W
Lead surgical apron + clean air suite	Underwear + lead surgical apron, Pb 0.5 mm, used to make x-ray pictures (mass 3.349 kg).	0,193 m^2*K/W
Standard surgical gown + lead surgical apron + clean air suite	(calculated by above mentioned equation)	0,235 m^2*K/W

Table 13 Thermal insulation of clothing

According to fact, that the surgical drape is made with same material as surgical gowns, in this study the thermal insulation of drape has been taken the same as surgical gown - 0,058 m^2*K/W (calculated by above mentioned Equation 5). The warm blanket thermal insulation has been taken from ISO 9920:2009 and slightly smaller than polyester/polyamide material insulation (considering that the polyester/polypropylene insulation is smaller due to smaller density). The thermal insulation of warm blanket has been taken as 0.11 m^2*K/W. After using the Equation 5, the total clothing insulation for patient is – 0.165 m^2K/W (bair hugger not ingluded).

3.3.4.2 The thermal camera observation in operating room

During the real operations and mock surgeries, the thermal camera was recording occupants near the surgical wound. The observations in dilution ventilation operating room took place in two days – 27. of March and 2. of April, and in laminar air flow operating room at 21. of March. This video has been used to estimate the skin temperature and the temperature difference during surgery and will be analyzed later in separate chapter. The estimation took place during the first 40 minutes of real surgery and the skin temperature of surgeon forehead has been marked down after every 1 minute. Also, the pictures of surgical lights with thermal camera has been taken and analyzed. In thermal camera analyze, the emissivity has been taken 0,95 to walls, human skin, equipments.

3.4 Survey

In this study, the survey among surgical staff in both above mentioned operating rooms have been conducted to get knowledge about occupants real sensation in operating room thermal climate. Also, the mock surgery staff has been asked to answer the questionnaire. In dilution ventilation OR, there was 3 answers from surgeon, 1 from distribution nurse, sterile zone nurse and patient, and 2 from anesthetist. In LAF ventliation OR, there was 1 answer from surgeon, sterile zone nurse, anesthetist and patient.

The questions in survey are corresponded to ISO 28802:2012 and EN ISO 10551, but are not asked at this precise moment. In questionnaires, there have been asked occupants to base on last operation they had. Occupants have been answered to subjective questions about thermal sensation, comfort and acceptance. In addition, occupants have been asked to evaluate their work level (according to ISO 8996:2004 Table A.2) and clothing. The final mean thermal sensation level has been correlated and the standard deviation has been calculated by IBM SPSS software.

The survey has been conducted in two parts, one during the observation days in DV OR (at 27 of March and 2 of April) and in LAF OR (at 21 of March). The second part of survey took place in between 29.04-5.05. There was 30 paticipants in dilution ventilation OR and 14 participants in LAF ventiated OR survey. The number by role is in Table 14.

Role	DV OR	LAF OR
Anesthetist	7	1
Clean zone nurse	8	5
Distribution nurse	5	4
Surgeon	10	3
Total	30	13

Table 14 The number of participants by role

The boundary conditions have been logged from servicecenter at St. Olavs hospital (both, in mock surgery and part of real operations, when the observation took place) and have been brought out above, in Table 4. The logging with TinyTag datalogger was between 26.04-5.05 and in places as near to surgical bed and also near to anesthetist (in DV OR) or distripution nurse area (in LAF OR). The boundary conditions from this period has been brought out in Table 15. In real operations the occupants location has been different than in mock surgery and is brought out above, on Figures 2&4.

		ta, °C	RH%
Dilution ventilation OR	Meaure point near anesthetist		
	MAX	24.12	39.24
	MIN	22.80	13.93
	Meaure point near surgeon		
	MAX	24.91	38.88
	MIN	23.13	14.34
Laminar air flow OR	Meaure point near nurse		
	MAX	22.68	44.65
	MIN	20.72	17.05
	Meaure point near surgeon		
	MAX	24.11	44.22
	MIN	20.97	17.29
Outdoor	MAX	12.8	53
	MIN	1.2	81

Table 15 The boundary conditions logged by TinyTag datalogger

4 RESULTS

In this chapter, the results of field experiments, observation and survey are presented. In first subchapter can see results of field experiments and the calculations. The experiences results are presented by operating room solution. Also, an additional PMV level for mock surgery occupants is brought out. In second subchapter, the results of observations are presented and at last, the results from survey.

4.1 Field experimental measurements at St. Olavs Hospital during and after mock-up surgery

4.1.1 Experiments in dilution ventilation OR

The temperature in dilution ventilation operating room were on second experiment 23.5 °C and relative humidity was 15% and on third experiment the conditions were respectively 23.7°C and 13%. The fourth experiment day, when the another measurement among distribution nurse took place, the air temperature was 24.2°C and relative humidity 12.1%. The indoor air temperature difference between experiment dates is at most 0.7°C and for the relative humidity, 2.9%. The overview has been brought out also in chapter Surgical facilities in Table 4.

The surface temperatures taken during experiments and observations with Bosch PTD1 device are shown in Table 16.

	Experiments				**Observation and survey**			**Description**
	1.3.19	**4.3.19**	**8.3.19**	**15.3.19**	**27.3.19 at 10:15**	**27.3.19 at 15:00**	**1.4.19 at 14:00**	
	EXP1	EXP2	EXP3	EXP4	OBS1	OBS2	OBS3	The abbreviation of experiment
T1	22.4	22.3	21.8	22.8	22.2	22.1	22.0	is the surface temp. of wall 1
T2	22.4	21.1	21.5	23.7	22.8	22.4	22.6	is the surface temp. of wall 2
T3	22.4	21.5	21.7	22.4	23.2	21.9	23.0	is the surface temp. of wall 3
T4	22.0	20.2	20.9	21.9	22.6	22.0	22.2	is the surface temp. of wall 4
T5	22.2	21.1	20.6	22.3	22.9	21.5	23.1	is the surface temp. of wall 5
T6	21.7	20.5	20.4	22.3	22.5	22.6	22.8	is the surface temp. of ceiling
T7	21.7	20.4	21.2	22.5	22.9	22.1	23.1	is the surface temp. of floor
T8	20.0	18.7	18.5	21.3	21.1	21.2	20.6	is the surface temp. of window

Table 16 The surface temperature of surrounding in DV OR

The calculations of mean radiant temperature (MRT) of these days shows, that the MRT changes between 20.7°C-22.7°C (the equipments surface temperature is not included). The comparison (look Figure 7) shows, that there is correlation with outdoor temperature, but in real operations, the correlation is vice versa.

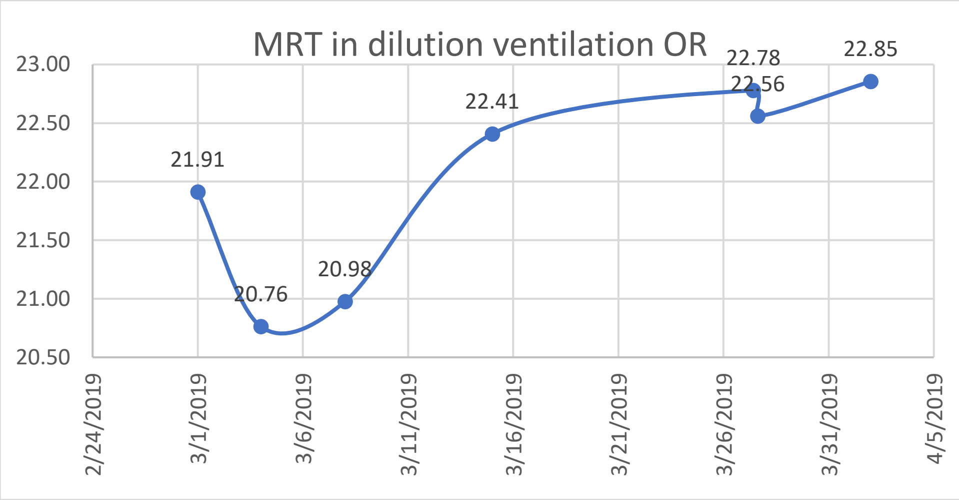

Figure 6 The mean radiant temperature in dilution ventilation OR

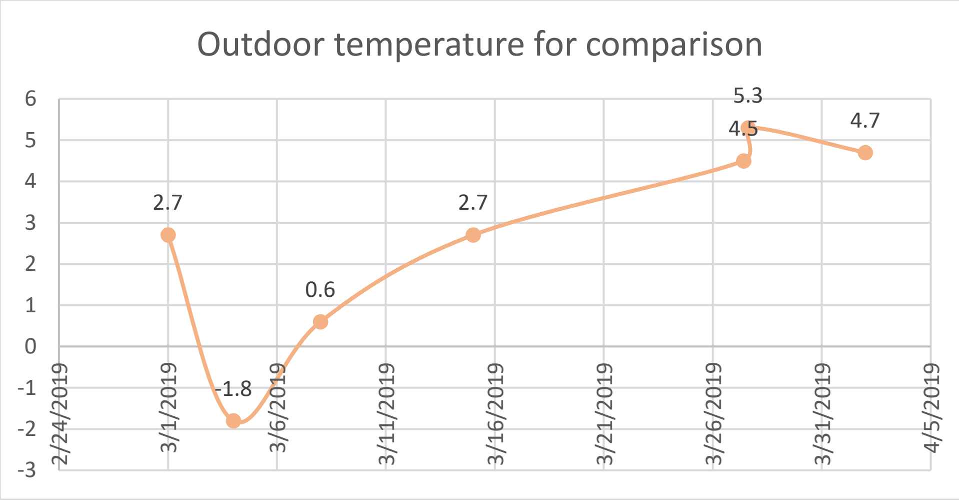

Figure 7 The outdoor temperature during measurements and observation in DV OR

The average operative temperature varies between 21.4-22.4°C. The higher operative temperature for distribution nurse is caused by the difference of experiment days and mean radiant temperature, and is not comparable with others.

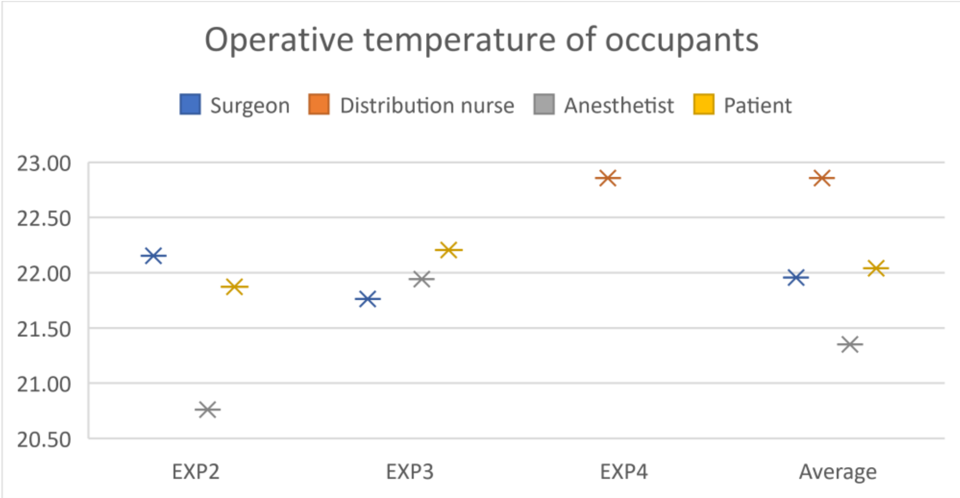

Figure 8 The operative temperature of occupants in DV OR

In following subchapters the results of measurement in vicinity of every person are brought out in detail. The final PMV level has been brought out in chapter 4.1.1.2.

4.1.1.1 Experimental measurements to investigate the comfort level of occupants

In Figure 9 has been brought out the local air temperature of every occupants during one experiment for distribution nurse and two experiments for others. The maximum temperature difference from occupant to occupant in abdomen level is from 23.1°C to 23.8°C.

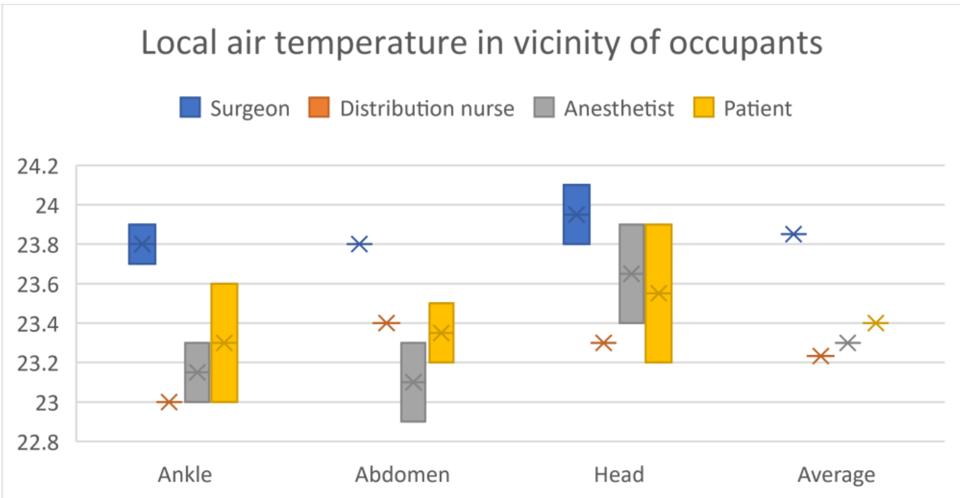

Figure 9 Local air temperature in vicinity of occupants in DV OR

As it can see in Figure 10, that the local velocity in abdomen level is unstabile - It will vary from 0.0 m/s to 0.08 m/s. In ankle level, the velocity is mainly stagnant.

The highest velocity is in the ankle level of patient – mean is 0.11 m/s. The unstability is caused by the dilution ventilation solution, so the air has no certain direction.

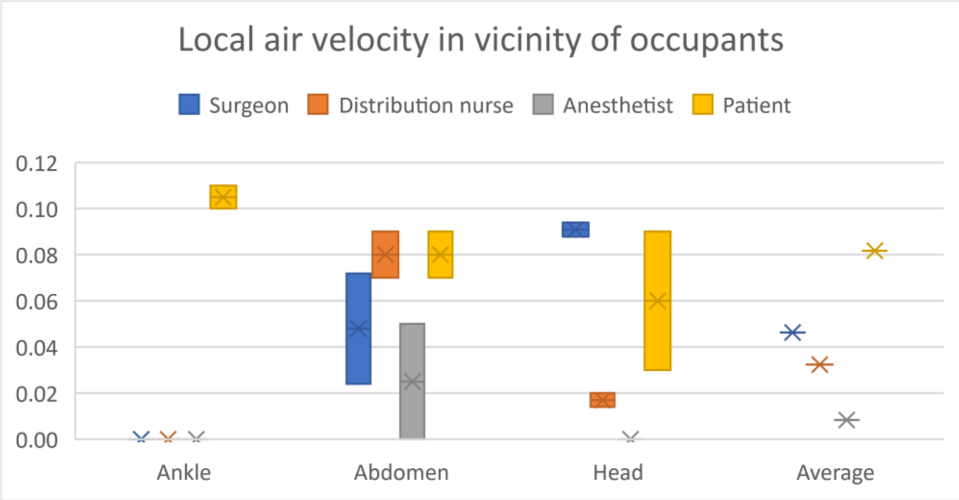

Figure 10 Local air velocity in vicinity of occupants in DV OR

Experimental measurements of determing the thermal comfort of surgeons

Results shows, that the air temperature near surgeon ranges in between 23.7-24.1°C and the warmest mean air temperature is 23.9°C, what is near to head (apparently because of surgical lights radiation). The air velocity near surgeon varies between 0.0 and 0.09 m/s and the highest is in head level (will be caused by the air distribution of surgical lights). As shown in Figure 8, the operative temperature varies in between 21.8°C and 22.2°C and the average over experiments is 21.96°C. As found out in observations (chapter 4.4), the surgeon overall metabolic rate in dilution ventilation room is 103 W/m^2 and the mean radiant temperature is calculated as 20.76°C and 20.98°C in EXP2 and EXP3. The clothing thermal insulation for surgeons in dilution ventilated OR is 0.202 m^2*K/W. Using these results, the temperature of clothing has been calculated as 25.6°C and 25.9°C (respectively in EXP2 and EXP3). Finally, the PMV level has been calculated for each height level and is shown in Figure 11. There can see, that the PMV is hereby more influenced by velocity (the velocity is higher in head level), than temperature (what is higher in head level) . Therefore, if to compare the different experiments PMV level, the EXP2, whats MRT and clothing temperature are lower, thereby the heat loss by radiation is lower, and occupant will feel more warm. In conclusion, the mean PMV level is about 0.4 points higher from comfort boundary in both experiment.

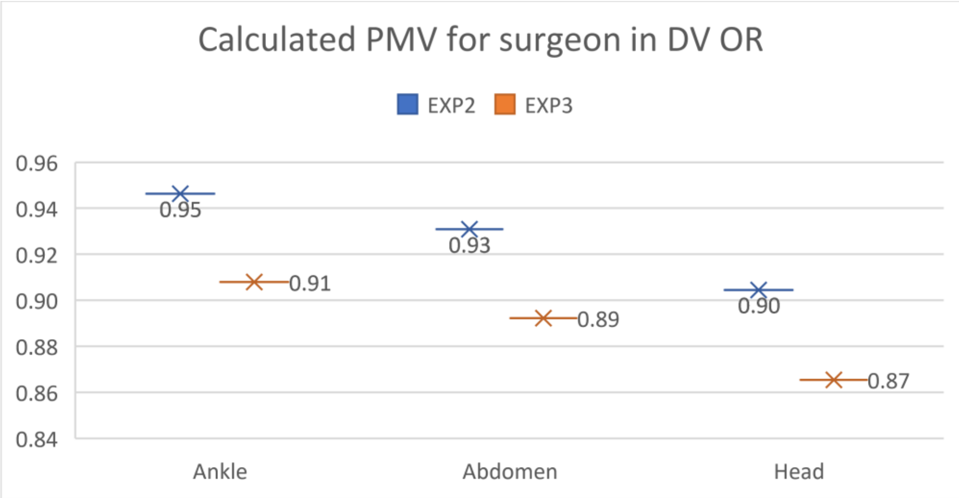

Figure 11 Calculated PMV of each height for surgeon in DV OR

Experimental measurements of determing the thermal comfort of anesthetists

The air temperature near anesthetist ranges in high interval - between 22.9-23.9°C. In both experiment day, the temperature difference from ankle to head level is 0.5-0.6°C. The warmest temperature is 23.9°C. The air distribution near anesthetist is mainly stagnant. As shown in Figure 8, the operative temperature varies in between 20.6°C and 21.9°C and the average over experiments is 21.4°C. As found out in observations (chapter 4.4), the anesthetists overall metabolic rate in dilution ventialted room is 85 W/m^2 and the mean radiant temperature is calculated as 20.76°C and 20.98°C in EXP2 and EXP3. The clothing thermal insulation for anesthetist is 0.154 m^2*K/W. Using these results, the temperature of clothing has been calculated as 27.23°C and 26.4°C (respectively in EXP2 and EXP3).

Finally, the PMV level has been calculated for each height level and is shown in Figure 12. There can see, that the PMV level differs between experiments – up to 0.48 points. This is apparently caused by wide temperature and velocity difference.

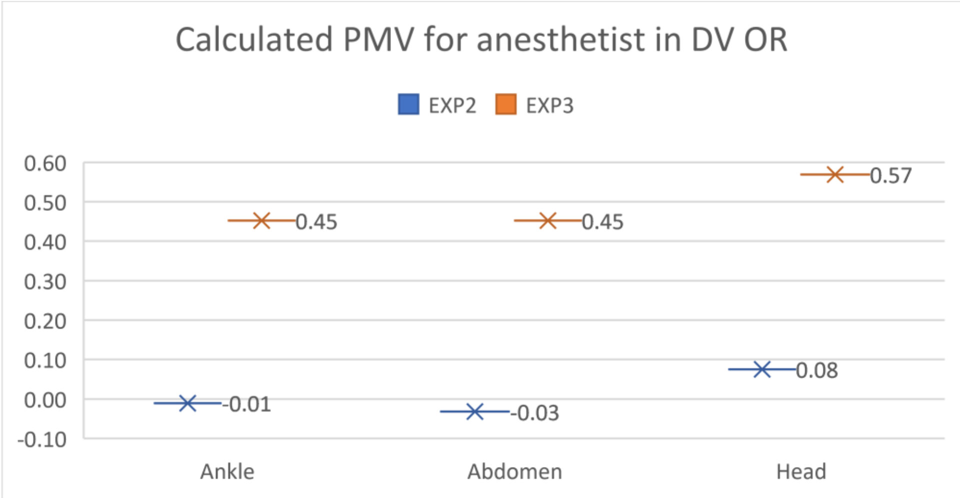

Figure 12 Calculated PMV level for anesthetist in DV OR

Experimental measurements of determing the thermal comfort of distribution nurse

Near to the distribution nurse the air temperature level differs from 23.0°C to 23.4°C (last near to abdomen). The difference of experiment days and mean radiant temperature (22.41°C), are causing the higher operative temperature level (Figure 8). The air velocity is highest in abdomen level (0.07-0.09 m/s), but the more detailed velocity measurements (done as the probe tip towards the air flow from diffuser, because during measurement, the distribution nurse felt drought from ventilation) shows, that the air velocity is close to 0.09 m/s also in ankle and head level.

As found out in observations (chapter 4.2), the distribution nurses overall metabolic rate in dilution ventialted room is 92.2 W/m^2. The mean radiant temperature for fourth experiment is calculated as 22.41°C. The clothing thermal insulation for distribution nurse in dilution ventilated OR is 0.193 m^2*K/W. Using these results, the temperature of clothing has been calculated as 26.7°C.

Finally, the PMV level has been calculated for each height level and is shown in Figure 13. There can see, that the PMV is hereby more influenced by temperature. In conclusion, in this calculation, the PMV level is in about 0.2 points above normal level and tend to approach to slightly warm sensation.

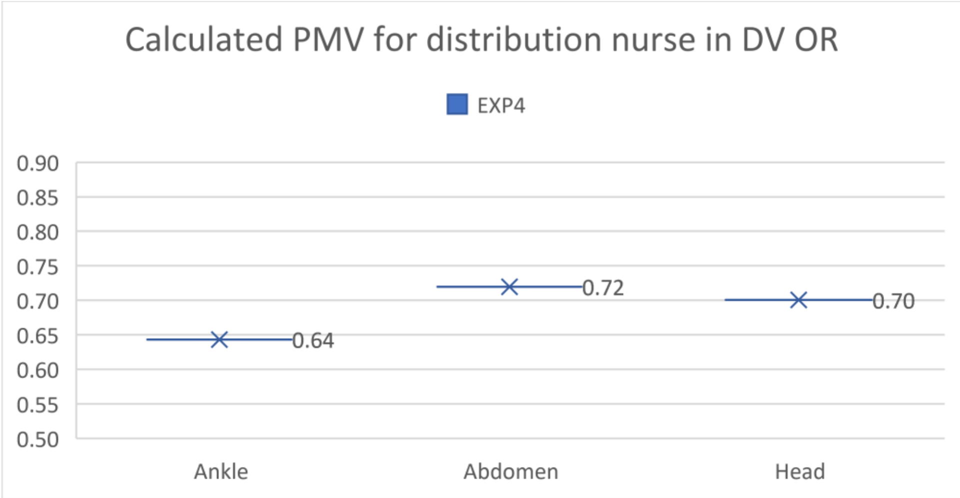

Figure 13 Calculated PMV level of each height for distribution nurse in DV OR

Calculation of predicted thermal comfort level of patient

During the two main experiment in dilution ventilated room, the air temperature vicinity of the patient was between 23.0-23.9 °C. The mean radiant temperature was 20.76°C and 20.98°C and operative temperature was between 21.9-22.2 °C. The air velocity was at range 0.03-0,11 m/s (respectively head level and ankle level). The room relative humidity between 12.8-15% (on temperature between 23.7°C and 23.5°C.

As mentioned earlier, for calculation of thermal comfort of patient, there have been taken averaged person between man and woman, whose metabolic rate is 2400 kcal/day, what is 68,4 W/m^2. Here is essential to maintain, that due to metabolic rate (woman have bigger metabolic rate per m^2 than man), the woman will experience higher thermal comfort level than average and men lower (±0,01-0,03 point).

As can see in Figure 14, that patients thermal comfort level is in the comfort criteria (-0,5<PMV<0,5), but mainly between neutral and slightly cool area.

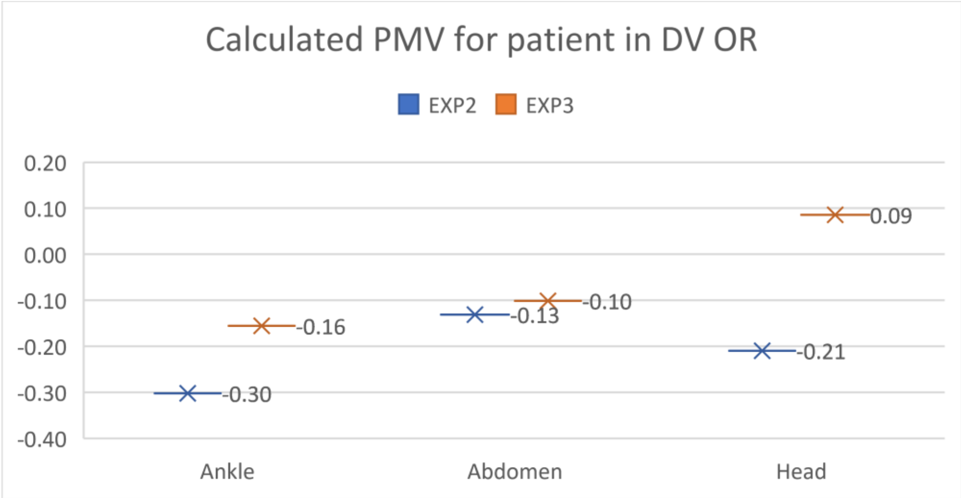

Figure 14 Calculated PMV level of each height for patient in DV OR

4.1.1.2 Thermal comfort level for every occupants in DV OR

The total PMV level for occupants is in following Figure 15 and Table 17.

Occupant	PMV	SD
Anesthetist	0.25	0.27
Distribution nurse	0.69	0.04
Patient	-0.14	0.13
Surgeon	0.91	0.03

Table 17 PMV level of every occupant in DV OR

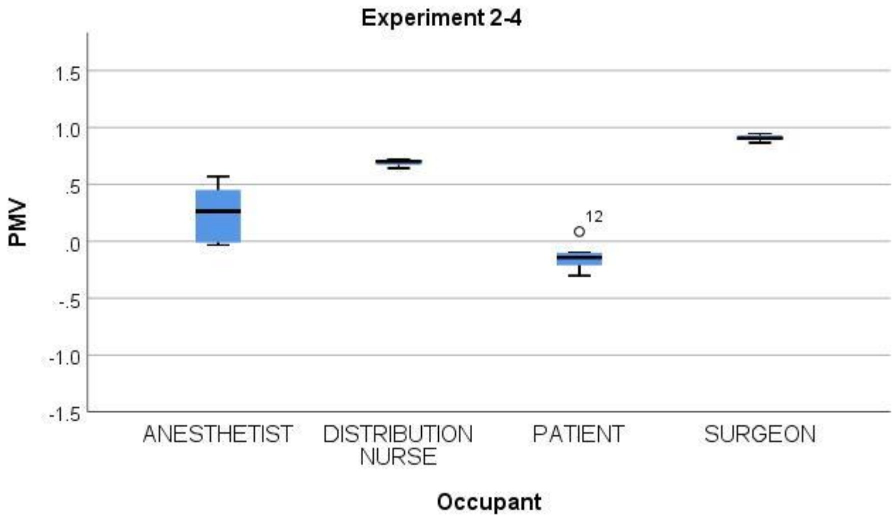

Figure 15 PMV level of every occupant in DV OR

4.1.2 Experiments in laminar air flow OR

The temperature in laminar air flow operating room was on experiment five 23.7 °C and relative humidity was 20.9% and on sixth experiment the conditions were respectively 22.3°C and 24.3%. The overview has been brought out also in chapter Surgical facilities in Table 4. The surface temperatures taken during experiments with Bosch PTD1 device are shown in Table 18.

	Experiments		Description
	23.3.19	**29.3.19**	
	EXP5	EXP6	
T1	22.4	22.9	is the surface temp. of wall 1
T2	22.4	22	is the surface temp. of wall 2
T3	22.4	22.0	is the surface temp. of wall 3
T4	22.0	22.2	is the surface temp. of wall 4
T5	22.2	22.2	is the surface temp. of wall 5
T6	21.7	21.8	is the surface temp. of ceiling
T7	21.7	20.9	is the surface temp. of floor
T8	20.0	19.9	is the surface temp. of window

Table 18 Surface temperatures during experiments in LAF OR

After calculations, the mean radiant temperature of experiment five is 21.13°C and for six experiment it is 21.6 °C (the equipments surface temperature is not included). The average operative temperature varies between 22.04-22.3°C (Figure 16).

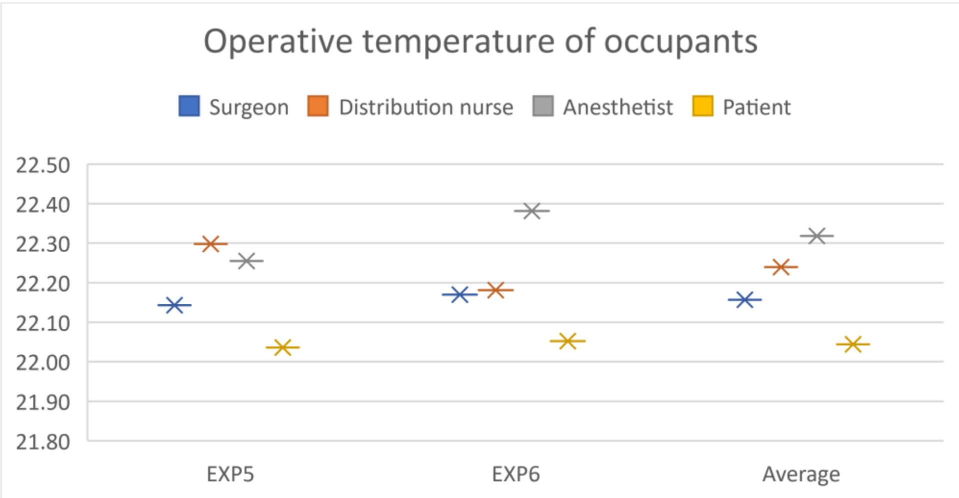

Figure 16 The operative temperature of occupants in LAF OR

In following subchapters the results of measurement in vicinity of every person are brought out in detail. The final PMV level has been brought out in chapter 4.1.2.3

4.1.2.1 Experimental measurements to investigate the comfort level of surgical staff

In Figure 17 has been brought out the local temperature of every occupants during two experiments. The temperature difference between occupants in abdomen level is from 22.5°C to 23.7°C.

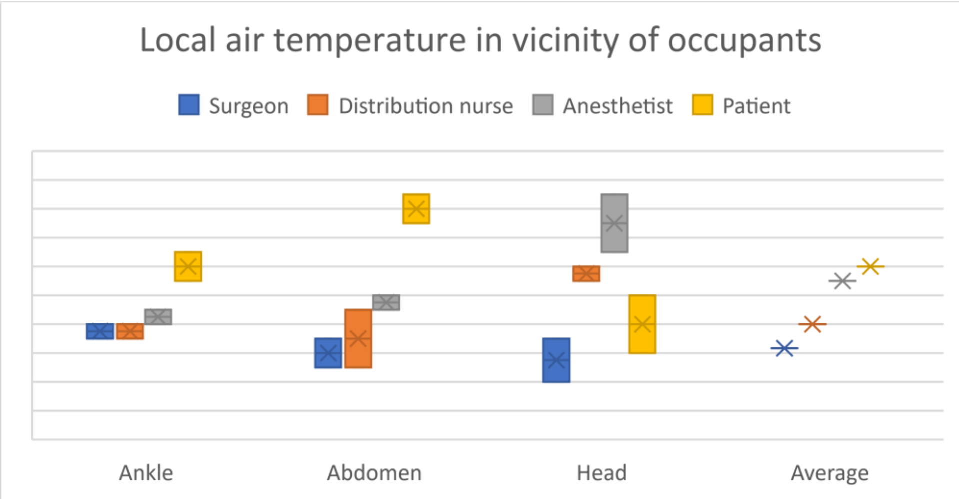

Figure 17 Local air temperature in vicinity of occupants in LAF OR

From Figure 18 can see, that the local velocity in abdomen level is unstabile - it will vary from 0.02 m/s, as for patient, to 0.36 m/s, as for distribution nurse. Alos, in ankle level, the velocity varies between occupants. The highest velocity is in the abdomen level of distribution nurse – mean is 0.36 m/s. Average air velocity for occupants body will vary from 0.12m/s to 0.22 m/s.

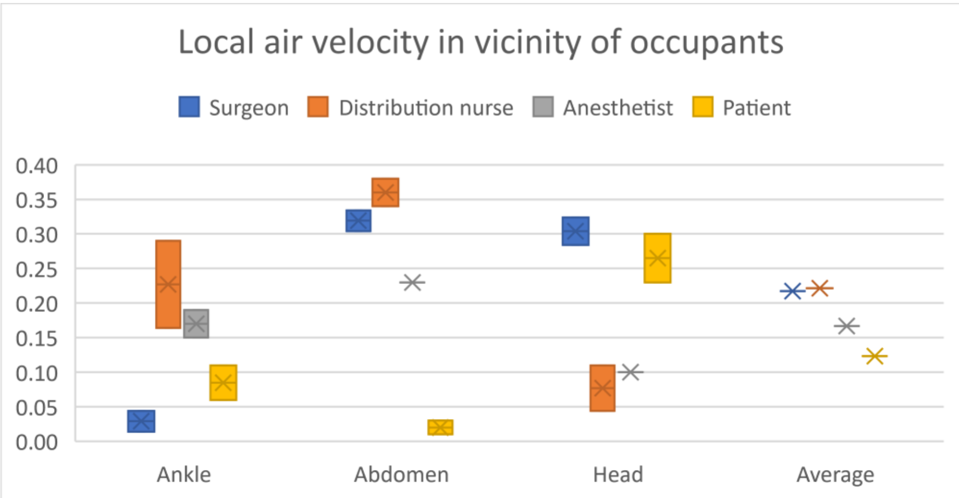

Figure 18 Local air velocity in vicinity of occupants in LAF OR

Experimental measurements of determing the thermal comfort of surgeons

Results shows, that the air temperature near surgeon ranges between 22.4-22.8°C and the warmest temperature is near to ankle, where air velocity is the lowest – mean is 0.03 m/s. However, the highest air velocity (0.32 m/s) is in the abdomen level. As shown in Figure 16, the operative temperature is stabile and the average is 22.16°C. As found out in observations (chapter 4.4), the surgeon overall metabolic rate in laminar air flow ventialtion room is 138.3 W/m^2 and the room mean radiant temperature is calculated as 21.13°C and 21.6°C in EXP5 and EXP6. The clothing thermal insulation for surgeons in this room is 0.202 m^2*K/W. Using these results, the temperature of clothing has been calculated as 24.8°C and 24.9°C (respectively in EXP5 and EXP6). Finally, the PMV level has been calculated for each height level and is shown in Figure 19. In conclusion, the mean PMV level is about 0.8 points higher from comfort boundary (0.5) in both experiment.

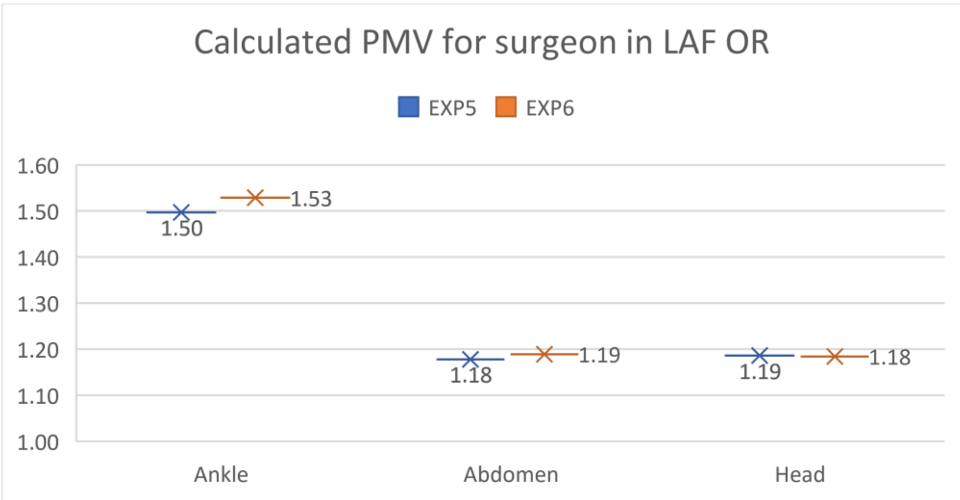

Figure 19 Calculated PMV level of each height for surgeon in LAF OR

Experimental measurements of determing the thermal comfort of anesthetists

The air temperature near anesthetist ranges between 22.9-23.7°C. In sixth experiment day, the temperature difference from ankle to head level is up to 0.9°C. The average temperature is 23.1°C. The air velocity near anesthetist is lower at head level - 0.1 m/s. And on abdomen level, it is 0.23 m/s. As shown in Figure 16, the operative temperature varies in between 22.25°C and 22.38°C. As found out in observations (chapter 4.4), the anesthetists overall metabolic rate in laminar air flow operating room is 90.13 W/m^2 and the mean radiant temperature is calculated 21.13°C and 21.6°C in EXP5 and EXP6. The clothing thermal insulation for anesthetist is 0.154 m^2*K/W. Using these results, the temperature of clothing has been calculated as 26.2°C and 26.3°C (respectively in EXP5 and EXP6).

Finally, the PMV level has been calculated for each height level and is shown in Figure 12. In conclusion, the mean PMV level is mainly in comfort zone (<0.5), but at head level, it is a little higher.

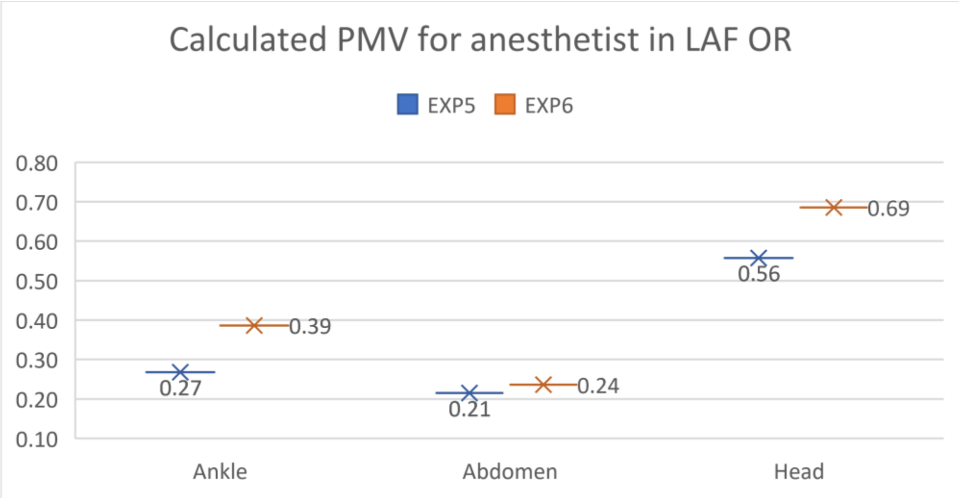

Figure 20 Calculated PMV level of each height for anesthetist in LAF OR

Experimental measurements of determing the thermal comfort of distribution nurse

Near to the distribution nurse the air temperature level differs from 22.5°C to 23.2°C (last near to head). The operative temperature level is in range 22.18-22.3°C (Figure 16). The air velocity is highest in abdomen level (mean is 0.36 m/s) and the velocity is lower, but still over 0.2 m/s in ankle level.

As found out in observations (chapter 4.4), the distribution nurses overall metabolic rate in dilution ventialted room is 74.75 W/m^2. The mean radiant temperature is varies from 22.25°C to 22.38°C. The clothing thermal insulation for distribution nurse in dilution ventilated OR is 0.154 m^2*K/W. Using these results, the temperature of clothing has been calculated as 26.06°C and in experiment six as 26.0°C.

Finally, the PMV level has been calculated for each height level and is shown in Figure 21. There can see, that the PMV varies around neutral zone. The lowest level is in abdomen level (mean is -0.29) and the highest is near the head level (mean is 0.38 points).

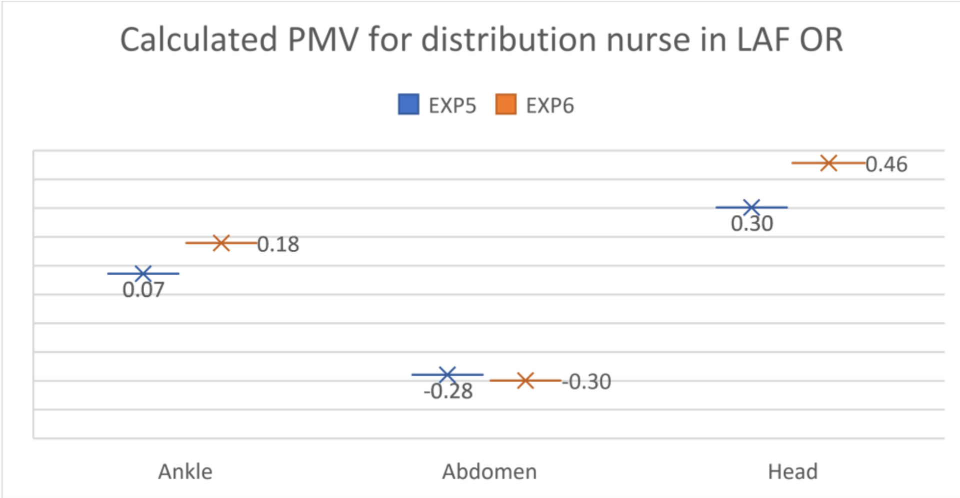

Figure 21 Calculated PMV level of each height for distribution nurse in LAF OR

4.1.2.2 Experimental measurements to investigate the comfort level of patient

This subchapter will focus on patient thermal comfort in laminar air flow operating room and will bring out the conditions, where patient will be placed and analyze about the thermal comfort.

During the two main experiment in laminar air flow room, the air temperature vicinity of the patient was between 22.6-23.7 °C. The mean radiant temperature was 22.25°C to 22.38°C and the mean operative temperature was 22.4 °C. The air velocity was at range 0.03-0.3 m/s (respectively abdomen and head level). The room relative humidity between 20.9-24.3% (on temperature between 23.7°C and 22.3°C.

Calculation of predicted thermal comfort level of patient

As mentioned earlier, for calculation of thermal comfort of patient, there have been taken averaged person between man and woman, whose metabolic rate is 2400 kcal/day, what is 68,4 W/m^2. Here is essential to maintain, that due to metabolic rate (woman have bigger metabolic rate per m^2 than man), the woman will experience higher thermal comfort level than average and men lower (±0,01-0,03 point).

As can see in Figure 22, that patients thermal comfort level is in the fifth experiment below the thermal comfort boundary – this is due to higher convective heat loss caused by higher velocity in ankle level. But mainly, the PMV is around neutral area (from -0,2 to 0,11).

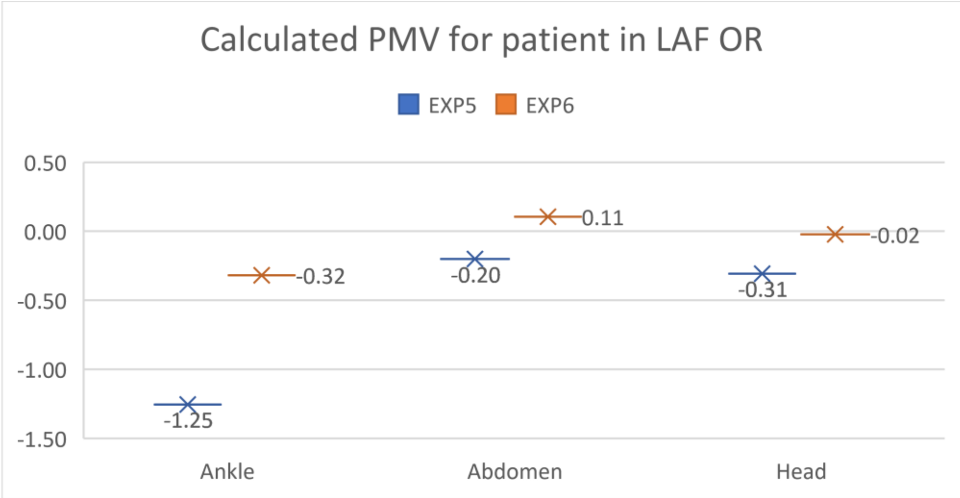

Figure 22 Calculated PMV level of each height for patient in LAF OR

4.1.2.3 Thermal comfort level for every occupants in laminar air flow OR

The total PMV level for occupants is in following table

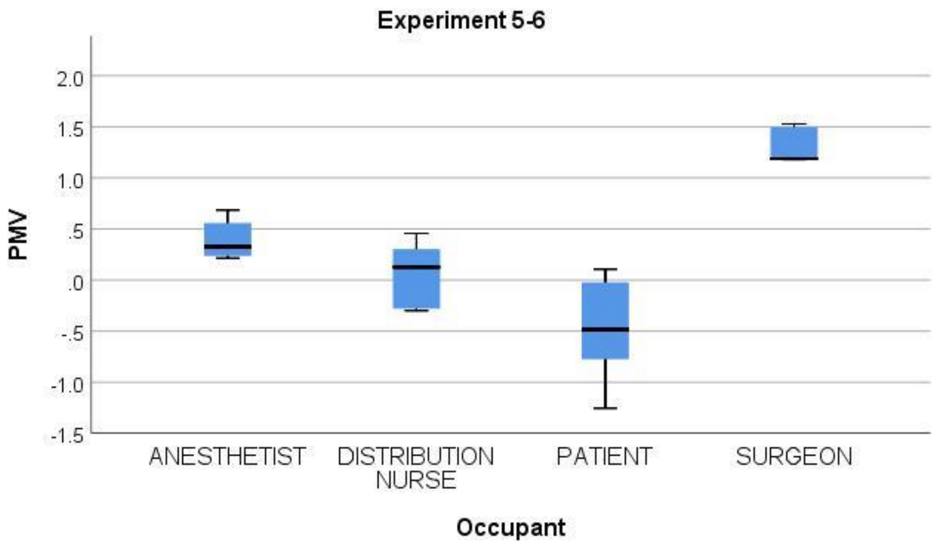

Figure 23 PMV level of every occupants in LAF OR

Occupant	PMV	SD
Anesthetist	0.39	0.19
Distribution nurse	0.07[1]	0.31
Patient	-0.49	0.51
Surgeon	1.29	0.17

Table 19 PMV level of every occupant in LAF OR

4.1.3 Thermal comfort during mock surgery in both operating room

For a later comparison, there has been calculated also the PMV level for mock surgery occupants. The environmental conditions are the same as described above, but the metabolic rate is calculated separately, according to actual activity and is brought out later in observation chapter. The clothing level is different from real surgery only in dilution ventilation OR, because, in mock surgery, there was not used the lead apron. The dilution ventilation OR results are in Figure 24, and the laminar air flow OR results are in Figure 25.

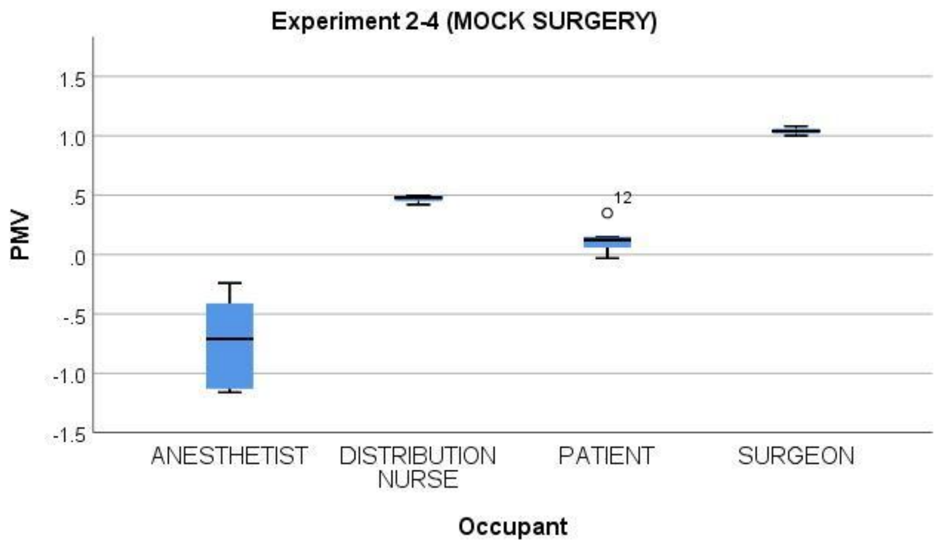

Figure 24 Calculated PMV level for occupants in mock surgery at DV OR

[1] Should be careful with conclusion, because the PMV varies in big interval among local body parts.

Occupant	PMV	SD
Anesthetist	-0.73	0.42
Distribution nurse	0.47	0.042
Patient	0.13	0.13
Surgeon	1.04	0.03

Table 20 PMV level of occupants in mock surgery at DV OR

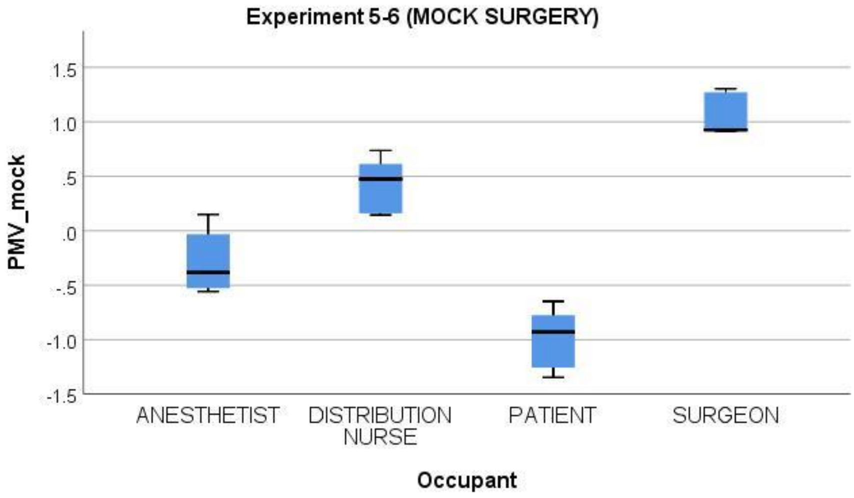

Figure 25 Calculated PMV level for occupants in mock surgery at LAF OR

Occupant	PMV	SD
Anesthetist	-0.29	0.29
Distribution nurse	0.43	0.24
Patient	-0.98	0.27
Surgeon	1.04	0.19

Table 21 PMV level for occupants in mock surgery at LAF OR

4.2 Observations

Following chapters are going to talk about the results what have been get from the observations.

4.2.1 Results of observating the activity level at mockup surgery

During 120 min lasting mock up surgery, the surgeon had 84% movements and 15% resting. Most movements were hand/finger movements evaluated as 85 W/m^2. Overall metabolic rate has been estimated as 120.17 W/m^2. The anesthetist was sitting all the time and therefore the metabolic rate is 65 W/m^2. The distribution nurse had 27.9% movements and 86.5% resting. Some body movements that the nurse had, were estimated as 180 W/m^2 and hand movements as 70 W/m^2. The overall metabolic rate has been estimated as 90.8 W/m^2.

4.2.2 Results of observating the activity level at real surgery in LAF OR

During 135 min lasting surgery, the surgeon worked 99% of time. Most movements were hammering or both arm medium work estimated as 130-140 W/m^2 + 20 W/m^2 for standing stooped body posture. Overall metabolic rate is 138.3 W/m^2. The anesthetist was moving 62.2% of time and 48.8% of time the person was sitting or stading as rest. Most movements, what have been done, were to regulate and measure the patient and that has been estimated as 110 W/m^2 + 15 W/m^2 for standing body posture. The overall metabolic rate has been estimated as 90.13 W/m^2. The distribution nurse had 78.5% of standing or sitting as rest and 21.5% working mainly with one/both arms (mean is 120 W/m^2 + 15 W/m^2 for standing body posture). The overall metabolic rate is 74.8 W/m^2.

4.2.3 Results of observating the activity level at real surgery in DV OR

During 101 min lasting surgery, the surgeon worked 79% of time. Most movements were medium hand (85 + 20 W/m^2) or one arm light work (90 + 20 W/m^2). Overall metabolic rate is 103 W/m^2. Due to long standing/resting time, the anesthetist work will match with low metabolic rate (between 70-130 W/m^2) and comparing to other occupants, the metabolic rate has been estimated as 85 W/m^2. The distribution nurse had 38% of standing as rest and 62% working mainly with hands or one arm (mean is 110 W/m^2 + 15 W/m^2 for standing body posture). The overall metabolic rate is 92.2 W/m^2.

4.2.4 Results from observation of thermal camera video and picture

4.2.4.1 Surface temperature of surgical lights and X-Ray

There have been brought out the area and surface temperature of surgical lamps in both operating room.

Operating room/lamps	**Area, m²**	**Surface temperature, °C**
LAF operating room: Big lamp Small lamp	0.58 0.38	31.03 32.9
DV operating room: Big lamp Small lamp	0.53 0.25	32.7 34.1

Table 22 The area and surface temperature of surgical lamps in LAF and DV operating room

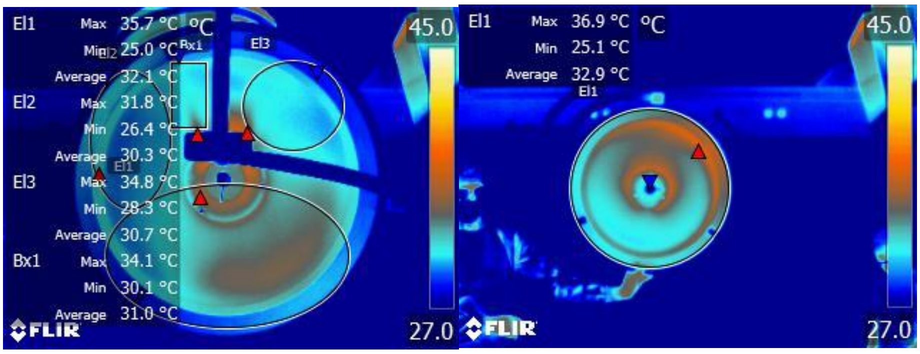

Figure 26 Big and small surgical lamp in LAF operating room

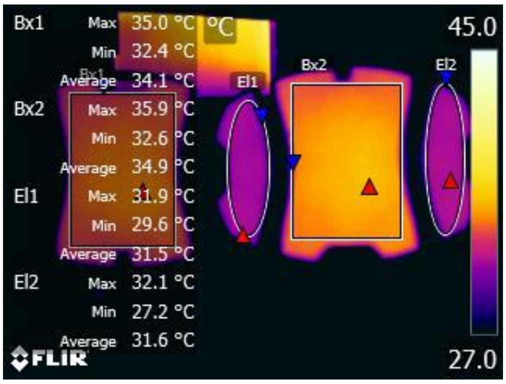

Figure 27 Big and small surgical lamp in dilution ventilation operating room

The one another warmer equipment in DV OR were X-Ray, which average surface temperature in „resting" position (not working at this moment) is for x-ray part (the lighter area on Figure 28) 28.4°C and for case, it is 23.9°C, what is close to room temperature.

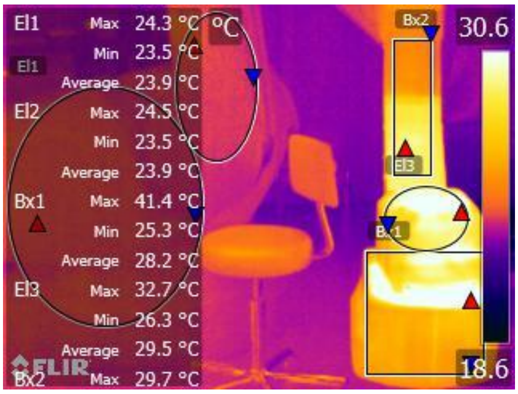

Figure 28 X-Ray equipment in DV OR

4.2.4.2 Observation of the skin temperature of surgeons

On Figure 29 and Figure 30 have been brought out the skin temperature of surgeon during one hour from the beginning of surgery. There can see, that 20 minutes from the beginning, the skin temperature on surgeons forehead in DV OR is 33.7°C and on surgeon in LAF OR is 34.5°C, and it tends to stabilize after 20 min. After, the forehead mean skin temperature of DV OR surgeon is mainly 34.4°C and in LAF OR it is 34.8°C. Temperature rise is therefore for DV OR surgeon 0.8°C and for LAF OR surgeon, it is 0.3°C.

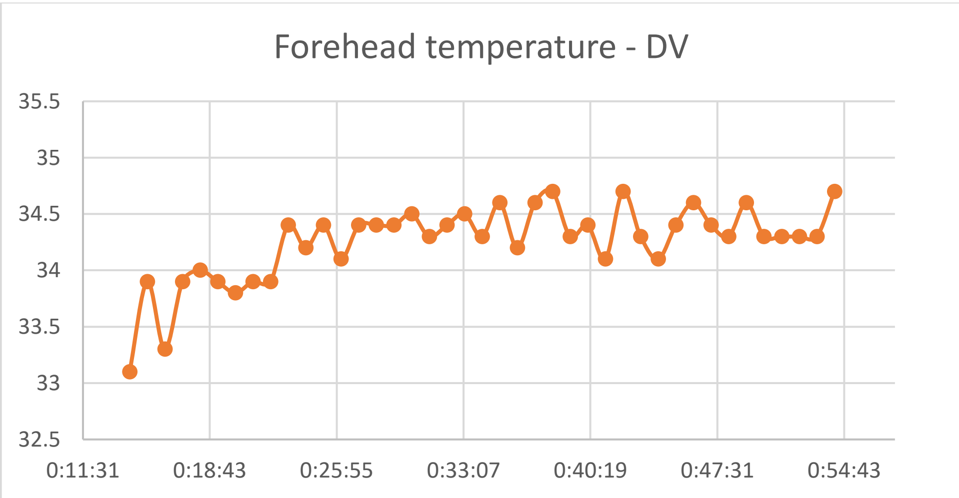

Figure 29 Surgeons forehead temperature in DV OR

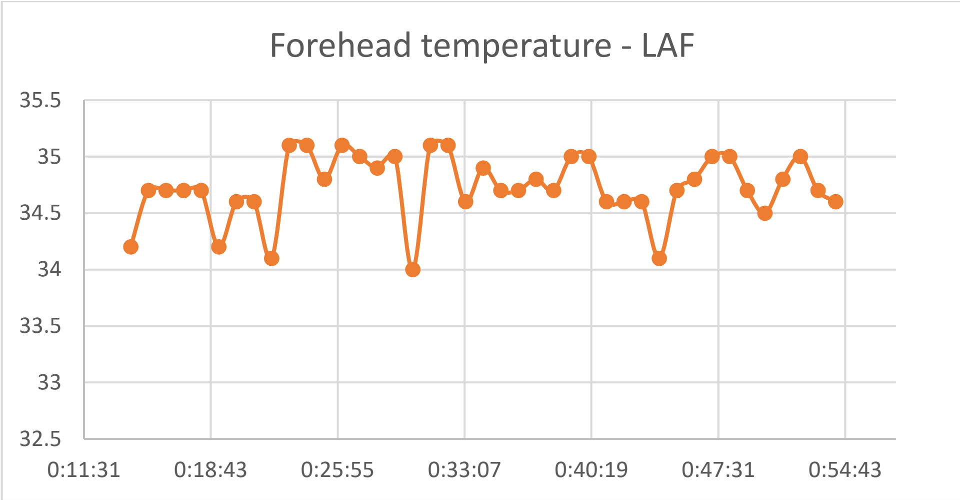

Figure 30 Surgeons forehead temperature in LAF OR

4.2.5 Observation of patient real thermal comfort

Observation of real thermal comfort of patient in dilution ventilated operating room

The investigation results from two operations in different days around patient body temperature, shows, that at first day in two operations, it varies from 35.8°C to 36.3°C and in second day at endovascular thrombectomy, it varies from 37°C to 38°C. As it can see from Figures 28-30, that after patient enter the room, then over one hour temperature decrease may reach from 0.2 to 0.7 °C, but after 1-1.5h, the temperature will increase again. As mentioned before, that in dilution ventilated OR they most of the time are doing prewarming with bair hugger and also will keep the body temperature around normothermia by using warm blankets over patient body during the operation.

From Figure 28-30 can see the comparison between body and air temperature. The air temperature is all the time over the 24°C (as recommended by ASPAN).

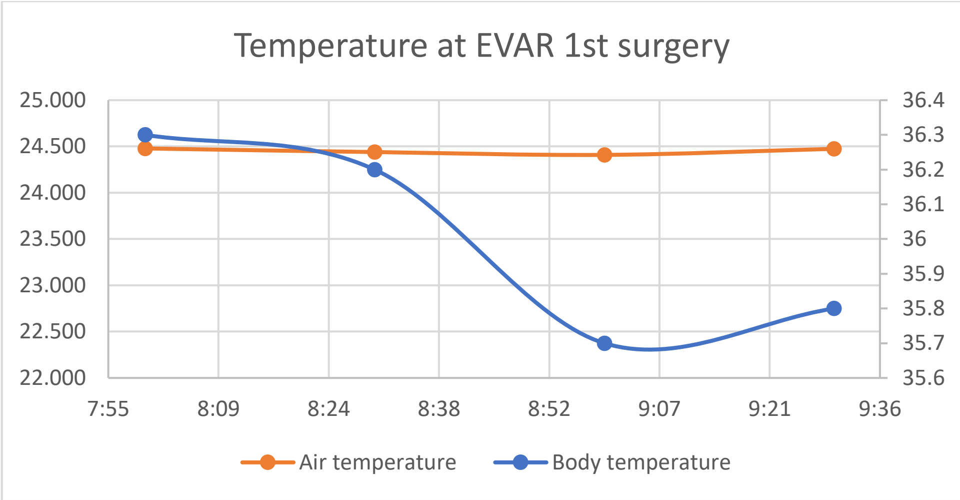

Figure 31 Correlation in between body and air temperature at EVAR 1st operation

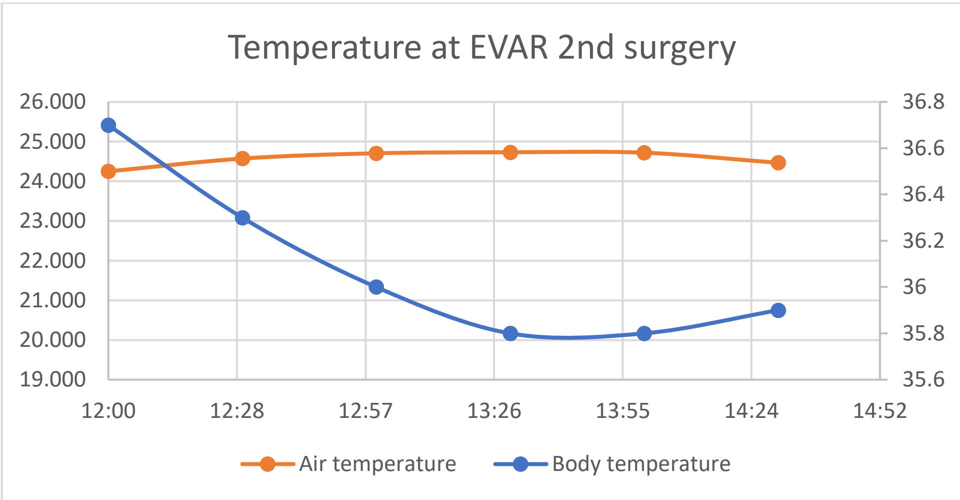

Figure 32 Correlation in between body and air temperature at EVAR 2nd operation

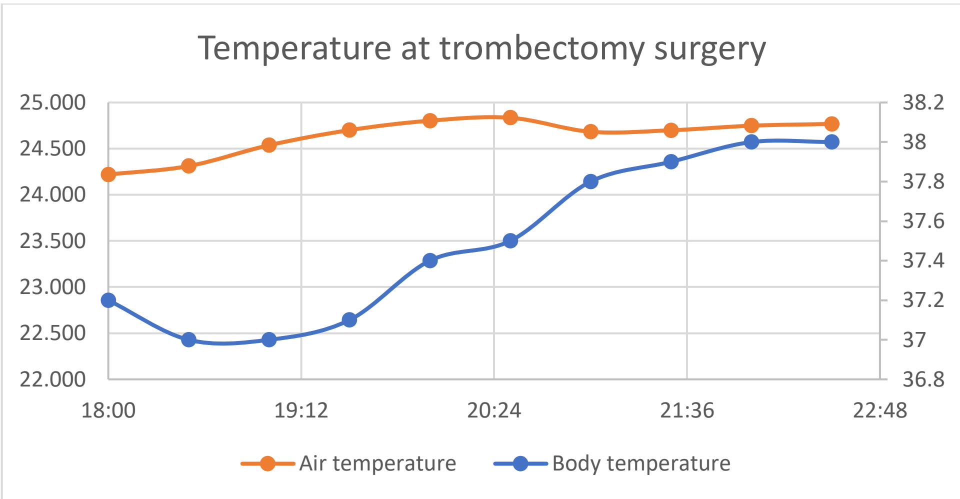

Figure 33 Correlation in between body and air temperature at Trombectomy operation

Observation of real thermal comfort of patient in LAF ventilated operating room

The air temperature varies through the operations from 21.7 °C to 24.1°C. The lowest beginning temperature is 21.8 °C in hip operation, it decrease a little after 15 min and then increase to 22.6°C. In 2nd knee operation, the air temperature increase to 24.1°C, then decrease to 23.3°C and then incrase again to 24.1°C. At this point, the temperature change will be caused by changing the setpoint of room temperature to lower level by surgical stuff. Also, the general temperature increasing may be caused by heat gain, what people and equipments will produce. Average temperature in each operation is 22.43°, 23.66° and 22.28° (respectively 1st knee, 2nd knee and hip operation). In conclusion, from this data can say, that the air temperature is at the beginning too low from suggestions (24.0°C), but during operation, it is around the suggestions (20°C-26°C).

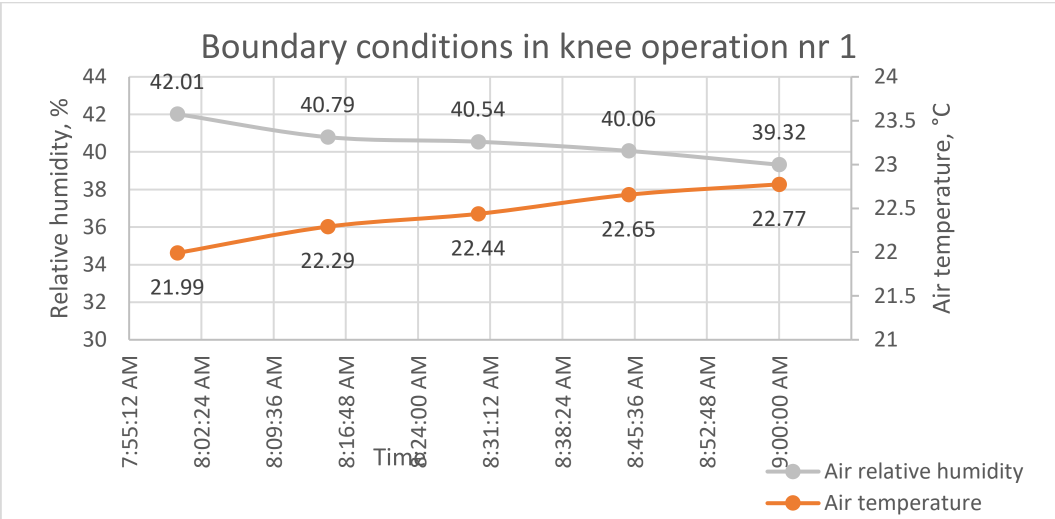

Figure 34 Boundary conditions in LAF OR during knee operation 1

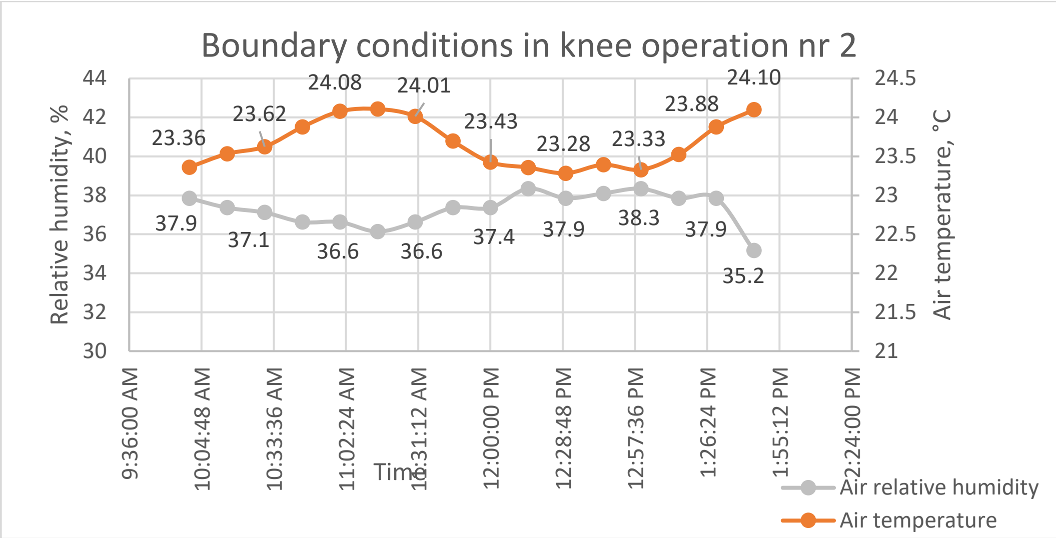

Figure 35 Boundary conditions in LAF OR during knee operation 2

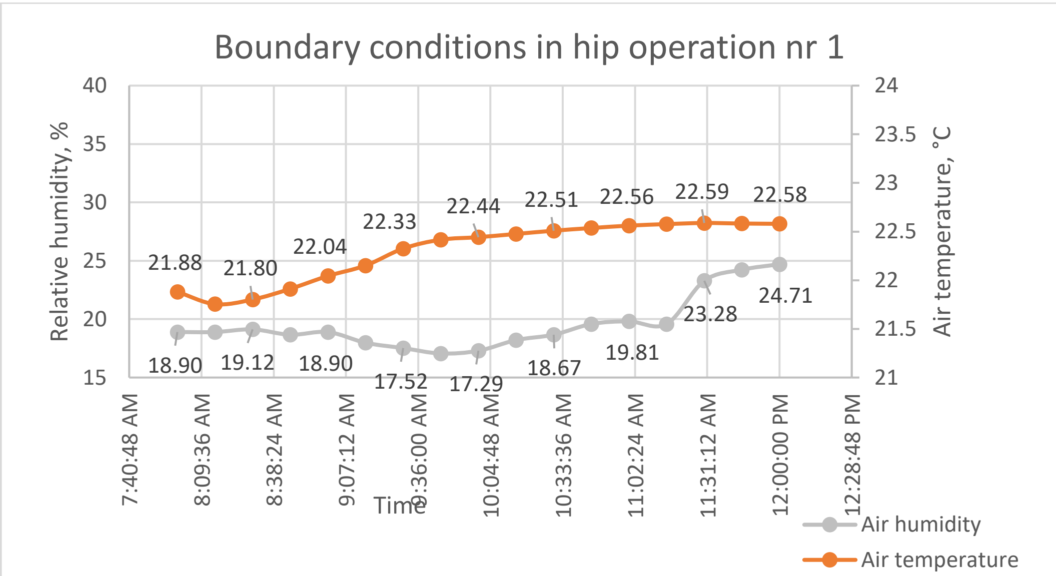

Figure 36 Boundary conditions in LAF OR during hip operation

4.3 Survey

Following subchapters presents the results of questionnaire received from surgical staff in dilution and lanimar air flow ventilation solution operating rooms. In

4.3.1 Survey among dilution ventilation OR surgical staff

The overall sensation about thermal comfort in dilution ventilated OR is in Figure 37. The sensation partically will be brought out on following subchapters. Also, because skin wettednes is one part of thermal comfort, there are results brought out in Figure 38. About overall comfort level, there is overview in Figure 39.

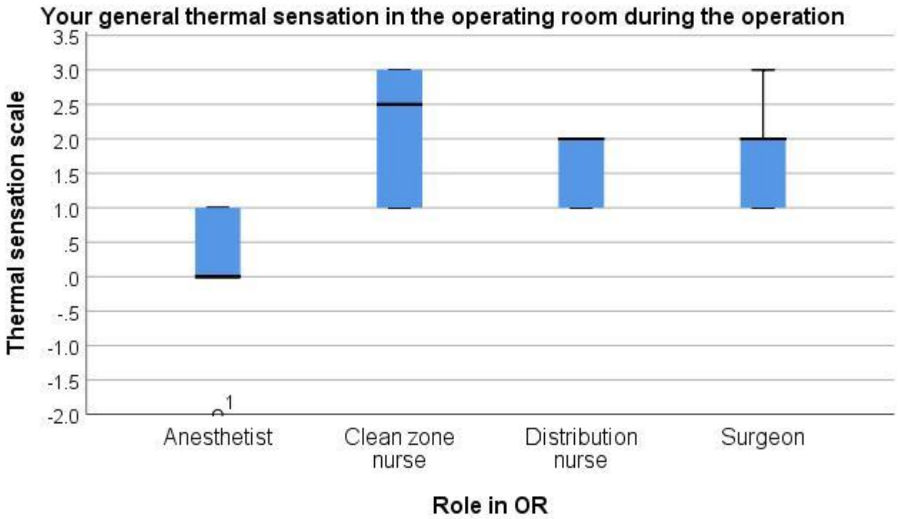

Figure 37 Occupants general thermal sensation during operation in the DV operating room

Occupant	Sensation	SD	Dissatisfaction, %
Anesthetist	0.14	1.07	0
Clean zone nurse	2.13	0.99	75
Distribution nurse	1.6	0.55	60
Surgeon	1.7	0.68	10

Table 23 Occupants general thermal sensation during operation in the DV OR

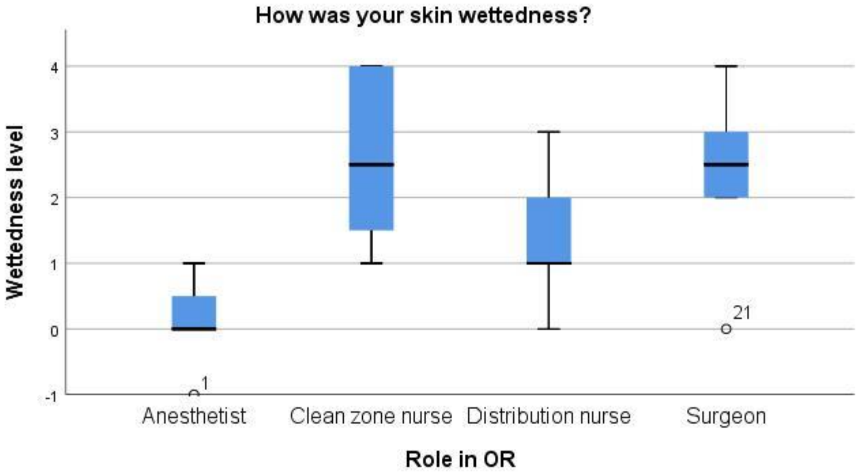

Figure 38 The skin wettedness level for every occupant in DV operating room (-1=dry; 0=neutral; 1=slightly wet…4=soaking wet)

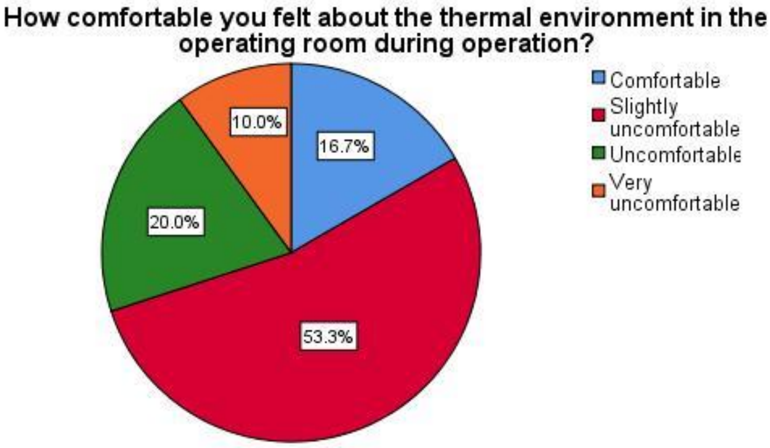

Figure 39 Overall sensation about thermal comfort in DV operating room

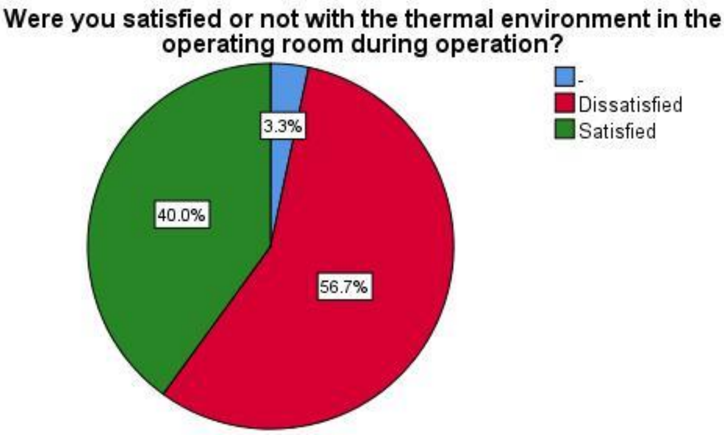

Figure 40 Satisfaction level of occupants in DV operating room

4.3.1.1 Clean zone nurse

Clean zone nurses were all female and the age was in range 31-60 years. From Figure 37 can see, that clean zone nurse feels the thermal environment in between warm and very warm (mean vote = +2.5). Thereby, the feeling about cold draught from ventilation was mainly stagnant (some cases neutral). Majority of answerers evaluates the skin wettednes as wet, very wet or soaking wet. Hereby, the feeling about humidity was dry/slightly dry to half of occupants. The wettedness may also be influenced by work and clothing level. As there can see on Figure 41, that clean zone nurse evaluates the work level mostly between sustained hand/leg work and light manual work/standing. It is essential to maintain, that clean zone nurse alone among all occupants was evaluating the work level as intense hand/upper body work. In that case, according to ISO 8996:2004, the metabolic level may vary in between 100-165 W/m^2. However, as all answerers wore lead apron and surgical gown as outer layer of clothing, except one person, then the clothing thermal insulation is mainly 0.235 m^2*K/W (1,5 clo).

In conclusion, half of occupants evaluated the thermal environment as uncomfortable/very uncomfortable and other half as slightly uncomfortable. Dissatisfaction percentage was 75%, but for 75% of persons the thermal environment was acceptable.

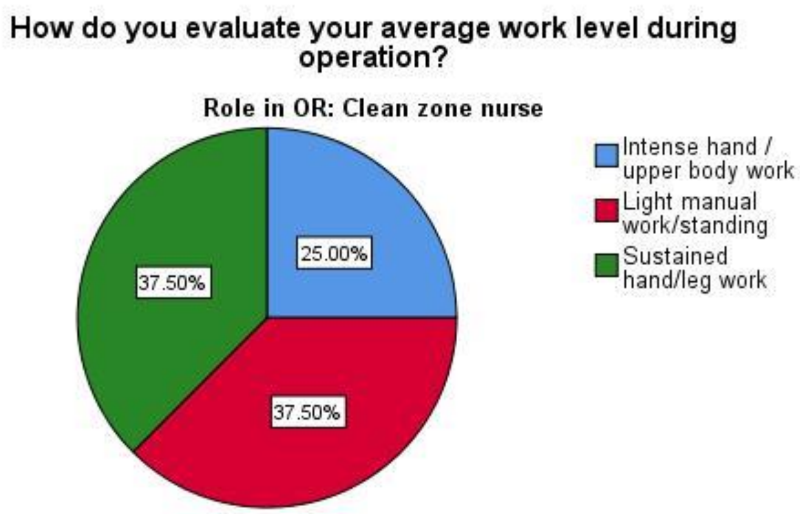

Figure 41 Work level of clean zone nurse during operation in DV OR

4.3.1.2 Distribution nurse

All answerers were female and in age range of 31-50 years. From Figure 37 can see, that anesthetist feels the thermal environment in between slightly warm to warm (mean vote = +2). Alltogether, 2 people felt seldom the gently breeze near head/chest and other persons marked the environment as neutral or stagnant. Majority of answerers evaluates the skin wettedness as slightly wet or neutral and two people felt the skin wet or very wet. The feeling about humidity was dry/slightly dry to 3 person and neutral for two person.

As there can see on Figure 42, that the distribution nurse evaluates the work level mostly as light manual work. According to ISO 8996:2004, the metabolic level may vary in between 70-130 W/m^2. However, majority of occupants wore green reusable suite with lead apron and the clothing thermal insulation in that case is not specified, but may vary around 0.20 m^2*K/W (ca 1,3 clo) (ISO 9920:2004 tables for estimation).

In conclusion, 80% of occupants evaluated the thermal environment as slightly uncomfortable and other as uncomfortable. There was 3 person dissatisfied and 2 person satisfied. Four person evaluated the environment as acceptable and one person was unacceptable (it may be caused by skin wettedness).

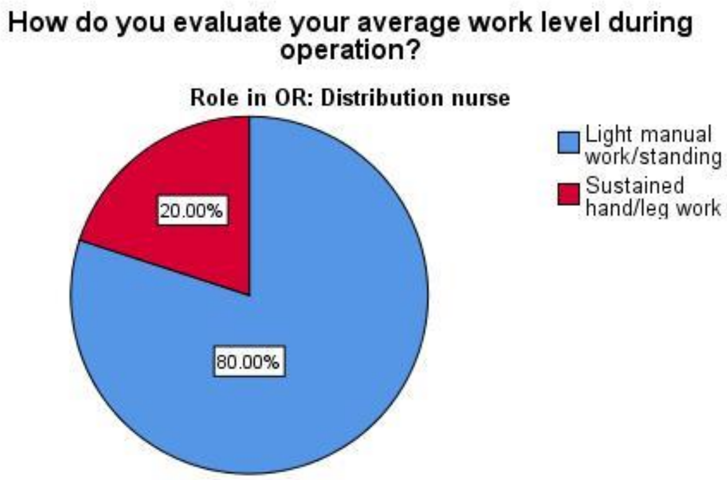

Figure 42 Work level of distribution nurse during the operation in DV operating room

4.3.1.3 Anesthetist

There has been answering 5 female and 2 man in age range of 31-40 and 51-60 years. From Figure 37 can see, that anesthetist feels the thermal environment in between neutral and slightly warm. One anesthetist felt even cool and was also one of two, who felt gently breeze from ventilation. Alltogether, 2 people felt seldom the draught/breeze near head/chest and three person marked the environment in this case as neutral or stagnant. Majority of answerers evaluates the skin wettedness as slightly wet or neutral and the feeling about humidity was neutral for all occupant.

As there can see on Figure 43, that anesthetist evaluates the work level mostly as light manual work. According to ISO 8996:2004, the metabolic level may vary in between 70-130 W/m^2. However, majority of occupants wore green reusable suite (two people had also lead apron in addition) and the clothing thermal insulation in that case is not specified, but may vary around 0.14-0.20 m^2*K/W (0.9-1.3 clo) (ISO 9920:2004 tables for estimation).

In conclusion, 70% of occupants evaluated the thermal environment as comfortable and other as slightly uncomfortable. There was every person satisfied and acceptable about this thermal environment.

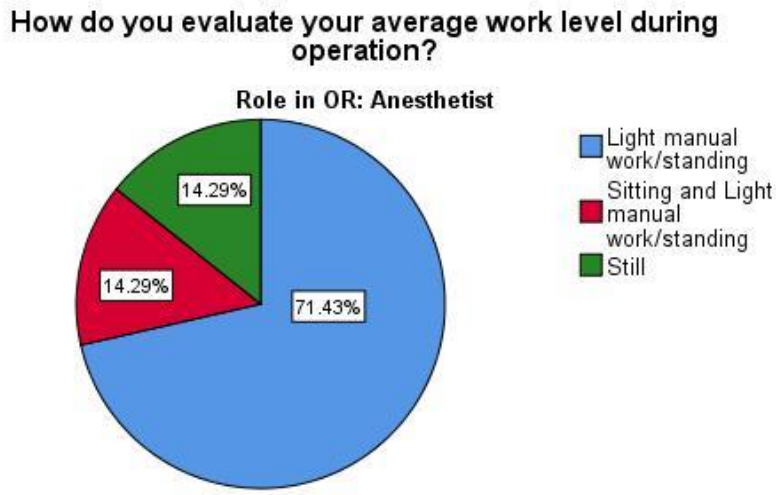

Figure 43 Work level of anesthetist during the operation in DV operating room

4.3.1.4 Surgeon

There has been answering 9 male and 1 female occupant in age range of 41-70 years. From Figure 37 can see, that surgeon feels the thermal environment in between slightly warm and warm (mean vote = +2). Aslo, the skin wettedness was high: 70% wet/very wet and 20% soaking wet. Mostly they evaluate the air distribution as stagnant. About humidity, half of occupants say, that this is neutral/dry, other half, that it is slightly humid/humid.

As there can see on Figure 43, that surgeons evaluates the work level mostly as sustained hand/leg work or light manual work/standing. According to ISO 8996:2004, the metabolic level may vary in between 100-165 W/m^2. However, all the occupants wore surgical gown with lead apron and the clothing thermal insulation is 0.235 m^2*K/W (1,5 clo).

In conclusion, 60% of occupants evaluated the thermal environment as slightly uncomfortable and other as uncomfortable/very uncomfortable. There was 80% dissatisfied, but acceptable about this thermal environment.

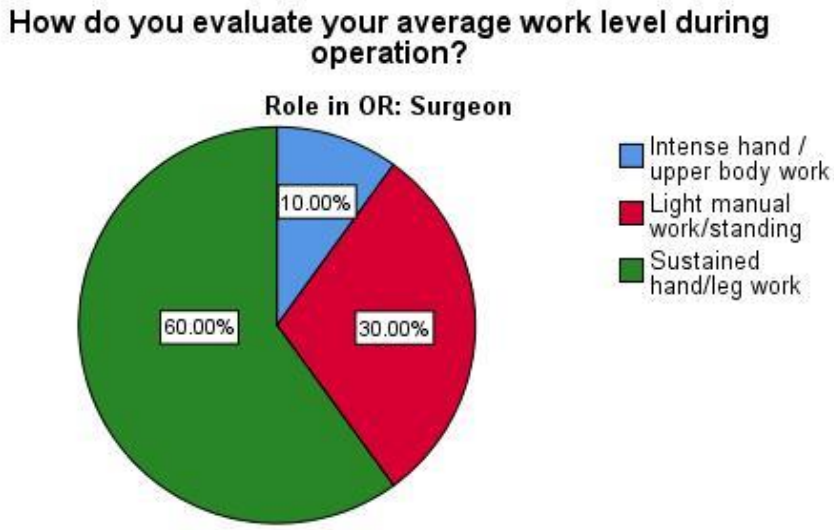

Figure 44 Work level of surgeons during the operation in DV operating room

4.3.2 Survey in LAF ventilated OR

The overall sensation about thermal comfort in dilution ventilated OR is in Figure 45. The sensation partically will be brought out on following subchapters. Also, because skin wettednes is one part of thermal comfort, there are results brought out in Figure 46. About overall sensation, there is overview in Figure 47 and in this operating room every person was satisfied with this thermal environment.

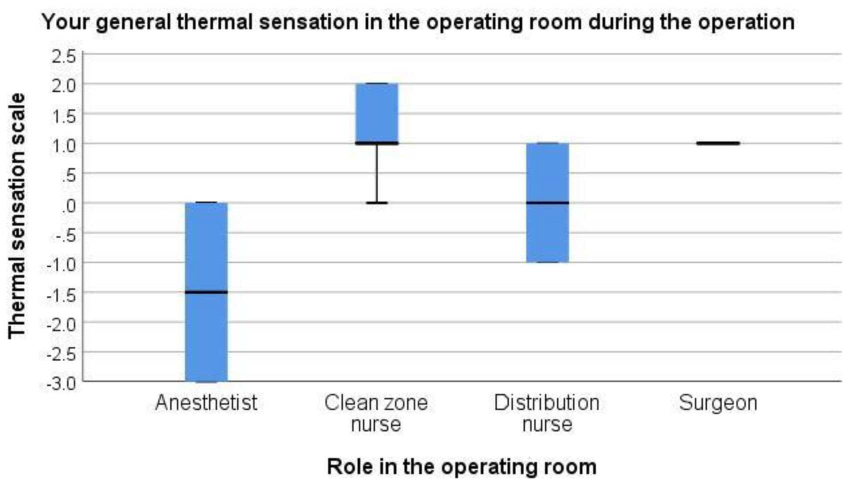

Figure 45 Occupants general thermal sensation during operations in LAF operating room

Occupant	Sensation	SD	Dissatisfaction, %
Anesthetist	0.0	-	0
Clean zone nurse	1.2	0.84	0
Distribution nurse	0.0	1.16	0
Surgeon	1.0	0	0

Table 24 Occupants general thermal sensation during operations in LAF OR

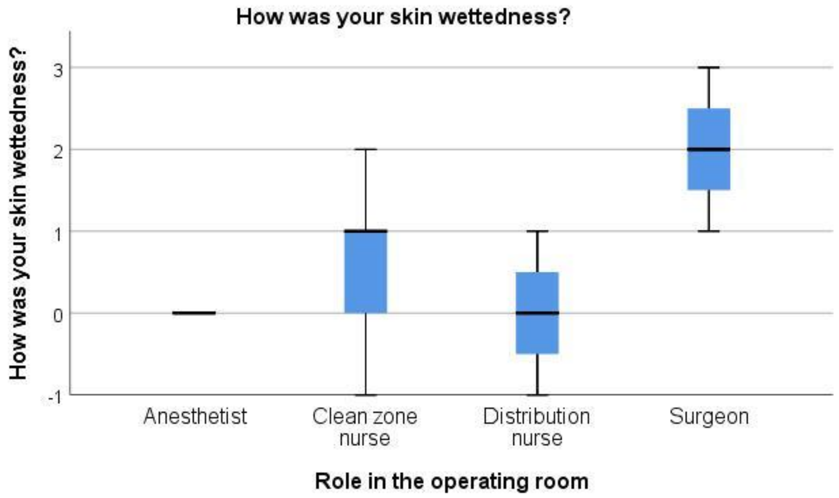

Figure 46 The skin wettedness level for every occupant in LAF operating room (-1=dry; 0=neutral; 1=slightly wet…4=soaking wet)

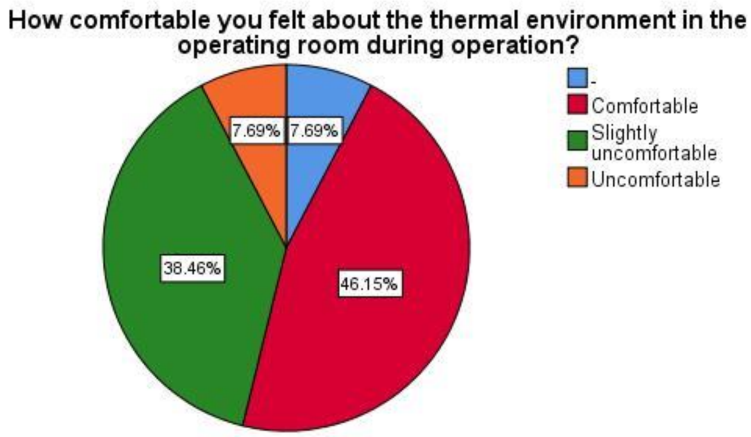

Figure 47 Overall sensation about thermal comfort LAF operating room

4.3.2.1 Clean zone nurse

Clean zone nurses were all female and the age was in range 21-70 years. From Figure 45 can see, that clean zone nurse feels the thermal environment in between neutral and warm (mean vote = +1). Thereby, the feeling about cold draught from ventilation was mainly neutral (some cases stagnant). Majority of answerers evaluates the skin wettednes as neutral or slightly wet. Hereby, the feeling about humidity was neutral/slightly dry to all occupants. As there can see on Figure 48, that clean zone nurse evaluates the work level mostly as light manual work/standing. In that case, according to ISO 8996:2004, the metabolic level may vary around 100 W/m^2. The clothing level was surgical gown for all answerers, so the clothing thermal insulation is 0.202 m^2*K/W (1,3 clo).

In conclusion, majority of occupants evaluated the thermal environment as slightly uncomfortable and one person as comfortable. All persons were satisfied with this thermal environment and evaluater it as acceptable.

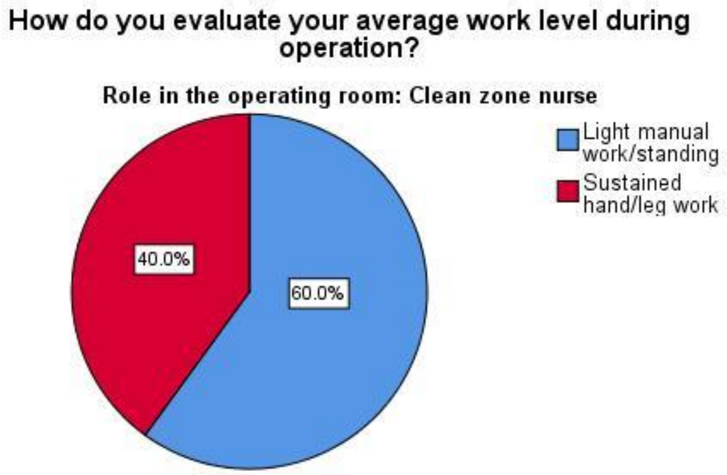

Figure 48 Work level of clean zone nurse during the operation in LAF OR

4.3.2.2 Distribution nurse

All answerers were female and in age range of 31-60 years. From Figure 47 can see, that anesthetist feels the thermal environment in between slightly cool to slightly warm (mean vote = 0). Alltogether, 1 person felt the slightly draught near the chest and other persons marked the environment as neutral or stagnant. Two answerers evaluates the skin wettedness as neutral, one as dry and one as slightly wet. In that last case, the person wore clean air suite, instead of green reusable clothing. The feeling about humidity was neutral for half of occupants and slightly dry for other half.

All the distribution nurses evaluates their work level as light manual work. According to ISO 8996:2004, the metabolic level may vary in between 70-130 W/m^2. However, majority of occupants wore green reusable suite and the clothing thermal insulation in that case is not specified, but may vary around 0.14 m^2*K/W (ca 0,9 clo) (ISO 9920:2004 tables for estimation).

In conclusion, 75% of occupants evaluated the thermal environment as comfortable and one person as slightly comfortable – this person also felt slightly draught from ventilation. Each distribution nurse was and voted the environment as acceptable.

4.3.2.3 Anesthetist

There has been answering 1 female in age range of 31-40 years. Person feels the thermal comfot as neutral, the skin wettedness and feeling about draught was also neutral. Feeling about humidity was slightly dry. The clothing was green reusable suite (insulation may vary around 0.14 m^2*K/W (0,9 clo)), the work level was light manual work/standing. Allover feeling was comfortable, person was satisfied and the environment was acceptable.

4.3.2.4 Surgeon

There has been answering 2 male and 1 female occupant in age range of 41-60 years. From Figure 47 can see, that surgeon feels the thermal environment as slightly warm (mean vote = +1). The skin wettedness mean vote is wet. Mostly they evaluate the air distribution as neutral, once as stagnant. About humidity, two occupants say, that this is neutral, one person, as slightly humid.

As there can see on Figure 49, that surgeons evaluates the work level mostly as intense hand/leg work, one person said, that the work level was sustained hand/leg work. According to ISO 8996:2004, the metabolic level may vary more around 100 than 165 W/m^2. However, all the occupants wore surgical gown and the clothing thermal insulation is thereby 0.202 m^2*K/W (1,3 clo).

In conclusion, there is one person felt comfortable, one uncomfortable and one did not know what to answer. Everyone were satisfied and acceptable about this thermal environment.

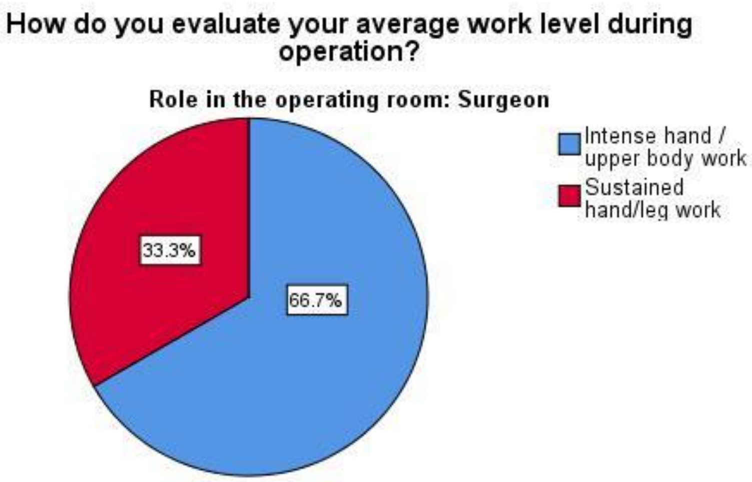

Figure 49 Surgeon work level in LAF OR

4.3.3 Feedback from mock surgery

4.3.3.1 Patient real thermal sensation during mock surgery

There has been asked mock surgery patient to answer about both operating room to the same questionnaire questions as surgical staff.

In dilution ventilation operating room, as mentioned above, the clothing was clean air suite and patient is covered by surgical drape. About thermal sensation, the patient felt all the time slightly warm and the skin was also slightly wet. The air distribution is estimated as stagnant all the time. The humidity has felt as slightly dry. The themral environment was slightly uncomfortable, but generally, the patient was satisfied and acceped this environment.

In laminar air flow operating room, as mentioned above, the clothing was clean air suite and patient is covered by surgical drape and also with warm blanket (upper body). About thermal sensation, the patient felt all the time slightly cool, but the skin was slightly wet under the surgical drape. From ventilation, the patient experienced slightly draught around chest area. The humidity has felt as neutral. The themral environment was slightly uncomfortable, but generally, the patient was satisfied and acceped this environment.

4.3.3.2 Surgical staff real thermal sensation during mock surgery

In dilution ventilation OR, the surgeon felt mostly warm all the time and the skin was slightly wet. About air distribution there has been evaluated as stagnant. The humidity has been evaluated mostly as dry. In general, the surgeon felt uncomfortable and not satisfied, but the thermal environment was acceptable. The anesthetist felt neutral and the skin wettedness was neutral. About air distribution there has been evaluated as stagnant very often. The humidity has been evaluated as neutral. In general, the anesthetist felt comfortable, satisfied and the thermal environment was acceptable. The distribution nurse felt very often as slightly warm and skin wettedness was neutral. About draught, there has been felt neutral. The feeling about humidity was dry. In general, the distribution nurse felt comfortable, satisfied and the thermal environment was acceptable. The sterile zone nurse felt neutral and the skin wettedness dry. About air distribution there has been evaluated as often stagnant. The humidity has been evaluated as very dry. In general, the surgeon felt slightly uncomfortable, satisfied and the thermal environment was acceptable.

In LAF OR, the surgeon felt often slightly warm and the skin was slightly wet. About air distribution there has been evaluated as stagnant. The feeling about humidity was neutral. In general, the surgeon felt comfortable, satisfied and the thermal environment was acceptable. The anesthetist felt very often as cool and the skin was dry. About draught there has been felt often a breeze in head level from ventilation. The feeling about humidity was very dry. In general, the anesthetist felt slightly uncomfortable, satisfied and the thermal environment was acceptable. The sterile zone nurse felt very often as slightly warm and the skin was dry. About draught there has been felt often a breeze in head level from ventilation. The feeling about humidity was very dry. In general, the anesthetist felt slightly uncomfortable, satisfied and the thermal environment was acceptable.

5 DISCUSSION

The objective of this study was to clarify the thermal comfort of four occupant groups in two different ventilation solution operating rooms at St. Olavs hospital. There has been concentrated on predicted and real thermal comfort of surgical staff and patient using three main methods: field experiment, observation and survey. The following chapter include all discussion over the results what have been collected in this study.

5.1 Comparison on results from field experiment

Generally, all surgical staff in dilution ventilation OR seems to experience at least 0.2°C higher operative temperature (as for anesthetist) than suggested (20.5°C). It tends to reach to thermal comfort (as PMV) for anesthetists and patient (who have lower activity and clothing level). But for surgeons and distribution nurses, it seems to reach to slightly warm thermal sensation due to their higher activity level. Furthermore, there can see, tha in dilution ventilation OR, the mean radiant temperature have higher impact to operative temperature, because of lower air velocity. Apparently, due to that the distribution nurse have way higher operative temperature, than for the others.

In laminar air flow operating room, the operative temperature is at least 1.6 degrees higher (as for surgeon) than suggested and it can see that the calculated PMV level, is also higher (must be noticed that, the real sensation is lower).

From measurements (and also from survey) there has been investigated, that the air humidity is very low. If suggested limit is 30-60%, then the humidity in dilution ventilated OR was around 12-39%. In LAF OR, the humidity was around 17-44%. As can see, in warmer period there is possible to reach to the suggested range, but in colder periods, the low humidity may cause several problems. It is mentioned in literature review, that high humidity will increase the airbone bacteria, but the very low humidity will conductive the blood coagulation and also, in thermal comfort and SSI interest, the sweating level will increase.

5.2 Comparison of result from observation

As found out in observations, that the surgeon and anesthetist metabolic rate is similar to earlier studies, also the dilution ventilation OR distribution nurses MET, but the difference is in distribution nurse in LAF OR metabolic rate, what differs about 6.7 W/m^2 and patient metabolic, what differs about 21,2 W/m^2. Therefore, is is essential to investigate the patient metabolic rate more.

5.3 Comparison of results from survey

In dilution ventilated OR, in survey period the air temperature near the anesthetists was around 22.8-24.12°C and the real thermal sensation varies in between neutral and slightly warm. As can see, there is similarity with Mora et al. study, where they stated, that the comfortable air temperature of nurses and anesthetists ranges from 23,0°C to 24°C.

To compare the anesthetist sensation between two operating room, then can see, that in both operating room, the variation is high, but in both operating room, every anesthetist is satisfied. There can see, that anesthetist will be the occupant, whose thermal comfort is very variable, but in between of the limits.

In dilution ventilated OR, the difference of the thermal sensation in between mock surgery survey and real surgery survey is bigger and in real operation the occupants tends to feel more warm. This phenomenon is apparently caused by higher clothing insulation and again by higher mean radiant temperature, because in real surgery they will use the x-ray device, TV and other equipments (what are not used during mock surgery).

The comparison between the answers from mock surgery survey and real surgery survey in LAF OR shows, that for anesthetist, there was 0.29 points cooler thermal sensation in mock surgery than in real operation and for distribution nurse, that was vice versa, but 0.43 points. For surgeon, the sensation level was almost the same (differs 0.04pt).

5.4 Comparison of results between different methods

In dilution ventilation OR, there is similariy in between PMV and real sensation. The comparison shows, that the real sensation of surgical staff is around 0.8-1.1 points higher than calculated PMV level – it is apparently caused by higher mean radiant temperature, what is generally higher during survey (the impact of equipments higher surface temperature). Apparently, the main role in MRT is on surgical lights, which surface temperature is up to 34.1 °C. Hovewer, for anesthetist, the PMV calculation shows 0.11 points higher level than real sensation.

As the PMV calculation seems to predict more lower PMV level for DV OR, then on the contrary, in LAF OR, the real sensation is 0.3-0.4 points lower than calculated PMV. For distribution nurse, the mean PMV calculation varies only 0.07 points, but there should be careful with conclusion, because in between of body parts, the local PMV differs up to 1.16 points. In this case, the mean radiant temperature can not be influencer, but the air velocity in LAF OR have great impact of heat loss from convection. So even if the surgeon

MET level is higher than in DV OR, then due to higher heat loss, the thermal sensation is lower.

From Figure 50 and Figure 51 can see the PMV and real thermal sensation for every occupant. Compared to other surgical staff, the anesthetist will experience the thermal comfort the most, but there should also take into account, that in LAF OR, there was 50% dissatisfied of this thermal environment. From PMV calculations can see, that patient tends to have cool thermal sensation and it comes out also from observation, when in DV OR, the patient sometimes had the body temperature under the normothermia level. As the PMV is even lower in LAF OR, then should be ecpecially pay attention on patient thermal comfort in LAF OR – already because of that, there is hard to use different warming solutions in this operating room. Furthermore, the highest dissatisfaction is in DV OR, where 80% of surgeons felt dissatisfied and the mean thermal sensation is close to warm (+1.7).

Mora et al. found from surveys, that the air temperature 19°C is good for surgeon thermal comfort. It seems to be as well in this study in dilution ventilation OR, because, if to reduce the air temperature to 19°C, then surgeon will feel thermal comfort. As well, if the temperature will be reduced to 21°C, then the PMV level of surgeon is 0.47 points, what is in between comfort limits. However, if the real sensation is higher, then even with 19°C, there will not be total thermal comfort. In patient interest, there can see, that even on air temperature of 24.5°C, the patient will experience the body temperature below the normothermia limit, so it is very hard to reduce the air temperature in these conditions.

For comparison, in Appendix C from Figure 52 and Figure 53 can see, the temperature difference between real surgery and experimental measurements (The constant line shows the temperature range, what was the outcome from measurements during experiments)

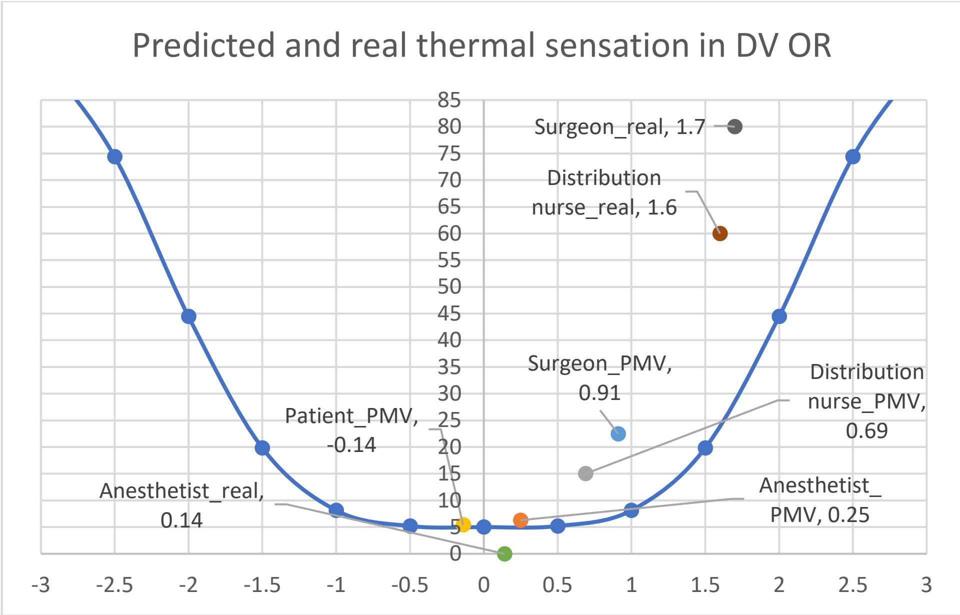

Figure 50 Comparison between predicted and real thermal sensation in DV OR

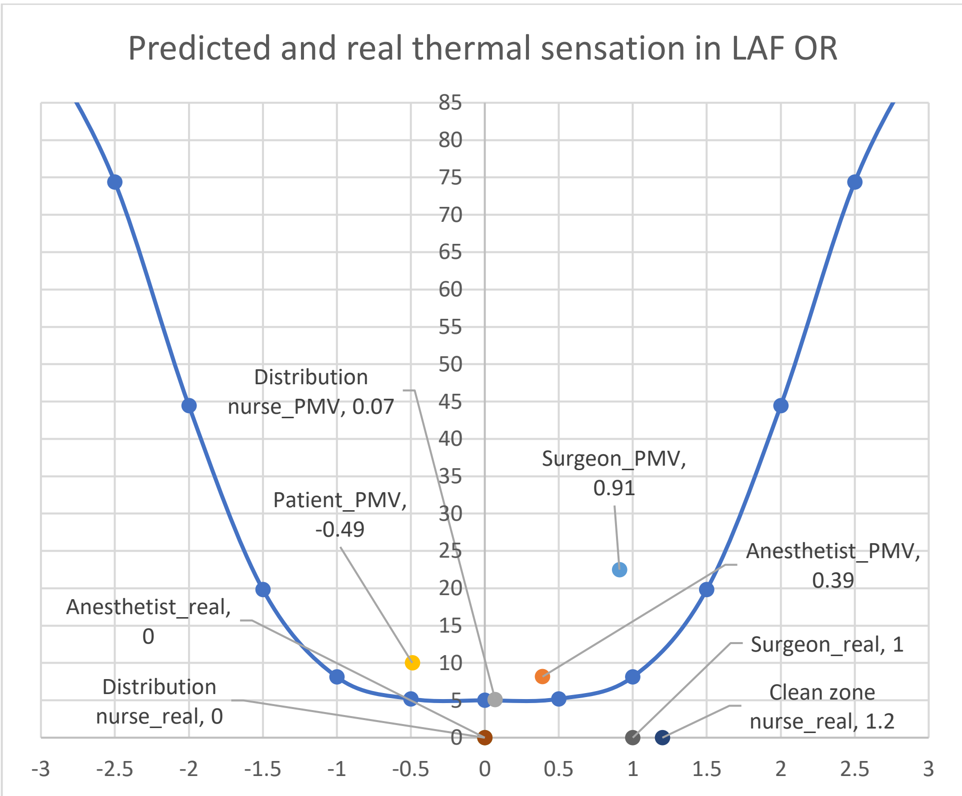

Figure 51 Comparison between predicted and real thermal sensation in LAF OR

5.5 Suggestions and guidance for improving the operating room thermal environment

On the basis of this study, can be suggest that one option to improve the thermal comfort level in OR at St. Olavs, is to reduce the mean radiant temperature. Dilution ventilation OR have many equipments, mostly surgical lights, what will influence occupants by radiant heating. As can see from thermal camera observation results, that the lamps surface temperature is around 32.7-34°C in DV OR and around 31-32.9°C in LAF OR. This is very high, if to compare with other surfaces around, and even due to that, they are closer to surgeon, the radiant heat to surgeon will be very high.

Another possibility is to, to investigate, how much it is possible to raise the air change rate in dilution ventilated OR (as suggested by ASHRAE 170 - to take out the heat gain produced by equipments) and still be in comfort zone range and also without enlarging the SSI.

Furthermore, as also suggested by Wyon et al. (9), can see in this study, that there should be focus on the clothing in operating room. Anesthetist, who have low activity level and at the same time, surrounded by air with lower temperature, should wear warmer clothing. The problem is mainly in LAF OR, due to low temperature and also a little draught.

5.6 Limitations of the study

As usual, there are some limitations also in this study. Firstly, there was no possibility to get feeback from patient, because in these operations they usually sleep.

Then secondly, because of difficult field environment, there has been used the uni-directional anemometer. Therefore, the air velocity will not be the same, what the occupant will experience.

Even if that was in mind at the beginning, then due to lack of time and knowledge, there has not done the measurements for thermal insulation of St. Olavs hospital clothing. Instead of that, the value has been taken from literature, what will be different than real clothing in St. Olavs hospital.

Finally, The ISO 7726:1998 suggest to calculate the mean radiant temperature using surface temperature of surrounding surfaces and the angle factor between a person and the surrounding surfaces. Unfortunately, due to complicated calculation, the estimation of angle factor is difficult in this case. Fanger says in his study, if the angle factor between persons and typical surfaces is inadequate, the rough approximations should be used by calculating the mean radiant temperature as the mean temperature of all the surface areas. (5)

5.7 Reability and validity of this study

As can see from Figure 50 and Figure 51, that even, if the PMV calculation could be similar to real sensation, then PPD calculation is totally different. Therefore, there is not right to do fundamental conclusions. The further invertigations should be done more specifically over all the variables, what will influence the thermal comfort, instead of calculating the PMV level. About survey, the best is to investigate the environment, conducting the field survey with asking questions about thermal comfort at the precise moment. Certainly, it should be done during simulated surgery.

However, the experiments are conducted in real operating room environment and the study will be therefore good overview of actual conditions of operating room. As all the equipments, what are used, are calibrated or correlated with another calibrated device. Therefore, the devices accuracy is acceptable. Also, there have been get great data to investigate from different sources– starting from studys own measurements and ending up to videorecording to observate the metabolic rate.

5.8 Future work

Thar has been mentioned before, that this is challenging to adjust the temperature in operating room, but it is not impossible. In this study has been investigated the thermal comfort of patient through observation of body and air temperature, but this is not enough to investigate patient total thermal comfort in OR. For future work, author suggests to investigate, how low the air temperature could be and how can improve the clothing thermal insulation of the patient, that they still meet thermal comfort and will be in the normothermia condition.

To investigate more the thermal comfort aspect as mean radiant temperature, it will be interesting to examine the equipments effect in operating room. As found out, that the surgical lights will effect surgeons thermal comfort, but there are also many other equipments what will produce the heat. Also, in DV OR they are using bair hugger, what will be one future study to do - it is heating the patient, but at the same time it will produce the heat aslo to the air and for other occupants.

Furthermore, there is lack of information about thermal and vapour resistance of surgical clothing (even less about clothing what covers the patient), what is the main aspect of determing the thermal comfort of surgical staff and patient.

6 CONCLUSION

The challenging arond thermal comfort in operating room is in its beginning, but to reach somewhere, there is need to collect the information constantly. This study has been focusing on the thermal comfort of the surgical staff and patient in operating room. The two research questions were, what is the predicted and what will be the real thermal sensation in operating room.

Predicted thermal sensation clarifying was based on predicted mean vote. For calculation and prediction, there has been used two methods: experimental measurements to measure the variables influencing the thermal comfort; observation to estimate the metabolic rate and clothing thermal resistance. The real sensation of surgical staff has been discovered through survey in two operating rooms. And the real thermal sensation of patient has been discussed by observation. Subsequent sections will conclude the results what has been clarified.

In dilution ventilation operating room, during the measurements the boundary conditions are: air temperature in range 23.5°C-24.2°C; relative humidity 12.1-15%; mean radiant temperature averaged as 20.89°C. As predicted through PMV calculation, then anesthetist and patient are in thermal comfort area. The surgeon and distribution nurse feeling is inclined to slightly warm. Hovewer, the results from survey in dilution ventilated operating room are showing different values. The boundary conditions are: air temperature in range 22.8°C-24.9°C; relative humidity 13.9-39.2%. To questionnaire, there have been answered 30 people from surgical staff. The mean thermal sensation of 10 surgeons and 5 distribution nurse is close to warm and there are dissatisfied 80% of surgeons and 60% of distribution nurses. The average sensation of 7 anesthetist is almost neutral and every person is satisfied. The thermal sensation of real patient will be concluded as slightly under the neutral, because the body temperature in some time is under the normothermia level.

In laminar air flow operating room during the measurements the boundary conditions are: air temperature in range 22.3°C-23.7°C; relative humidity 20.9-24.3%; mean radiant temperature averaged as 21.37°C. From PMV calculation can conclude, that the surgeon feels slightly warm, anesthetist and distribution nurse feels close to neutral, and patient experiences close to slightly cool and will almost be under the thermal comfort limit.However, again, survey analyze in laminar air flow operating room surgical differs adequately from predicted vote. The boundary conditions are: air temperature in range 20.7°C-24.11°C; relative humidity 17.1-44.7%. To questionnaire, there have been answered 13 people from surgical staff. The mean sensation of 3 surgeons is slightly warm and everyone are satisfied. The sensation of one anesthetist and 4 distribution nurse is neutral and there is every person satisfied. The thermal sensation of real patient can not adequately concluded.

As conclusion from survey there can be say, that in LAF OR, there is total thermal comfort, but in dilution ventilating operating room the occupants will feel in some case cold and in some case extremely warm and this is the operating room, where should be put an attention.

During this study, there has been done some simplifications in determing the thermal comfort, therefore, there can not be do final conclusion for thermal comfort of operating room. On the other hand, this study involves itself analyzing of many valuable data and can be good foundation for future work.

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8 APPENDICES

8.1 Appendix A - The calibrations of VelociCalc Plus device

8.1.1 Temperature calibration

The temperature calibration of this device has been done with Reference Temperature Calibrator Model RTC-157 (accuracy ±0.04 °C).

Real temperature, °C	Measured temperature, °C
15	14.5
20	19.5
25	24.6
30	29.5
Δ	**-0.5**

Table 25 The temperature calibration data of VelociCalc Plus

8.1.2 Anemometer calibration

Model 8388			
Pressure (Pa)	Measured Velocity (m/s)	Real velocity (m/s)	Correlation
0	0.03	0	-0.0300
10	0.06	0.032	-0.0280
25	0.08	0.051	-0.0292
50	0.1	0.072	-0.0282
75	0.11	0.088	-0.0221
100	0.13	0.101	-0.0286
200	0.17	0.143	-0.0268
500	0.24	0.226	-0.0139
1000	0.34	0.319	-0.0206
2000	0.48	0.451	-0.0286
4000	0.67	0.638	-0.0320
6500	0.84	0.813	-0.0270

8.1.3 Relative humidity correlation with Pegasor AQ Indoor

Relative humidity, %		
Measured with Pegasor AQ Indoor	Measured with model 8388	Correlation
12.0	10.0	2.0
13.0	11.0	2.0
14.0	12.0	2.0
15.0	13.0	2.0
16.0	14.0	2.0
17.0	15.0	2.0
18.0	16.0	2.0
19.0	17.0	2.0
20.0	18.0	2.0
21.0	18.0	3.0
22.0	19.0	3.0
23.0	20.0	3.0
24.0	21.0	3.0

Table 26 VelociCalc Plus correlation with Pegasor AQ Indoor

8.2 Appendix B – VelociCalc Plus Functions

Time Constant Function - The available time-constant choices (1, 5, 10, 15 and 20 seconds) will sequence on the display. The time-constant is actually an averaging period. The VELOCICALC display is always updated every second, however, the reading displayed is the average reading over the last time-constant period. For example, if the current time-constant is set to 10 seconds, the display will show readings averaged over the previous 10 seconds, updated every second. This is also called a 10 second "moving average."

Store and Average Functions - The VELOCICALC has the ability to compute the average of a number of individual stored readings. Every time the STORE key is pressed, the currently displayed reading is added to a store buffer. When the AVERAGE key is pressed, the readings in the store buffer are divided by the number of stored readings to get the average.

8.3 Appendix C – Exhaust temperature range during real operations

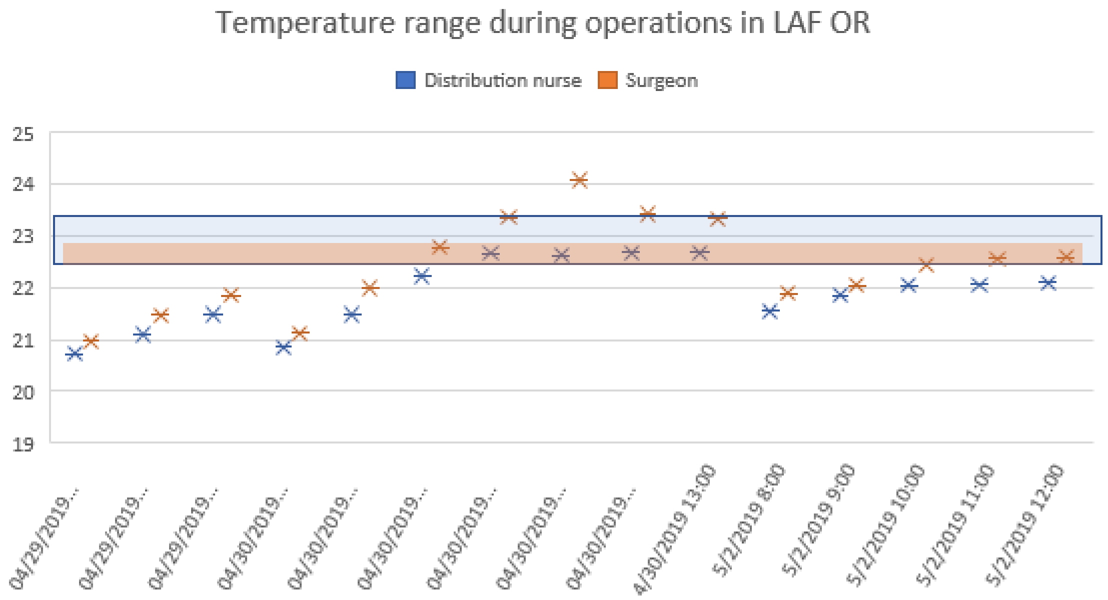


Figure 52 Air temperature range during operations in survey answering period in LAF OR (air temperature range from field experiment measurements in the vicinity of surgeon and distribution nurse added)

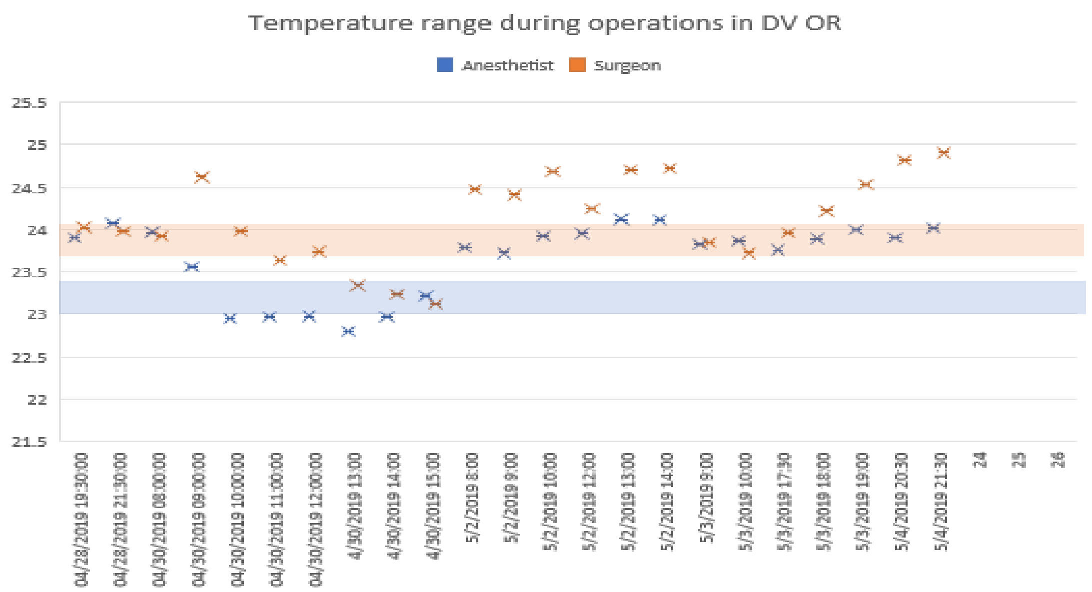


Figure 53 Air temperature range during operations in survey answering period in DV OR (air temperature range from field experiment measurements in the vicinity of surgeon and distribution nurse added)

8.4 Appendix D – The questionnaire of in St.Olavs hospital

Spørreskjema om brukernes tilfredshet på ventilasjon og termisk miljø i operasjonsrom på St.Olavs hospital

Hvis du ikke vet hva du skal svare, vennligst sett et kryss foran spørsmålet.

Generell informasjon (følgende informasjon vil kun bli brukt til forskning og vil ikke deles med andre, som ikke er med i denne studie)

1. Din rolle i operasjonsrommet:

☐Kirurg	☐Distribusjons sykepleier	☐Ren sone sykepleier
☐Anestesi sykepleier	☐Assistant kirurg	☐Andre: ____________

2. Kjønn

☐Mann	☐Kvinne

3. Alder

☐under 20	☐20-30	☐31-40	☐41-50
☐51-60	☐61-70	☐over 70	

4. I hvilket operasjonsrom var du?

☐Stue 1 på AHL	☐Stue 8 på Bevegelsessenteret

5. Følte du stress, uvanlig svette eller frysninger, som kan ha vært forårsaket av mentalt stress eller sykdom under operasjonen?

☐Ja	☐Nei

   a) Hvis "Ja", og hvis du vil svare, kommenter hvorfor?:________________________

   ____

6. Ditt ytre lag av klær i operasjonen (velg det alternativet som passer best med det du hadde på deg)

☐A)

☐B)

☐C)

☐D) Andre, kommenter hvorfor:____

7. Ditt indre lag av klær i operasjonen (velg alle alternativene du brukte under operasjonen).

☐Sokker	☐Skjorte med korte	☐Langermet T-skjorte
☐Undertøy	☐Lette bukser	☐ Andre:____________________

8. Hvordan vurderer du ditt generelle aktivitetsnivå under operasjonen?

☐ Stillesittende	☐Lett manuelt arbeid / stående	☐Vedvarende hånd / benarbeid	☐Intense hand/ overkroppen arbeid	☐Veldig intens aktivitet

Termisk miljø

Baser svarene dine på hvordan du følte deg i operasjonsrommet under den siste operasjonen du hadde.

9. a) Hvordan var din generelle termiske følelse/sensasjon i operasjonsrommet?

Kald	Kjølig	Litt kjølig	Nøytral	Litt varm	Varm	Veldig varm
☐-3	☐-2	☐-1	☐0	☐+1	☐+2	☐+3

b) Hvor ofte følte du det?

Aldri	Sjelden	Ofte	Veldig ofte	Hele tiden
☐0	☐1	☐2	☐3	☐4

10. Hvor mye svettet du?

Tørr	Nøytral	Litt fuktig	Fuktig	Veldig fuktig	Gjennomvåt
☐0	☐1	☐2	☐3	☐4	☐5

11. Vennligst svar på følgende spørsmål om din følelse av kald trekk i operasjonrommet:

a) Fikk du kald trekk fra ventilasjonen i rommet?

Kraftige trekk	Trekk	Litt trekk	Nøytral	Bris	En lett bris	Stillestående
☐-3	☐-2	☐-1	☐0	☐+1	☐+2	☐+3

b) Hvor ofte følte du det?

Aldri	Sjelden	Ofte	Veldig ofte	Hele tiden
☐0	☐1	☐2	☐3	☐4

c) Hvor følte du den kalde trekken hovedsakelig?

☐ føtter	☐ knær	☐ hofter	☐ bryst	☐ hode	☐ Stillestående

12. Hvordan følte du luftfuktigheten var under operasjonen?

Veldig fuktig	Fuktig	Litt fuktig	Nøytral	Litt tørr	Tørr	Veldig tørr
☐−3	☐−2	☐−1	☐0	☐+1	☐+2	☐+3

13. Hvor behagelig følte du det termiske miljøet var under operasjonen?

Behagelig	Litt ubehagelig	Ubehagelig	Veldig ubehagelig	Ekstremt ubehagelig
☐0	☐1	☐2	☐3	☐4

14. Var du fornøyd eller ikke fornøyd med det termiske miljøet under operasjonen?

Fornøyd	Ikke fornøyd
☐	☐

15. Var det termiske miljøet akseptabelt eller uakseptabelt for deg under operasjonen?

Akseptabelt	Uakseptabelt
☐	☐

Akustisk miljø

Baser svarene dine på hvordan du følte deg i operasjonsrommet under den siste operasjonen du hadde.

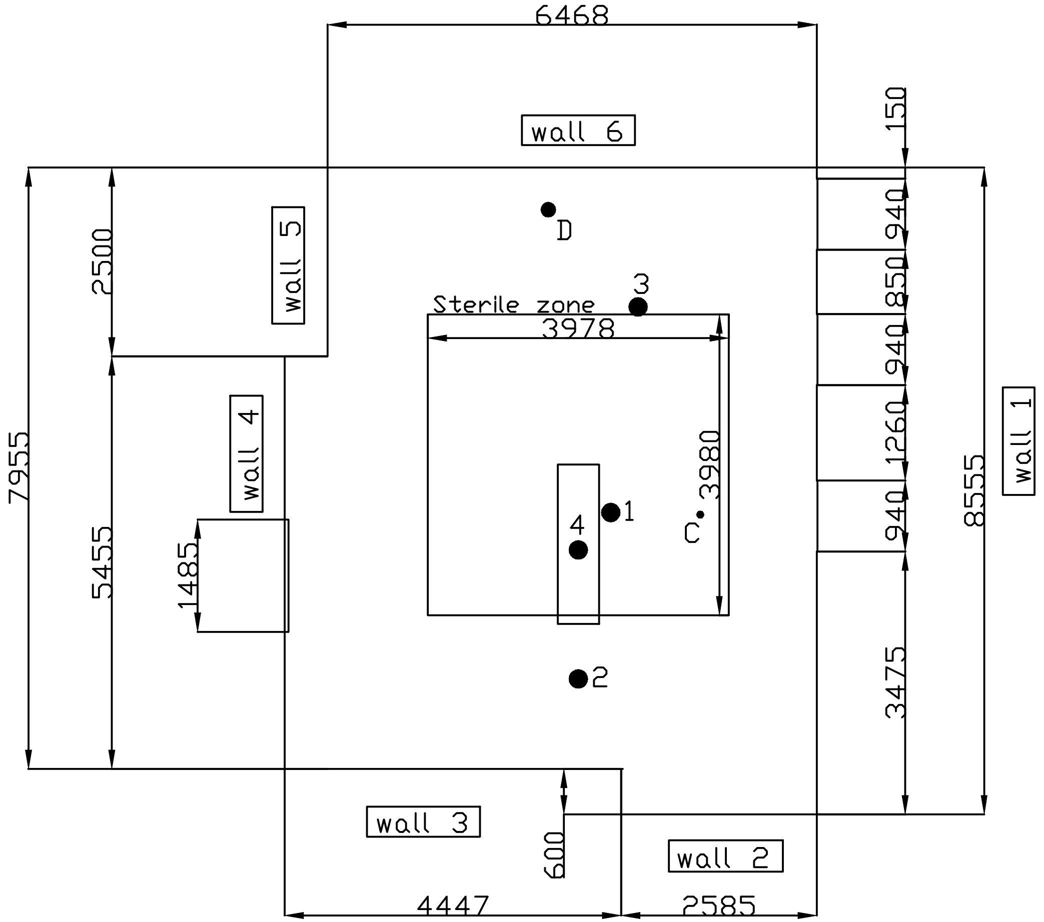
16. Hvordan er din oppfatning av støy fra ventilasjonssystemet i operasjonsrommet?

Veldig stille	Stille	Merkbart	Åpenbart høylytt	Veldig høylytt
☐−2	☐−1	☐0	☐1	☐2

17. Påvirket støyet fra ventilasjonen deg under operasjonen?

☐	Veldig irriterende, kan nesten ikke konsentrere seg
☐	Bare bra når du konsentrere deg om arbeidet
☐	Nei, det hadde ingen innflytelse på meg.

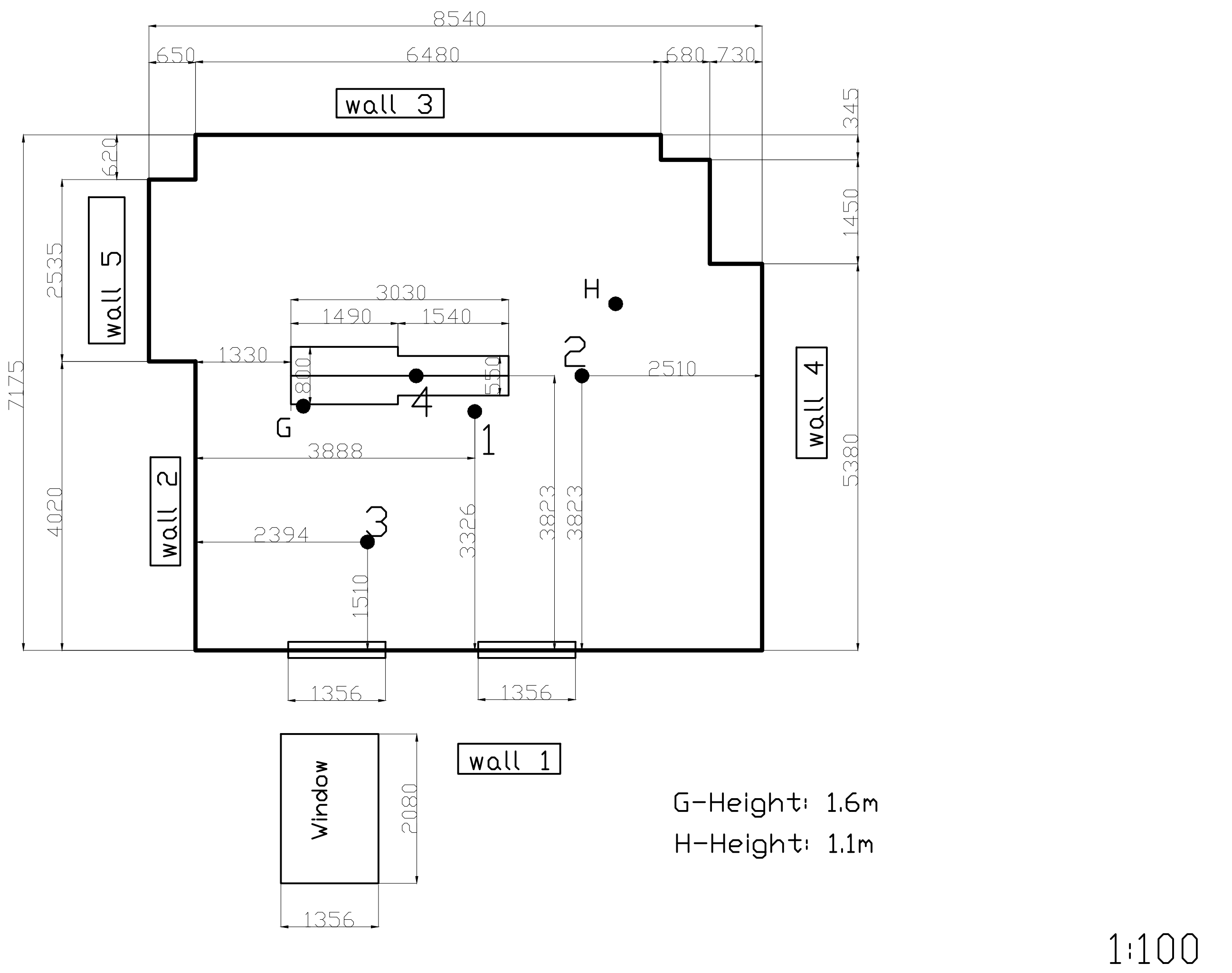
8.5 Appendix E – Operating room plans



C - Height: 1.3m

D - Height: 0.57m

1:100



8540
650
6480
680
730
wall 3
345
1450
5380
620
2535
7175
4020
wall 5
wall 2
wall 4
3030
1490
1540
1330
800
550
2510
H
2
4
G
1
3888
3
2394
3326
3823
3823
1510
1356
1356
Window
2080
1356
wall 1
G-Height: 1.6m
H-Height: 1.1m
1:100

8.6 Appendix F – Agreement with FOR

ST. OLAVS HOSPITAL
UNIVERSITETSSYKEHUSET I TRONDHEIM

St.Olavs Hospital
Operating Room of the Future, FOR

Managing Director

Telefon: +47 72823244
Telefaks: +47 72823270
Mobil: +47 982 80 585
www.stolav.no

Contract agreement

Between

Name
NTNU- Norwegian University of Science and Technology, Pb 8905
7491 Trondheim, Norway

ORG. NR: 974 767 880

ATT: Helena Kuivjõgi

and

St. Olavs Hospital, Operatingroom of the future (FOR)

ORG. NR: 883 974 832

Olav Kyrres gt 17
7006 Trondheim
ATT: Daglig leder, Jan Gunnar Skogås

About the execution of assignments, hereinafter referred to as the assignment, with the following title:

Name of assignment

Field investigation of thermal comfort level of patients and surgical staff in operating rooms at St. Olavs hospital

1. Contents

As we know, in hospital, there is essential to predict thermal comfort, because it will influence the working conditions of medical staff and the wellbeing and health of patients.

The main idea of my project is to clarify the thermal comfort level of patients and surgical staff in mixing and laminar air flow ventilated OR in St. Olavs Hospital.

My study so far, shows that there is very hard to provide thermal comfort to all occupants in OR-s.

Secondly, there are few studies regarding patient, so it is necessary to held that point of view also, because patient will experience more thermal discomfort.

What i want to do, is to focus on PMV index, what is thermal comfort index. To clarify that, i am doing measurements in hospital OR-s, evaluate surgical staff activity level and clothing insulation and conduct a questionnaire.

The tasks are carried out by:
Masterstudent Helena Kuivjõgi

2. **Duration**

   Based on the prerequisites of the contract, the following periods are set:

   Startdate: 11.02.2019

   End date: 01.08.2019

   The agreement is valid from the start date when it is signed by both parties. The agreement is extended if the parties still have needs beyond the end date.

3. **Contact persons**

   a) FOR, R&D coordinator Liv-Inger Stenstad
   b) NTNU, Helena Kuivjõgi
   c) NTNU, Professor Guangyu Cao
   d) FOR, by Jan Gunnar Skogås

3. **Reporting and ownership rights to project results**

   NTNU by Institutt for energi- og prosessteknikk has the ownership rights to the project results.
   St. Olavs hospital, FOR can use the knowledge acquired in the project.
   Any publication of project results must take place in agreement with the parties.

   <u>When publishing this text must be included:</u>

The research leading to these results was performed in, and based on data from, the infrastructure "The Operating Room of the Future at St. Olavs hospital", a collaborative infrastructure between the St. Olavs hospital and the Norwegian University of Science and Technology (NTNU), Trondheim, Norway.

4. **Other conditions**

   All projects to be carried out at FOR, must first be approved by the Scientific advisory board.

   Before starting a project, it is important that representatives of FOR come together with the project practitioner so that one can go through the clinical everyday life and the routines that apply. One should also convey ethical considerations and reflections on doing clinical trials involving both staff and patients. The results should preferably be published in peer-reviewed journals.

   The purpose of this is, among other things, that the daily management at FOR and the relevant clinic must know about which projects are being carried out. It may also be appropriate in some cases to adjust the protocol. There must also be enough resources to carry out the projects. One should also discuss the realism of the

St.Olavs Hospital
Operating Room of the Future, FOR

Managing Director

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project in terms of scope and content. When the project is completed and before the results are published, these **must be presented first to FOR and the department, clinic where the project is completed.**

All research projects involving patients and patient data must be approved by the Regional Ethics Committee (REK).

6. Agreement document

The agreement consists of two parts:

- This document - called agreement
- Confidentiality Agreement
- Non-disclosure agreement

7. Agreement copy and signatures

This agreement is signed in 2 copies, one copy of which depends on each of the parties.

Trondheim, 28 / 2 2019	Trondheim, 01 / 3 2019
Managing director, FOR St. Olavs hospital	Name student NTNU, Institutt for energi- og prosessteknikk
Name: Jan Gunnar Skogås	Name: Helena Kuivjõgi

ATTACHMENTS:

- ✓ Confidentiality Agreement
- ✓ Non-disclosure agreement
- ✓ Protocol

ST. OLAVS HOSPITAL
UNIVERSITETSSYKEHUSET I TRONDHEIM

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Agreement on Confidentiality

Between

St.Olavs hospital, Operating Room of the Future

And

Helena Kuivjõgi

Related to and as long as the parties have research activities at the Operating Room of the Future at St Olavs hospital/NTNU

All information which the Parties have received from each other in writing, orally or in any other manner, shall be treated confidentially and may not be used without a written agreement, unless the receiving Party can prove that the information was:

i) publicly known at the time of receipt
ii) known by the recipient at the time of receipt
iii) received legally from a third party without any agreement on confidentiality
iv) developed independently by the recipient

Disputes that may arise in connection with this Agreement or is a result there of, shall be settled by private negotiations between the Parties. If such agreement cannot be obtained within a reasonable time period, the parties shall choose Trondheim District Court as legal venue.

The present Agreement shall be governed by and construed in accordance with the laws of Norway.

For
Student: Helena Kuivjõgi

Kuivjõgi

Date: 01/3 – 19

For
Operating Room of the Future:

[signature]

Date: 28/2 – 19

ST. OLAVS HOSPITAL
UNIVERSITETSSYKEHUSET I TRONDHEIM

Taushetserklæring

Jeg er kjent med at jeg gjennom mitt arbeid kan få tilgang til taushetsbelagte opplysninger, og forplikter meg til å overholde bestemmelsene om taushetsplikt slik de framkommer i foretakets prosedyre, med grunnlag i nedenfor stående lovbestemmelser:

Alle som arbeider ved St. Olavs Hospital, studenter, lærere ved høyskole og universitet, partnere/leverandører plikter å hindre at andre får adgang eller kjennskap til det hun/han i forbindelse med tjenesten eller arbeidet får vite om folks legems- eller sykdomsforhold eller andre personlige forhold som de får vite om i egenskap av å være helsepersonell og/eller i tjeneste for et offentlig forvaltningsorgan.

Taushetsplikten gjelder også:

- pasientens fødested, fødselsdato, personnummer, pseudonym, statsborgerforhold, sivilstand, yrke, bopel og arbeidssted. Opplysning om en pasients oppholdssted kan likevel gis når det er klart at det ikke vil skade tilliten til helseinstitusjonen.
- tekniske innretninger og fremgangsmåter samt drifts- eller forretningsforhold som det vil være av konkurransemessig betydning å hemmeligholde av hensyn til den som opplysningen angår.

Opplysninger til andre forvaltningsorganer kan bare gis når dette er nødvendig for å bidra til løsning av oppgaver etter forvaltningsloven, eller for å forebygge vesentlig fare for liv eller alvorlig skade for noens helse.

"Taushetsplikten gjelder også etter at du har avsluttet tjenesten eller arbeidet. Overforstående opplysninger kan ikke utnyttes i egen virksomhet eller i tjeneste eller arbeid for andre."

Den som forsettelig eller grovt uaktsomt krenker taushetsplikten kan straffes med bøter eller med fengsel inntil 6 måneder.

Begås taushetsbrudd i den hensikt å tilvende seg eller andre en uberettiget vinning er stafferammen 3 år. Det samme gjelder når det foreligger andre særdeles skjerpende omstendigheter.

St. Olavs Hospital 01/3 - 19
dato

HELENA KUIVJÕGI
Navn med blokkbokstaver

HKuivjõgi
Signatur

Avdeling

firmatilhørighet

Følgende lovparagrafer omhandler taushetsplikten og brudd på taushetsplikten:

- **Helsepersonelloven § 21**
- **Lov om spesialisthelsetjenesten § 6.1**
- **Forvaltningsloven § 13**
- **Straffeloven § 121**
- **Lov om folkeregistrering §13**
- **Lov om helseregistre og behandling av helseopplysninger § 15**
- **Lov om personopplysninger kap. II**
- **Forskrift til personopplysningsloven, kap. 2**
- **Pasientrettighetsloven tas med, §3-6 Rett til vern mot spredning av opplysninger**

St. Olavs Hospital HF
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Field investigation of thermal comfort level of patients and surgical staff in operating rooms at St. Olavs hospital

Description of project:

In hospital, there is essential to predict thermal comfort in operating rooms (OR), because it will influence the working conditions of medical staff and the wellbeing and health of patients.

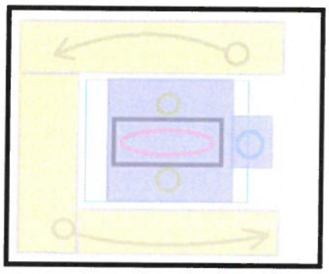
In operating room is very hard to provide thermal comfort to all occupants in OR-s. Regarding to that it is essential to explore this area more and more. Also, there are few studies regarding patient thermal comfort. So, it is necessary to held that point of view also, because patient will experience more thermal discomfort.

The main idea of my project is to clarify the thermal comfort level of patients and surgical staff in mixing and laminar air flow ventilated OR in St. Olavs Hospital.

What I want to do, is to focus on PMV index, what is thermal comfort index. To clarify that, i am doing measurements in hospital OR-s, evaluate surgical staff's activity level and clothing insulation and finally, I conduct a questionnaire among all occupants in OR.

Measurements:

For my analyzes, I need to measure indoor air conditions. If it is possible, i would like to do them all during the mock surgery procedure. In mock surgery I am planning to measure air velocity, air temperature and relative humidity in the vicinity of the occupants (picture 1)



Picture 1. Measurement points

Also, during mock surgery, i plan to measure the surface temperature of clothing and surface temperature of surroundings.

Also, in my study, i will analyse the clothing, what every occupant will wear and i need to get information about the material of clothing from manufacturer.

Estimating:

I would like to estimate as real activity level as possible. I am planning to do it with a depth registration camera to record every occupant movements (Jakub Wladyslaw Dziedzic's study) during mock surgery. And also, if it is possible, then during real surgery.

Questionnaire:

Furthermore, I will conduct a questionnaire to get general sensations of occupants (surgical staff and patient) over one month. I would like to ask different operating teams, who have been participated in different kind of operations in LAF ventilated room and in mixing ventilated room.

I want to compare my questionnaire with PMV value, which I get from the measurements.

NTNU

Kunnskap for en bedre verden