Operating theatre room temperatures and relative humidity levels at a central hospital

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg in partial fulfilment of the requirements for the degree of Master of Medicine in the branch of Anaesthesiology.

Johannesburg, 2019

Declaration

I, Phyllis Mabotse Phukubye declare that this research report is my own unaided work. It is being submitted for the Degree of Master of Medicine in the branch of Anaesthesiology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

Signed on this 2nd day of March 2020

Abstract

Background

The aim of this study was firstly to assess the accuracy of the current OT room thermometers against a “gold standard”, as well as to evaluate OT rooms’ temperature and relative humidity (RH) at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) during summer and winter.

Methods

Temperature and RH were assessed using a calibrated sling hygrometer and the OT room wall thermometer. Bland and Altman plots were used to analyse the strength of the relationship between the two instruments. The attending anaesthetists were asked their opinion of the appropriateness of the OT room temperature and this was related to the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) guidelines.

Results

There were strong correlations ($r \geq 0.7$) between the OT wall temperatures and the sling hygrometer in both summer and winter. There were weak correlations ($r < 0.4$) between the ambient temperature and OT room thermometers. Good agreement between the OT room thermometer and the sling hygrometer was found for temperature only. RH in the cardiac OT (78%) was higher than recommended by the ASHRAE guidelines. There was no correlation between seasonal variation in the summer and winter months in the OT rooms, as well as no correlation between the anaesthetist’s opinion of the appropriateness of the OT room temperature and the temperature on the thermometer.

Conclusion

The current OT room wall thermometers at CMJAH are accurate for temperature but not for RH; therefore, subjective reliance on temperature is unnecessary. OT room thermal guidelines need to be formulated, as the current ASHRAE guidelines do not accommodate different patient’s thermoregulatory requirements. It is

possible that at CMJAH, some surgeries are occurring in inappropriate thermoregulatory conditions, which could affect patient and OT room safety.

Acknowledgements

I would like to thank the following people:

My liefie, Hilton Phukubye-Johnson for your love and sustenance; my son, Moahi, for your inspiration to be the best version of myself daily.

the Phukubye and Johnson family for your continual support and to

Charles Adjei from the Department of Biostatisticians at the PV Tobias building, University of Witwatersrand, Johannesburg.

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Abbreviations

ASHRAE	The American Society of Heating, Refrigeration and Air-conditioning Engineers
CMJAH	Charlotte Maxeke Johannesburg Academic Hospital
GA	General anaesthesia
HVAC	Humidity ventilation and air conditioning
OT	Operating theatre
RH	Relative humidity
SD	Standard deviation
WHO	World Health Organisation

ASHRAE	The American Society of Heating, Refrigeration and Air-conditioning Engineers
CMJAH	Charlotte Maxeke Johannesburg Academic Hospital
GA	General anaesthesia
HVAC	Humidity ventilation and air conditioning
OT	Operating theatre
RH	Relative humidity
SD	Standard deviation
WHO	World Health Organisation

Statement

The Research Report consists of a literature review, draft article, study proposal and appendices. The study proposal is included for background reference and is not for examination.

The formatting of this Research Report complies with the University of the Witwatersrand's Style Guide for Theses, Dissertations and Research Reports. The formatting of the draft article may differ from the rest of the Research Report in order to comply with the author guidelines of the South African Journal of Anaesthesia and Analgesia, the journal to which it is intended to be submitted.

Section 1: Review of the literature

1.1 Introduction

Hospital buildings are complicated facilities that need to cater for different patient needs; the operating theatre (OT) complex adds to the complexity of a hospital design and construction, because the internal OT complex must be tightly controlled within certain building regulations and industry guidelines to provide optimal operating conditions (1). These building regulations are based on the International Standards Organization norms which give recommendations for the building structure as well as the equipment needed to facilitate tightly regulated internal thermal conditions in the OT complex (2). The American Society of Heating Refrigerating and Air-conditioning Engineers (ASHRAE) (3) is an industry regulatory body that prescribes the conditions needed for the internal thermal environment of OT complexes. The use of the OT room varies depending on the patient profile as well as the surgical activity being carried out; the thermal conditions of the OT room need to be appropriately regulated to meet these varied needs. Once in theatre and anaesthetised, patients cannot maintain their normothermic state (3, 5) and their inability to do so can cause a number of deleterious effects on the clinical outcome (4). There is no clear consensus on the recommended room temperature for a standard OT room. Wilke et al (5) recommends 18 - 21°C whilst Dascalaki et al (6) report that 22 - 24° C is appropriate. The World Health Organization (WHO) (7) recommend that OT room temperatures range between 18 - 22˚C; whilst the ASHRAE guidelines state 18 - 23˚C (8) as optimal. These temperature ranges may be too wide to accommodate patient populations that need tighter control of the external thermal conditions, such as neonates, arthroplasty patients, burns patients and cardiac bypass patients.

This literature review will focus on the thermal conditions of OT rooms, specifically in relation to temperature and relative humidity (RH).

The physiology of thermoregulation

“Thermoregulation is the maintenance and regulation of an internal body thermal environment” (9). Humans maintain a relatively constant core body temperature, over a range of ambient temperatures (1). The accepted average core temperature for a healthy adult is between 36.5 – 37.5°C (10). This temperature is said to be the optimal temperature for body enzymatic function to occur (1). The body strictly regulates its thermal state via a feedback loop, which sends afferent signals to the hypothalamus (regulatory centre) and efferent signals are relayed to the body to institute autonomic responses and behavioural changes (1). These behavioural changes include actively attempting to warm oneself when cold, like putting on warmer clothes or removing clothing when hot. The autonomic responses include peripheral vasoconstriction when cold, to conserve heat in the important internal body organs; peripheral vasodilation causes blood to be diverted away from the internal organs to the skin and peripheries, here skin contact with the environment causes heat loss via convection, conduction and evaporation (via sweating) (1). Shivering is also a form of conserving heat by activating “involuntary high frequency muscular contractions” (1) which will cause an increase in metabolic rate and thus heat production.

Specific patient populations have impaired thermoregulatory systems and need stricter control of the external environment to ensure normothermia. Infants, in particular preterm neonates have immature thermoregulatory systems and are at higher risk of temperature changes (7). The following patients also have impaired thermoregulatory mechanisms; the elderly, patients with endocrine dysfunction and patients with metabolic dysfunction. Anaesthetised patients can be included as well, due to their inability to exert efferent responses to temperature changes (1).

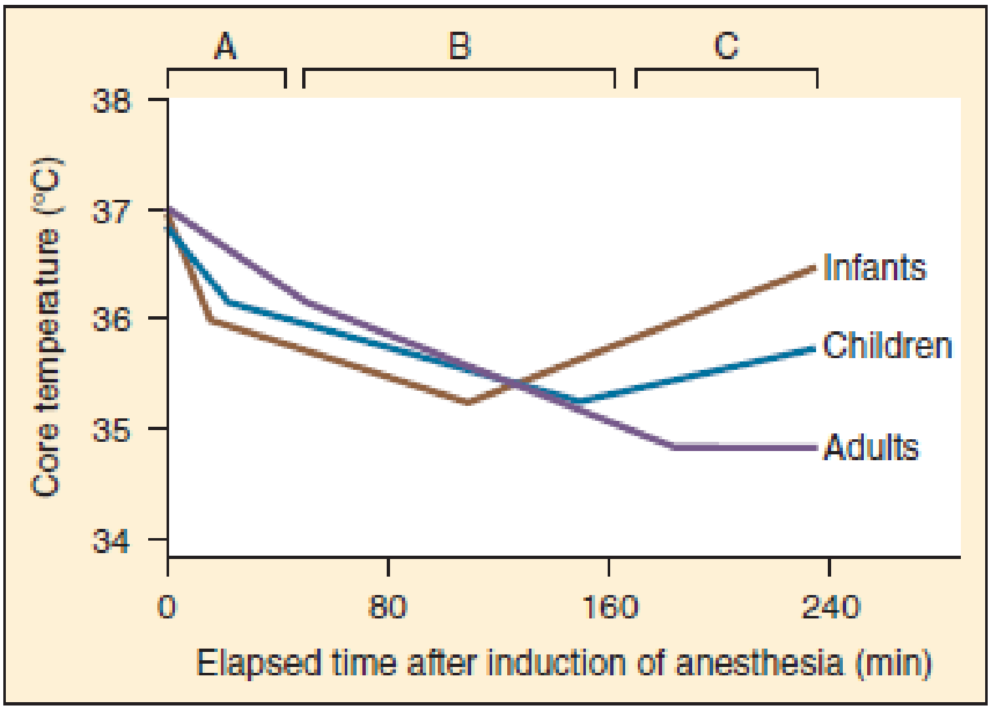
The anaesthetised patient and thermoregulation

Anaesthetised patients lose their innate ability to thermoregulate and thus rely on the anaesthetist to actively protect them from the adverse effects of temperature extremes that can cause thermal injury. Knaepel et al (11) showed that inadvertent perioperative hypothermia affects about 70% of surgical patients and it can be caused by a variety of factors, such as exposure of the patient to the cold OT room (heat loss by radiation), direct anaesthetic effects and the administration of cold intravenous and/or irrigation fluids (9). Neuraxial anaesthesia causes hypothermia due to large-scale vasodilatation resulting from the sympathectomy caused at the level of the neuraxial injection (11).

General anaesthesia (GA) inhibits the thermoregulatory system by direct and indirect effects of anaesthetic drugs; one of the results of this inhibitory effect on the brain is the decreased metabolic function that ensues, this further adds to hypothermia by preventing heat gain mechanisms (10). The inability of the anaesthetised patient to initiate the behavioural mechanisms needed to preserve normal thermoregulation, contributes further to the development of thermal stress in the OT room during surgery (1). Both hypo- and hyperthermia can quickly develop if the anaesthetist is not meticulous in monitoring the patient's body temperature. The OT room temperature will predict how fast the patient loses heat to the external environment. The main mechanisms of heat loss in the OT room are through radiation, convection, evaporation and conduction (11).

When a patient is under GA, heat is lost in three phases: the initial phase (first hour) decreases the core temperature by 1 – 1.5°C and occurs due to vasodilation and thus redistribution of core body heat to the periphery. The second phase causes a precipitous linear decline in body temperature as the heat loss to the environment outweighs the metabolic rate of the patient (thus the metabolic production of heat). In this phase the heat loss to the environment is mainly through radiation and convection, however if the patient is in direct contact with a cold OT table, then conductive heat loss is also a major contributor to heat loss. The final phase, also called the "plateau phase" occurs about three to five hours after commencement of surgery and the rate of heat loss equals the rate of heat gain. This is called the "plateau phase" (1). Figure 1 illustrates the three phases of heat loss intra operatively, whilst a patient is under GA.

Figure 1: Phases of heat loss in an anaesthetised patient under general anaesthesia (3).



A = First phase, where internal redistribution of heat occurs. B = Second phase, where the thermal imbalance occurs, as there is an on-going net loss of heat to the environment. C = Final phase, where temperature steady state is reached, in children this is the rewarming phase (3).

The influence of hypothermia on the anesthetised patient

Normal core body temperature is between 36.5 and 37.5 °C (10). Hyperthermia is a core body temperature above 37.5 °C and hypothermia is a core body temperature of less than 36.5 °C (9). "WHO has classified mild hypothermia as a core temperature of 36 – 36.4°C, moderate hypothermia as 32 – 35.9°C and severe as less than 32°C"(7).

The hypothalamus acts as a thermistor that responds to a range of temperature changes; the responses can cause a decrease or increase of the body temperature, depending on the patient needs (9). Mechanisms such as vasoconstriction and vasodilation are examples of how the body, under infra tentorial influence, regulates the internal temperature (11).

The consequences of hypothermia include:

- increased blood loss,
- increased blood transfusion and associated risks,
- coagulopathies,
- cardiac abnormalities including arrhythmias, fibrillation and asystole,
- decreased drug metabolism (i.e. longer drug duration of action),
- surgical site infection,
- shivering and the consequences of increased metabolic rate,
- increased length of hospital stay and
- patient discomfort. (11)

To avoid hypothermia it is recommended that measures be put into place to prevent and treat hypothermia, namely; “pre-warming, using forced air warming devices, administering warm intravenous fluids, wrapping neonates in plastic or cotton, heated OT tables and increase the ambient OT room temperature”(9).

The influence of hyperthermia on the anaesthetised patient

Hyperthermia (core body temperature > 37.5˚C) can occur in an anaesthetised patient, although not as common an occurrence as hypothermia (10). The OT room temperature contributes to elevated patient temperature if the OT room air conditioning system is not functioning well and room temperatures are too high. High RH levels (>60%) also contribute to hyperthermia, but adversely limit the intrinsic ability of the adult body to decrease high body temperatures by perspiration (10). As the air becomes more saturated with water it becomes harder for the patient to lose heat via evaporation.

According to Lenhardt et al (2008) (12), hyperthermia has adverse effects on the anaesthetised patient by increasing metabolic requirements and having profound cardiovascular consequences which are deleterious to the ill patient. These changes include:

- peripheral vasodilatation
- reduced mean arterial pressure resulting in
- increased heart rate and cardiac output
- perspiration and possible dehydration

- increased metabolic rate and consequently and
- increased oxygen consumption (12).

Measuring OT room temperature

Temperature is defined as the measure of thermal energy (13). The 2001 ASHRAE guidelines for "Standard temperature measurement" (14), describe instrument accuracy, as "the ability of the instrument to indicate or record the true value of a measured quantity" precision is measured as the "closeness of agreement among repeated measurements of the same physical quantity by the same method, under the same conditions and with the same instrument".

Thermometers

Temperature can be measured using non-electrical as well as electrical devices.

Mercury thermometer

A mercury thermometer is a non-electrical device that can be used to measure room temperature (15). It consists of a glass tube filled with mercury. The principal behind it is based on the expansive properties of mercury, influenced by temperature (13). As the temperature increases, the mercury expands and the volume of mercury increases as indicated on the graduation marks on the thermometer. Mercury thermometers are reliable, easy to use, and relatively inexpensive. The disadvantages of mercury thermometers include mercury toxicity (should the mercury leak out of the thermometer) and it takes time to equilibrate (13), thus it is not ideal for measuring rapidly changing temperatures. Alcohol can replace the mercury but because alcohol boils at 78.5°C, this thermometer is not recommended for high temperature ranges.

Bourdon gauge thermometer

A Bourdon gauge uses the principal that dissimilar metals act differently at the same temperature. One metal tends to contract whilst the other expands depending on the metallic properties. The gauge measures pressure (13) and is attached to a "sensing element containing a tube of mercury or a volatile fluid.

Variation in temperature causes a volume or pressure change in the sensing fluid and this is recorded on the Bourdon gauge" (13).

Thermoelectric thermometers

Electrical techniques for measuring temperature are underpinned on the Seebeck effect (13), which describes the observation that when two dissimilar metals are joined, a voltage is generated at the junction when the temperature changes. This movement of current can be measured by a galvanometer (15). Thermocouples of constantan and copper are the most commonly used for measuring ambient temperature (15).

Measuring OT room RH levels

Humidity is defined as "the amount of water vapour present in a sample of gas, expressed as weight or volume of water vapour per complex weight or volume of gas" (5). Absolute humidity is the amount of water vapour present in a volume of gas (g/m^3 or mg/litre); RH is the amount of water vapour present in a volume of gas, "expressed as a percentage of the maximum possible amount which could be present at that temperature and pressure" (5). The accurate measurement of the OT room RH is necessary to evaluate the true thermal conditions that patients and theatre staff are exposed to (16).

Inaccurate measurements, due to faulty or poorly calibrated instruments will give a false impression of the OT room conditions, the ramifications of which have a number of clinical consequences for patients (5). The respiratory system of an anaesthetised patient in a poorly humidified OT room is the most affected system. Endotracheal intubation bypasses the patient's ability to warm and humidify the inspired air which causes increased insensible losses to the environment, dysfunction of the cilia, inspissation of respiratory secretions, increased predisposition to respiratory tract infection and even atelectasis (5). Low humidity levels also increase the patient's evaporative losses to the environment predisposing patients to hypothermia (5), some patients, particularly paediatric and burns patients may not tolerate such thermal changes. Low humidity levels also promote coagulopathies (6) and may cause increased static electrical charge in the OT room which can become a fire hazard (5, 6).

RH levels above 60% could facilitate microbial growth (5) and promote the growth of mould and fungi as well (6). Increased RH levels also increase the patient's temperature which could cause or worsen heat related conditions (5). The recommended RH levels differ across sources, with Wilke et al (5) stating that the optimal RH should be between 40 – 60% and between 30 – 60% according to Dascalaki (6), the ASHRAE guidelines originally stated 30 – 40% but have since revised the lower range to 20% (17), this study will use the ASHRAE guidelines.

The measurement of room temperature and RH can be done using a number of methods and instruments.

Instruments that measure RH levels

Instruments that measure the amount of water vapour in the air are called hygrometers and they typically measure RH (18). Absolute humidity is rarely measured, but if the saturated vapour pressure and ambient temperature are known, then absolute humidity can be calculated (18).

Wet and dry bulb hygrometer

The wet and dry bulb hygrometer is composed of two mercury thermometers placed side by side, the dry bulb thermometer measures the ambient temperature whilst the wet bulb is covered in a wick, is attached to a water reserve and kept constantly wet (5, 18). The wet wick is exposed to the ambient temperature and the moving stream of air around it causes evaporation which results in cooling of the wet bulb thermometer, this cooler thermometer measures a lower reading than the dry bulb thermometer and the difference between the two is called the ‘’wet bulb depression’’. The wet bulb depression is needed to calculate the RH against a standardised correction table (5). When the ambient air is dry, the rate of evaporation from the wet bulb is increased and the wet bulb thermometer will therefore have a lower reading than the dry bulb thermometer; and conversely, when the ambient temperature has a lot of moisture in it, the rate of evaporation from the wet bulb will be slower. The ‘‘wet bulb depression’’ value is related to the rate of evaporation in the air, which is related to the humidity level in the air.

The sling psychrometer, which is also known as the whirling or sling hygrometer is a wet and dry bulb hygrometer that is swung in the air to get maximum exposure of the wet bulb to the ambient environment, the swinging increases the level of accuracy of this instrument (5) because the rate of evaporation that occurs from the wick represents the vapour pressure gradient which determines the “wet bulb depression”. RH is then determined by reading a psychrometric chart which correlates with the vapour pressure (18). To ensure accuracy, the sling psychrometer must be swung in the air for a minimum of one minute (15), to ensure maximal exposure of the wet bulb to the environment. The thermometer reading should be checked at least twice to ensure that the wet bulb temperature does not continue to drop after the measurement has been taken. Some disadvantages of the sling psychrometer are that the wick can become dirty and infiltrated with debris if distilled water is not used to wet it, however this can be remedied by washing the wick with soap and water and thoroughly rinsing it (15). Another limitation of the sling psychrometer is that thermal radiation emitting from surrounding surfaces can cause variations in measurements (15). The sling hygrometer has an accuracy level of about 3% (5).

Hair hygrometer

A hair hygrometer is one of the oldest and least expensive instruments used to measure humidity levels (18). Hair changes its length depending on the amount of water vapour around it; it lengthens when exposed to high levels of water vapour and it shortens in drier conditions. Nylon or other synthetic material can be used in place of a strand of hair, as they share similar properties. The hair strand (or similar material) is mechanically attached to a pointer or via a strain gauge which displays an analogue number as the hair lengthens and contracts (5).

According to Wilkes et al (5) “response times, range and accuracy are poor” and Shelly et al (18) state that the hair hygrometer is only accurate at a RH level between 30 – 90%. Both studies corroborate that the response time with hair hygrometers is generally slow and thus hair hygrometers are of limited use in environments where humidity changes rapidly.

Regnault's hygrometer

This device is also known as a dew point hygrometer. Dew point is the temperature at which the ambient temperature is fully saturated with water and condensation begins (5). The Regnault's hygrometer is composed of a silver tube with liquid ether inside. Air bubbles through the device; it cools the ether causing condensation (18). As soon as condensation is visualised on the exterior of the silver tube, it is noted as the dew point and thus the saturated vapour pressure at that temperature (5). Ether is used due to its ability to cool rapidly and the silver tube is used due to its conductivity (5). If the ambient temperature, pressure and water vapour pressure are known, then RH can be calculated or read off a graph (5). The disadvantage of this hygrometer is that it is operator dependent as it depends on visualising the exact moment condensation begins (5).

Electrical hygrometer

Electrical hygrometers employ differing principals of electrical charge and current flow. Humidity transducers for example, consist of two transducers separated by hygroscopic material which absorbs or releases water to or from the atmosphere, this causes a change in the resistance or the capacitance which is recorded and converted into a value for RH (5). There are many types of electric hygrometers that are based on the above electrical principals. The advantages of these devices are that they have moderate accuracy; they are small, low cost and have a rapid response time (5).

1.2 Summary

The OT room thermal conditions play an integral part in the holistic management of anaesthetised patients, who cannot regulate their thermoregulatory system appropriately under both general and neuraxial anaesthesia. The onus is on the anaesthetist to defend the patient's physiology against the stressful OT room conditions. Many authors have explained the deleterious effects of both hypo and hyperthermia on patients and little work has been done on the effects of RH levels, which forms an important part of the OT room environment. Guidelines have been extrapolated from other industries for hospital OT rooms, but there is no congruence in the literature on the exact temperature ranges required, moreover for RH levels. There is far less literature on the appropriate OT room temperature and RH levels for specific patient populations undergoing specific surgical interventions. A patient specific guideline would enable the surgical team to better plan surgical interventions for specific patient populations who require a more active intervention in regulating the OT room thermal environment.

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Acknowledgements

In a separate section, acknowledge any financial support received or possible conflict of interest. This section may also be used to acknowledge substantial contributions to the research or preparation of the manuscript made by persons other than the authors.

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The following are sample references:

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Section 3: Draft article

Operating theatre room temperatures and relative humidity levels at a central hospital

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Key words: Operating theatre thermal conditions, temperature, relative humidity, sling hygrometer.

Abstract

The aim of this study was firstly to assess the accuracy of the current OT room thermometers against a "gold standard", as well as to evaluate OT rooms' temperature and relative humidity (RH) at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) during summer and winter.

Methods

Temperature and RH were assessed in the cardiac, paediatric and orthopaedic OT rooms using a calibrated sling hygrometer as well as the OT room wall thermometer. Bland and Altman plots were used to analyse the strength of the relationship between the two instruments. The attending anaesthetists were asked their opinion of the appropriateness of the OT room temperature and this was related to the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) guidelines.

Results

There were strong correlations ($r \geq 0.7$) between the OT wall temperatures and the sling hygrometer in both summer and winter. There were weak correlations ($r < 0.4$) between the ambient temperature and OT room thermometers. Good agreement between the OT room thermometer and the sling hygrometer was found for temperature only. RH in the cardiac OT (78%) was higher than recommended by the ASHRAE guidelines. There was no correlation between seasonal variation in the summer and winter months in the OT rooms, as well as no correlation between the anaesthetist's opinion of the appropriateness of the OT room temperature and the temperature on the thermometer.

Conclusion

The current OT room wall thermometers at CMJAH are accurate for temperature but not for RH; therefore, subjective reliance on temperature is unnecessary. OT room thermal guidelines need to be formulated, as the current ASHRAE guidelines do not accommodate different patient's thermoregulatory requirements. It is

possible that at CMJAH, some surgeries are occurring in inappropriate thermoregulatory conditions, which could affect patient and OT room safety.

Introduction

The operating theatre (OT) complex is an intricately designed and constructed area in the hospital building. The complicated and specialised OT complex must be built in compliance with industry standards and according to regulatory guidelines to ensure the safe delivery of anaesthetic and surgical services to patients. The external hospital building structure, as well as the internal environment of the OT complex, must be tightly controlled and meet the recommendations as set out by industry guidelines. The American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) is an internationally recognised regulatory body that focuses on building systems, energy efficiency, indoor air quality, refrigeration and sustainability of indoor environments and propagates for the "advancement of human well-being through sustainable technology for the built environment".[1] There are ASHRAE standards set out for the regulation of the internal OT room environment. This internal OT room environment includes, but is not limited to, room temperature, relative humidity (RH) levels, air cleanliness and ventilation.[2-4] Currently, the ASHRAE guidelines state that the OT room temperature should be between 18 – 22 ˚C and RH level between 20 - 60%.[5, 6] The ASHRAE standards for the internal OT room environment are extrapolated from non-medical industries and have been applied across the board for OT complexes in hospital buildings. Currently, there is no clear consensus by medical regulatory bodies on the optimal OT room temperature and RH conditions for specific surgical disciplines and or procedures.

There are certain patient populations and specific circumstances where the recommended thermal conditions of the OT rooms need to be altered due to patient physiology, anaesthetic procedure, surgical procedure and other non-specified factors.[7] These patients include, but are not limited to, paediatric patients (more so neonates), orthopaedic patients (especially arthroplasty), geriatric patients, burns patients and patients undergoing cardiothoracic operations.

General anaesthesia (GA), as well as regional anaesthetic techniques cause patients to lose their ability to maintain normothermia, this is both due to the dual effect of the inability to maintain heat as well as resetting of the thermostatic set point under GA.[7] The anaesthetist (and theatre staff) is therefore obligated to protect the patient's physiology and maintain normothermia.

OT room RH levels change depending on the ambient temperature and are thus a challenge to regulate.[8] It is difficult for the hospital's Humidity, Ventilation and Air-conditioning (HVAC) unit to adjust the relative humidity levels in theatre due to the complex interactions between ambient thermal conditions and internal OT room requirements.[9] Relative humidity levels play an integral role in regulating microbial spread in the OT complex.[8] Low relative humidity levels create an environment conducive to the spread of bacteria by affecting the sterility of the surgical equipment, as well as limiting air flow and air cycle, which fosters bacterial growth.[10] Electronic medical devices are also sensitive to relative humidity levels and their proper functioning is reliant on an appropriate level of humidity.[10] Finally, a relative humidity level below 20% has been shown to increase the electrostatic discharge level in theatre, posing a fire hazard.[10]

Currently, the onus is on the anaesthetist at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) to subjectively determine whether the OT room temperature and relative humidity are appropriate to anaesthetise a patient and start the surgical procedure. Not all OT rooms have thermometers; where present their reliability and regular calibration needs confirmation. Thus, at CMJAH, it is possible that surgical lists can be allowed to commence, with no objective verification of optimal and appropriate OT room temperature and relative humidity levels. It is possible that patients at CMJAH are being anaesthetised and operate on under sub-optimal OT room thermal conditions. No recent audit of the OT room temperatures and relative humidity levels at CMJAH has been done. The aim of this study was to evaluate the appropriateness of OT room temperature and relative humidity levels in CMJAH.

Methods

An ethics waiver was granted by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, as no patients were involved in the study. This was a descriptive, contextual, prospective study.

The study population included the paediatric, orthopaedic, obstetric and cardiothoracic OT rooms at CMJAH, however the obstetric theatre was excluded due to the lack of an OT room wall thermometer. Purposive sampling method was used.

The OT room temperature and RH levels were measured using a Brannan sling hygrometer, composed of a wet and dry bulb thermometer. The sling hygrometer was calibrated and certified as accurate by an organisation approved by the South African Bureau of Standards. Data were collected in the paediatric, orthopaedic and cardiothoracic OT rooms by one author (PP). First, the ambient temperature was taken from outside the entrance of the CMJAH, followed by measurements made in the OT rooms. Measurements were taken, between 07:00 and 08:00, on weekdays over a 30 day period in the summer (4 December 2017 to 2 February 2018) and in the winter (12 June 2017 to 3 August 2017). Once inside the empty OT room, the sling hygrometer was swung for a full minute, over the OT room table with the doors closed. Both the wet and dry bulb readings were recorded and a published table (26) was used to convert the measured wet bulb thermometer readings into RH levels. The OT room wall thermometer type (electrical, non-electrical); manufacturer, condition and readings (temperature and RH) were documented. Finally, the attending anaesthetists were asked their perception of the OT room temperature and if they deemed the thermal conditions appropriate for patients to be anaesthetised. Safe thermal conditions were considered to be between 18 – 23˚C and RH between 40 – 60% (6). If the thermal conditions were found to be inappropriate, the attending anaesthetist was notified immediately.

Data were captured onto a Microsoft® Excel (2013) spread sheet and in consultation with a statistician analysed using Stata/SE12 (Statsoft,USA).Nominal and ordinal variables were summarised using frequencies and percentages. As continuous variables were not normally distributed, they were described using medians and interquartile ranges. Correlation was done using Pearson's product-moment correlation coefficient and the agreement between the sling hygrometer and OT room wall thermometer was assessed using the Bland and Altman method (30).

Results

During the 30 day summer period in the Cardiac and Orthopaedic OT rooms, 26 (86.7%) anaesthetists respectively correctly perceived the OT room temperature as "appropriate”. In the Paediatric OT, 20 (66.6%) anaesthetists correctly perceived the OT room temperature as "appropriate”.
During the 30 day winter period, in the Cardiac, Orthopaedic and Paediatric OT rooms 25 (83.3%), 21 (70.0%) and 14 (46.6%) anaesthetists correctly perceived the OT room temperature as "appropriate".

The anaesthetists were only asked about appropriateness of temperature and not humidity levels.

The thermometers in all three OT rooms were electrical, wall-mounted and in good condition. The manufacturers of the OT room wall mounted thermometers were different, but each thermometer clearly stated the OT room temperature in degree Celsius and RH as a percentage. All three OT room wall mounted thermometers were placed within two meters of the OT bed, high up on a wall, except for the thermometer in the cardiac theatre which was placed on a table in the corner of the OT room.

The mean (SD) ambient temperature for the summer period was 17.3˚C (3.43) and 18.4 ˚C (3.61) for the winter period.

The means (SD) and correlations of temperatures of the OT wall mounted thermometer (wall) and sling hygrometer are shown in Table I.

Table I: Recorded summer and winter OT room temperatures

Summer			
	Wall	Sling	Correlation
	Mean (SD) in ˚C		R
Cardiac	19.05 (2.33)	19.07 (1.62)	0.70
Orthopaedic	19.01 (1.28)	18.97 (1.44)	0.87
Paediatric	21.86 (1.86)	21.89 (1.96)	0.94
Winter			
Cardiac	19.69 (1.22)	19.63 (1.35)	0.88
Orthopaedic	18.34 (1.87)	18.38 (2.20)	0.95
Paediatric	22.76 (1.18)	22.92 (1.27)	0.95

Overall there were strong correlations ($r \geq 0.7$) (27) between the OT wall temperatures and the sling hygrometer in both summer and winter months, as seen in Table I.

The means (SD) and correlations of the OT wall RH levels and sling hygrometer RH levels are shown in Table II.

Table II: Recorded summer and winter OT room RH levels

Summer			
	Wall	Sling	Correlation
	Mean (SD) in %		R
Cardiac	43.89 (14.92)	78.09 (10.05)	0.29
Orthopaedic	33.07 (7.89)	59.86 (8.51)	0.43
Paediatric	29.1 (8.05)	37.23 (14.07)	0.13
Winter			
Cardiac	26.77 (5.63)	41.36 (9.29)	0.40
Orthopaedic	29.37 (6.01)	47.16 (7.97)	0.16
Paediatric	21.13 (1.61)	31.1 (8.28)	0.15

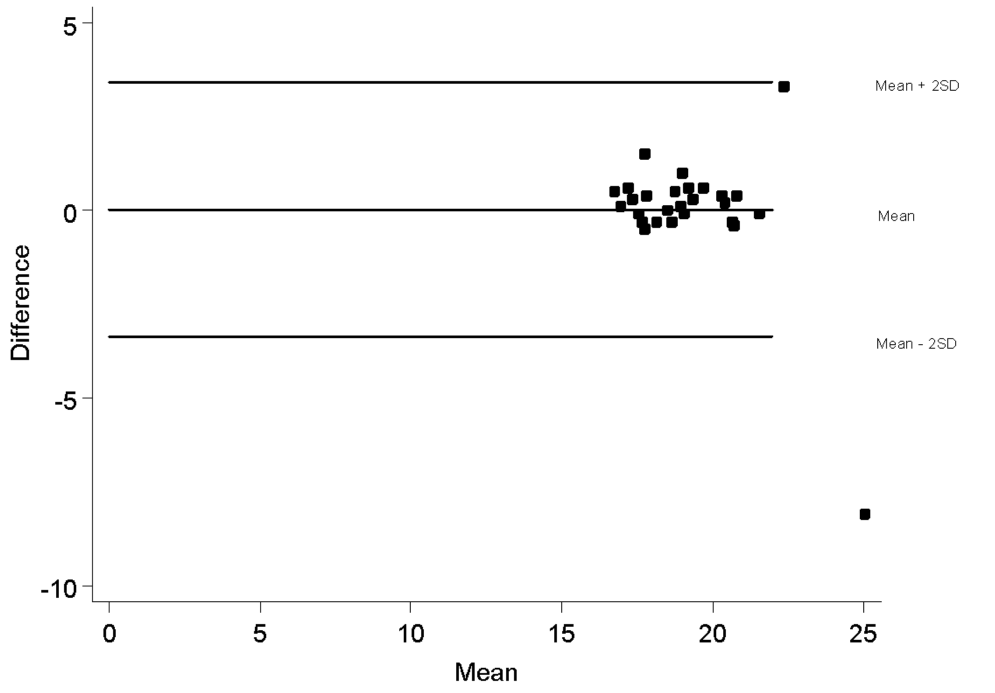
There was a weak correlation (r ≤0.4) between all the OT room RH levels in both summer and winter periods.

The means (SD) and correlations of the ambient temperature and the sling hygrometer in summer and winter are shown in Table III.

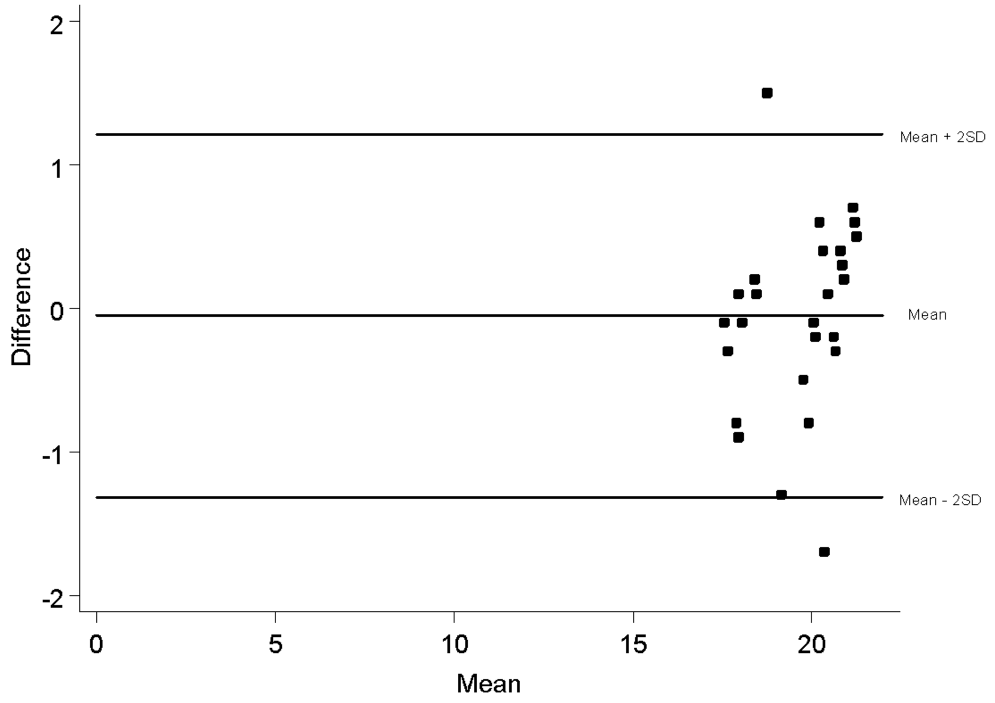
Table III: Recorded mean ambient temperatures and sling hygrometer temperatures

Summer			
	Ambient	Sling	Correlation
	Mean (SD) in ˚C		r
Cardiac	17.33 (3.43)	19.07 (1.62)	0.18
Orthopaedic	17.33 (3.59)	18.97 (1.44)	0.43
Paediatric	17.33 (3.43)	21.89 (1.96)	0.41
Winter			
Cardiac	8.43 (3.61)	19.63 (1.35)	0.33
Orthopaedic	8.43 (3.61)	18.38 (2.20)	0.08
Paediatric	8.43 (3.61)	22.92 (1.27)	0.33

Bland and Altman plots showing the strength of agreement between the OT wall thermometer and sling hygrometer in each OT room in summer and winter.

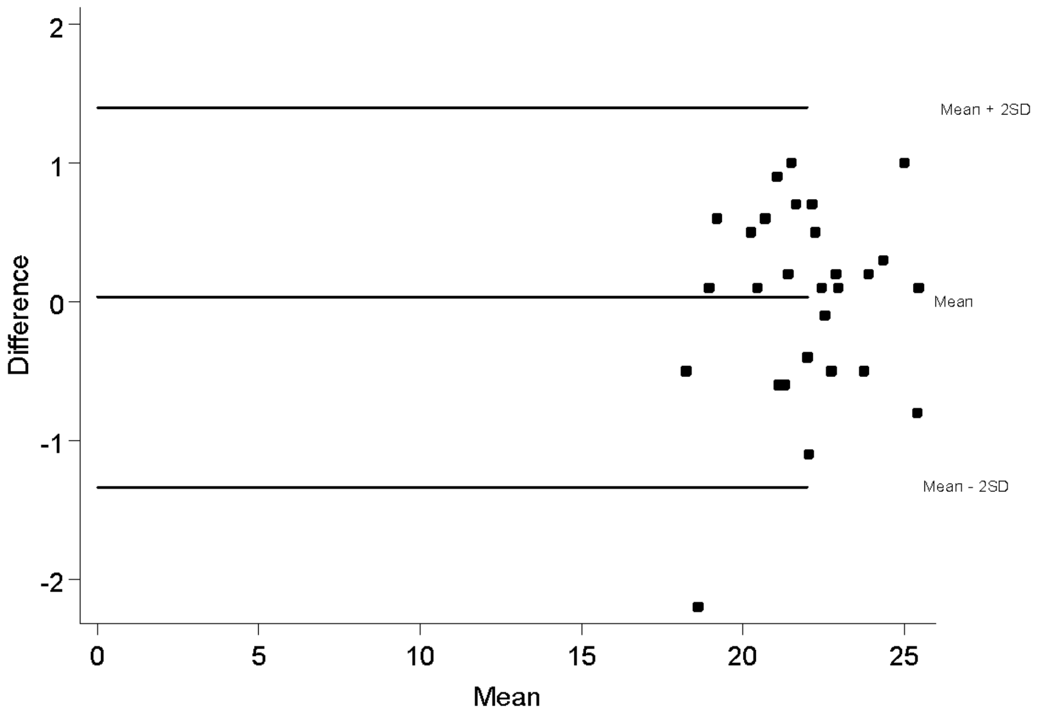


Cardiac OT room Summer

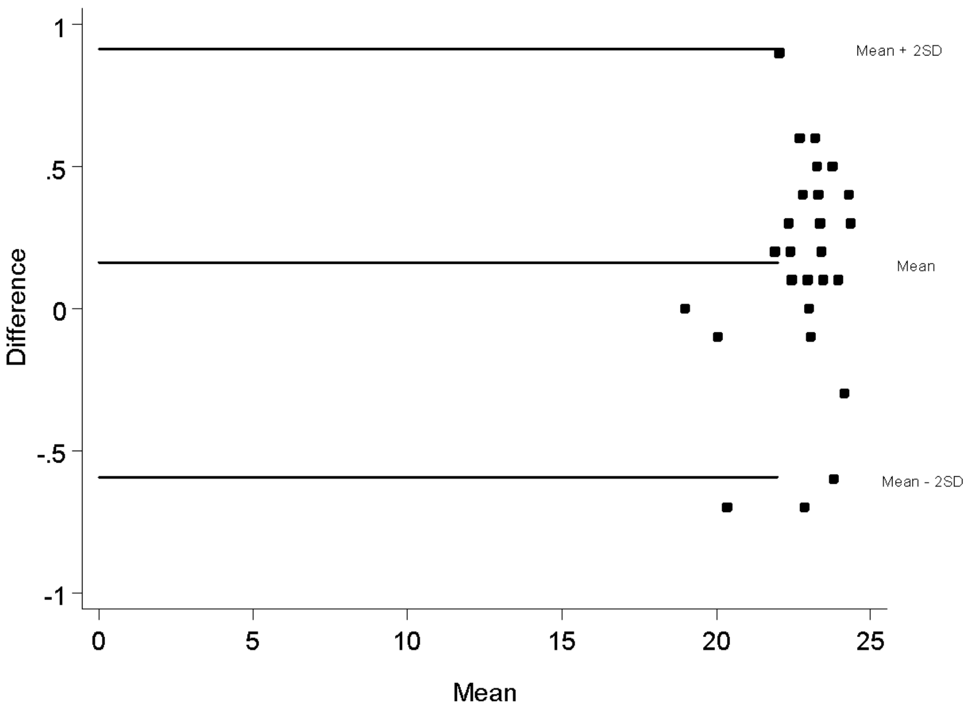


Cardiac OT room Winter

Figure 1 Bland and Altman plot of the cardiac OT room temperatures

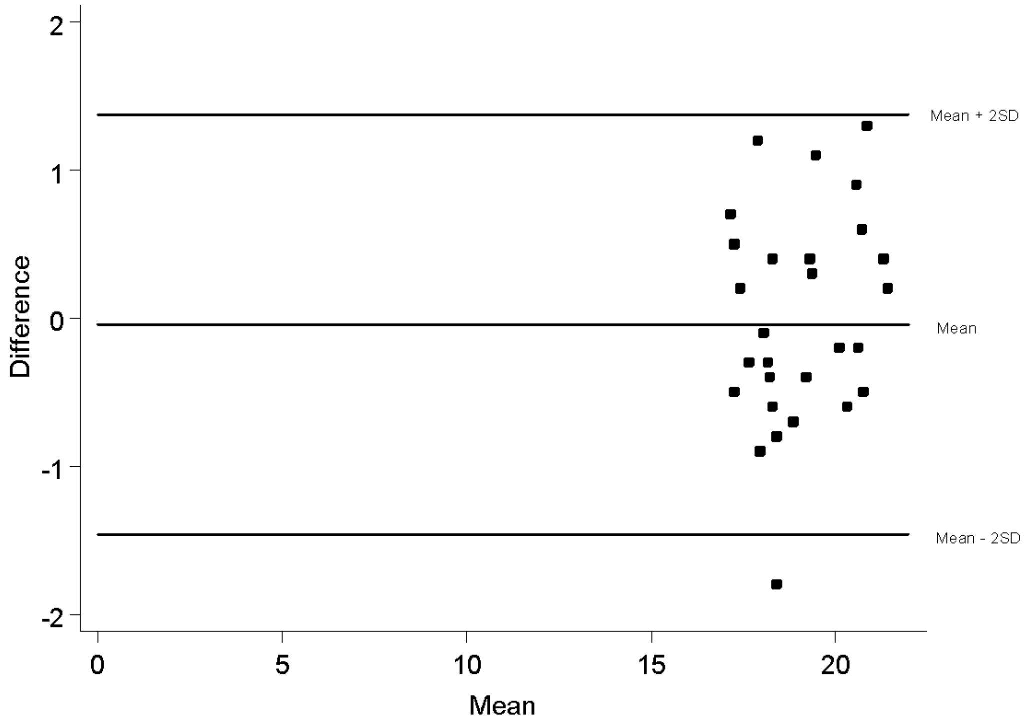


Paediatric OT room summer

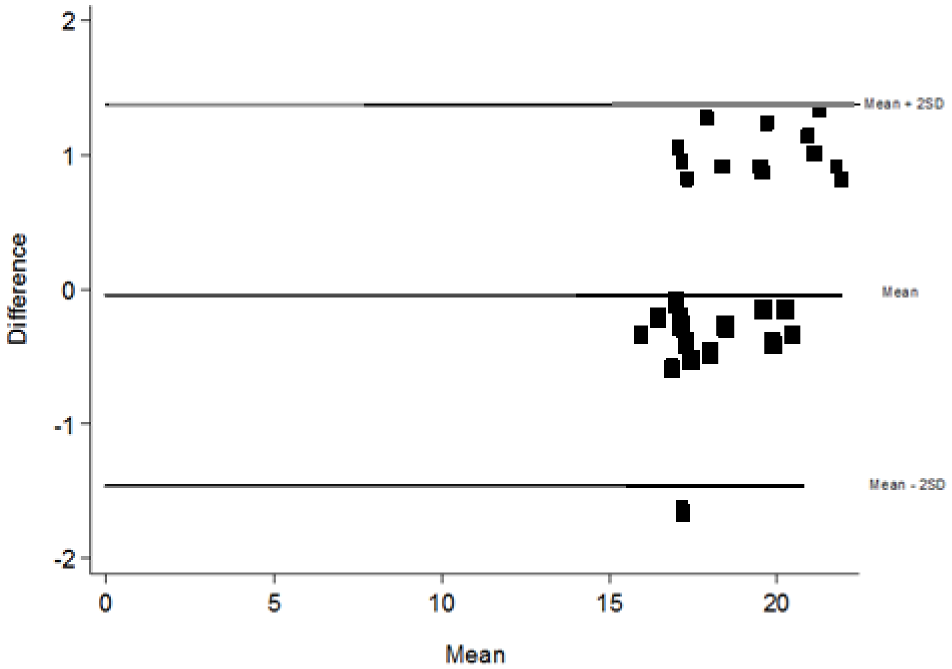


Paediatric OT room winter

Figure 2 Bland and Altman plot of the paediatric OT room temperatures



Orthopaedic OT room summer



Orthopaedic OT room winter

Figure 3 Bland and Altman plot of the orthopaedic OT room temperatures

Discussion

Four OT rooms were selected for this study, namely, cardiac, orthopaedic, paediatric and obstetric. The obstetric OT room had to be excluded due to the lack of a wall mounted thermometer. Of the three OT rooms included in this study, all had electrical, well-functioning wall mounted thermometers which gave clear readings of the OT room temperature and RH levels. It was uncertain if these thermometers had been recently calibrated or if they were accurate due to the lack of maintenance records. Despite this, there was good agreement between the sling hygrometer and the OT room thermometers. Therefore, the OT room staff can rely on the current wall mounted thermometers for accurate readings of the temperature in these OT rooms.

The ambient temperature in both winter and summer periods showed poor correlation with the internal OT room temperature. Anecdotally it was assumed that there was a strong correlation between the ambient temperature and the internal OT room thermal conditions, as the HVAC system at CMJAH is old and poorly kept, however this study showed that despite an old HVAC system, the OT complex's thermal conditions are independent.

The ASHRAE guidelines recommend an OT room temperature between 18 – 22˚C and an RH of 20 – 40%.[11] The average temperatures in the cardiac, orthopaedic and paediatric OT rooms were 19.07, 18.97 and 21.89˚C in the summer period and the temperatures remained similar in the winter period. The lack of major temperature differences observed between the two periods of data collection, illustrates that the OT room temperatures were well controlled during the study period, despite speculation that the HVAC system at this hospital was old and possibly dysfunctional. Although 21.89˚C in the paediatric OT room is within the ASHRAE guidelines, Torossian[9] recommended a lower limit of 24˚C in paediatric OT rooms, as the author found that anaesthetised neonates' risk of hypothermia doubled at temperature below 23˚C. In winter the average temperature in the paediatric OT room was slightly elevated at 22.92˚C. This could be due to the perception of theatre and maintenance staff that the cooler (ambient) winter temperatures affect the internal OT room temperature, such that the HVAC system might be adjusted accordingly.

Paediatric OT rooms are generally warmer as this population is at a higher risk of thermoregulatory disturbances; burns OT rooms are even warmer with temperatures being as high as 27˚C in some centres.[12] Anaesthetists were better at estimating the temperature in the colder OT rooms than the warmer OT room, especially in winter. This inability to accurately assess the OT room temperature in the winter could be attributed to the diverse, personal influence of the cooler ambient temperature on each anaesthetist, notwithstanding the effect of thermal clothing in the winter.

Although all attending anaesthetists were informed of the temperature and RH measured by the sling hygrometer, as well as the ASHRAE guidelines, this study did not follow up on whether surgeries were cancelled or postponed if the temperatures were reported to be inappropriate.

RH is often ignored and not considered an important component of OT room thermal conditions. However it has a pivotal role to play in preserving the sterility of the OT room environment as well as potentially increasing the risk for fire due to static electricity.[6] When the RH is too high, the growth of bacteria increases and mould and fungi are also more likely to flourish, this increased load of microbes increases the risk of surgical site infection. The level of discomfort for OT room staff also worsens.[6] An RH level between 20 and 60% is proposed to be appropriate for OT surgical procedures;[11, 20] in all three OT rooms the RH levels were higher in the summer data and lower in the winter data. The cardiac OT room in summer had a relatively high RH level of 78%, whilst the other two OT rooms were within the recommended 20 – 60%. Anecdotally it was known that there was a high sepsis rate post operatively in cardiac patients and the high RH levels may have been one of the factors that could have contributed to this high sepsis rate.

There are limited studies that agree on an exact temperature and RH level that is appropriate for anaesthetised patients undergoing surgery, those that do exist either prescribe to the ASHRAE guidelines or vacillate on numbers similar to those mentioned in the guidelines.[3, 10, 14, 20] The ASHRAE guidelines themselves are constantly being updated and the lower limit for RH has moved from 30 to 20%,[9] but no clear reason given as to the clinical implications of this new lower limit. As the ASHRAE guidelines were developed for general use in the OT complex and not for specific OT rooms, it is recommended that an OT room specific guideline be developed to accommodate the different thermoregulatory needs of different patient populations.

Conclusion

The current OT room thermometers at CMJAH are accurate with regards to temperature but not with RH levels. Anaesthetists need to improve their assessment of the OT room temperature for paediatric patients and are generally good at assessing the appropriateness of the temperature in the cooler OT rooms. The subjective reliance of temperature at CMJAH should be replaced by the anaesthetist reading the OT wall thermometers. High RH levels in the cardiac OT room could contribute to the surgical site infection rate if not rectified. Patient specific thermal guidelines need to be formulated as the ASHRAE guidelines do not accommodate different patient thermoregulatory requirements.

Conflict of interest

The authors declare that we have no financial or personal relationships which may have inappropriately influenced us in writing this paper.

Acknowledgement

This research was done in partial completed in partial fulfilment of a Master of medicine degree.

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Section 4: Proposal

Operating theatre room temperatures and relative humidity levels at a central hospital

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Co-supervisor	Johan Kotze Department of Anaesthesiology

4.1 Introduction

The operating theatre (OT) complex is an intricately designed and constructed area in the hospital building. The complicated and specialised OT complex must be built in compliance with industry standards and according to regulatory guidelines to ensure the safe delivery of anaesthetic and surgical services to patients. The external hospital building structure, as well as the internal environment of the OT complex, must be tightly controlled and meet the recommendations as set out by industry guidelines. The American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) is an internationally recognised regulatory body that focuses on building systems, energy efficiency, indoor air quality, refrigeration and sustainability of indoor environments and propagates for the "advancement of human well-being through sustainable technology for the built environment" (1). There are ASHRAE standards set out for the regulation of the internal OT room environment. This internal OT room environment includes, but is not limited to, room temperature, humidity levels, air cleanliness and ventilation (2-4). This study will focus on the OT room temperature and relative humidity (RH) levels.

The ASHRAE standards for the internal OT room environment are extrapolated from non-medical industries and have been applied across the board for OT complexes in hospital buildings. Currently, there is no clear consensus by medical regulatory bodies on the optimal OT room temperature and RH conditions for specific surgical disciplines and or procedures; however it is generally acceptable to apply the current ASHRAE standards of an OT room temperature range of between 18 to 22 °C (5, 6) and a RH level of 20% - 60% (8). A literature review by Knaepel et al (7) describe optimal OT room temperature as being "no less than 22 °C", and OT room RH levels to be a range between 20 to 60% (7, 8).

There are certain patient populations and specific circumstances where the recommended thermal conditions of the OT rooms need to be altered due to patient physiology, anaesthetic procedure, surgical procedure and other non-specified factors (9). These patients include, but are not limited to, paediatric patients (more so neonates), orthopaedic patients (especially arthroplasty), geriatric patients, burns patients and patients undergoing cardiothoracic operations. Paediatric and neonatal patients, for example, require the OT room temperature to be no less than 24 °C (9) and a relative humidity level of 50 to 60% (10). The World Health Organization (WHO) recommends a minimum OT room temperature of 25 °C for obstetric surgery (11). For orthopaedic patients, the recommended temperature range is generally lower at 18 to 22 °C (specifically those undergoing arthroplastic procedures, as they are at an increased risk of infection) (7). Patients who have suffered from burn injuries, undergoing surgery are recommended to be in an OT room temperature of no less than 25 °C, particularly for procedures involving debridements and sloughectomies (12).

While being under anaesthesia, as well as regional anaesthetic techniques, patients lose their ability to maintain normothermia this is both due to the dual effect of the inability to maintain heat as well as resetting of the thermostatic set point under general anaesthesia (9). The anaesthetist (and theatre staff) is thus obligated to protect the patient's physiology by maintaining normothermia.

Hypothermia is often seen to be the most important and deleterious consequence of thermoregulatory dysfunction in the anaesthetised patient (9) and can lead to life threatening complications. The prevention of which can be made by firstly, ensuring the appropriate thermal OT room environment (7); followed by the elicitation of active warming measures to meet the patient's thermal needs. The consequences of hypothermia range in severity from patient to patient but include problems with patient monitoring devices, coagulopathies, wound sepsis, delayed drug metabolism, cardiac arrhythmias and delayed awakening (7, 13, 14). The immune system is also negatively affected, as the leucocyte superoxide production is impaired along with neutrophil dysfunction (15). Hyperthermia, although not commonly caused by a high OT room temperature (16), can also cause serious consequences for patients such as heat stroke as well as enzymatic and organ dysfunction, .

OT room RH levels change depending on the ambient environmental temperature and are thus a challenge to regulate (17). It is difficult for the hospital's Humidity, Ventilation and Air-conditioning (HVAC) unit to adjust the RH in theatre due to the complex interactions between ambient thermal conditions and internal OT room requirements (18). RH levels play an integral role in regulating microbial spread in the OT complex (17). Low RH levels create an environment conducive to the spread of bacteria by affecting the sterility of the surgical equipment, as well as limiting air flow and air cycle, which fosters bacterial growth (8). Electronic medical devices are also sensitive to RH levels and their proper functioning is reliant on an appropriate level of humidity (8). Finally, a RH level below 20% has been shown to increase the electrostatic discharge level in theatre, posing a fire hazard (8).

There are multiple ways of measuring temperature and relative humidity levels. The instruments used to measure temperature and relative humidity are usually divided into non-electrical and electrical (19). The mercury thermometer is a well-known, easy-to-use, reliable thermometer. It applies the principal of a change in volume of mercury with temperature; as the temperature increases, the mercury expands and rises; graduations on the glass cylinder correlate with the temperature reading. Alcohol can be used as an alternative to mercury, especially when measuring very low temperatures (19). Other non-electrical thermometers include the dial thermometers (bimetallic strip and Bourdon gauge thermometer). The bimetallic strip relies on the properties of two dissimilar metals; these metals are arranged in a coil and attached to a lever. As the temperature rises, the metals expand or tighten and pull the attached lever to correlate with a temperature scale (19). The Bourdon gauge is a pressure gauge made of a hollow metal tube which is attached to a sensing element containing mercury or a volatile fluid. When the ambient temperature changes the tube contracts or expands causing a change in position of the pointer, marking the temperature scale (19). The electrical techniques employed to measure the ambient temperature are based on three electrical concepts:

1. Resistance thermometer

A Wheatstone bridge and galvanometer are used to describe the linear relationship between temperature and electrical resistance. As the temperature rises, so does the electrical resistance in the metal. The platinum resistance thermometer is the most common type used and can measure an array of small temperature ranges.

2. Thermistor

The thermistor is also based on the relationship between temperature and resistance. Unlike the resistance thermometer, there is an exponential decrease in the resistance of the metal as the temperature rises. Thermistors are made of fused heavy metal oxides resistors incorporated into a Wheatstone bridge. They have the advantage of being made into small beads and can thus fit into a smaller temperature probe. Thermistors are also relatively easy and inexpensive to manufacture (19).

The thermistor is widely used in OT rooms and is usually wall mounted. It is also incorporated in some anaesthetic machines and can be used to measure theatre temperature.

3. Thermocouple

The Seebeck effect is a principle that governs the function of the thermocouple. The Seebeck effect states that at the junction of two dissimilar metals there is an electrical potential produced that can be altered by temperature. If there is a reference point in the circuit, with known temperature, the temperature of the unknown junction can be measured. Metals that are commonly used are copper or an alloy of two or more different metals.

There are a number of other ways of measuring temperature including infrared and liquid crystals.

The techniques of measuring relative humidity include the hair hygrometer as well as the wet bulb hygrometer. The hair hygrometer is an older technique that uses the fact that a strand of hair gets longer as the humidity rises; the hair strand is attached to a pointer moving over a scale. The wet and dry bulb hygrometer is composed of two mercury thermometers; one measures the true ambient temperature the other reads a lower temperature due to the cooling effect of water evaporating from the wet wick attached to the bulb of the thermometer. The difference between the two temperature readings is related to the rate of evaporation which depends on the humidity level. This difference in temperature correlates with the relative humidity and can be found in previously established and documented tables.

The theatre ventilation system controls air flow volume and flow pattern, namely laminar or turbulent. The microbes inherently contained in the air will circulate with the air and follow the circulation patterns. Monitoring and maintaining a meticulous internal thermal environment in the OT complex has been shown to positively influence patient surgical outcomes (7).

4.2 Problem statement

Currently, the onus is on the anaesthetist at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) to subjectively determine whether the OT room temperature and relative humidity are appropriate to anaesthetise a patient and start the surgical procedure. Not all OT rooms have thermometers; where present their reliability and regular calibration needs confirmation. Thus, at CMJAH, it is possible that surgical lists can be allowed to commence, with no objective verification of optimal and appropriate OT room temperature and relative humidity levels. It is possible that patients at CMJAH are being anaesthetised and operate under sub-optimal OT room thermal conditions. No recent audit of the OT room temperatures and relative humidity levels at CMJAH has been done.

4.3 Aim and objectives

4.3.1 Aim

The aim of this study is to evaluate the appropriateness of OT room temperature and relative humidity levels in CMJAH.

4.3.2 Objectives

The primary objectives of this study are to:

- describe the anaesthetist's assessment of the OT room temperature;
- describe the profile and reading of the OT room thermometers;

- describe the OT room temperature using a wet and dry bulb thermometer;
- describe the OT room relative humidity using a wet and dry bulb thermometer;
- describe the ambient temperature measured by wet and dry bulb thermometer and
- describe the seasonal variation of OT room temperature and relative humidity.
- The secondary objectives of this study are to:
- determine the agreement between the anaesthetist's assessment of OT room temperature with the temperature measured by the wet and dry bulb thermometer;
- determine the agreement between the temperature recorded by the existing OT room thermometer to that of the wet and dry bulb thermometer;
- determine the agreement between the relative humidity level recorded by the existing OT room thermometer to that of the wet and dry bulb thermometer and
- determine the agreement between the temperature and relative humidity level as measured by the wet and dry bulb thermometer with the ASHRAE guidelines (41.1-1986) (20).

4.4 Research assumptions

The following definitions will be used in the study.

Anaesthetist: is a qualified doctor working in the Department of Anaesthesiology including medical officers, registrars and consultants.

Temperature: The temperature will be measured in degrees Celsius (°C).

Dry bulb temperature: the thermal energy of a gas or mixture of gases, measured by a thermometer after correction for radiant temperature (20).

Wet bulb temperature: the temperature at which liquid or solid water by evaporating into the air can bring that air to saturation adiabatically at the same temperature (20).

Humidity: humidity must be measured as absolute or relative humidity

- **Absolute humidity**: The mass of water vapour present per unit volume of gas. If the gas is fully saturated with water vapour this is referred to as the absolute humidity at saturation for that temperature (21). Absolute humidity is measured in g/m3 or mg/litre
- **Relative humidity**: the amount of water vapour present in a volume of gas, expressed as a percentage of the maximum possible amount of water that could be present in the gas at that temperature (21). Relative humidity level is measured as a percentage. In this study relative humidity (RH) will be used.

Wet and dry bulb thermometer: two mercury thermometers placed side by side in an encasing held together by a swivel, for circulating. One thermometer is the dry bulb thermometer and measures the room air temperature, whilst the other thermometer has a wet wick surrounding the bulb, which when spun in the room air, records a lower room temperature due to evaporation. The difference in the two recorded temperatures can be read off a hygrometer chart or table to ascertain the relative humidity.

Sling hygrometer: also known as the whirling hygrometer is a wet and dry bulb hygrometer that needs to be circulated in the room to get maximum exposure of the wet bulb to the ambient environment. This will be the thermometer used in this study.

Thermometer profile: this is the profile of the existing thermometer in the OT room, its presence, placement, functionality and any other observations on its condition.

Operating theatre (OT) room: in this study we are going to use one general surgery paediatric theatre, one cardiothoracic theatre, one obstetric theatre and one orthopaedic theatre.

4.5 Demarcation of study field

The study will be conducted in the OT complex of CMJAH affiliated to the Department of Anaesthesiology at the University of the Witwatersrand. CMJAH is a 1200 bed central hospital. The hospital has 23 theatres and performs approximately 23 000 operations annually.

4.6 Ethical considerations

An ethics waiver will be requested from the Human Ethics Committee of the University of the Witwatersrand (Appendix 1) as no patients will be involved in this study. Approval to conduct the study will be obtained from the Graduates Studies Committee of the Witwatersrand and the CEO of CMJAH.

The attending anaesthetist will be asked about the appropriateness of the OT thermal conditions prior to the measurement of the OT room temperature and relative humidity, however the anaesthetist will not be identified and their answer will not bias the data capturing. Confidentiality will be insured as only the researcher, supervisors and statistician will have access to the raw data. The data collected will be stored for six years in a locked cupboard.

If the thermal conditions are found to be inappropriate, the practicing anaesthetist will be notified immediately.

This study does not involve any drug or therapeutic management, and will be conducted in adherence with the Declaration of Helsinki (22) and the South African Good Clinical Practice guidelines (23).

4.7 Research methodology

4.7.1 Research design

Data collection

Data collection will commence once all the relevant approvals have been received.

The OT room temperature and relative humidity level will be measured using a sling hygrometer; which is an instrument consisting of two mercury thermometers attached to a frame that is fastened to a swivel handle (24). One thermometer is the “dry bulb” thermometer and the second thermometer’s bulb has a cotton wick wrapped around it which is dipped in distilled water; called the “wet bulb” of the thermometer (24). The sling hygrometer is swung in the atmosphere for a full minute. The “dry bulb” thermometer measures the room air temperature (25). As the sling hygrometer is swung in the air, evaporation cools the wet wick of the “wet bulb” thermometer and thus a lower temperature is recorded. The difference between the two measurements is noted and correlated off an RH conversion table (24, 25) (Appendix 4).

The sling hygrometer will be obtained from a reputable medical device manufacturer, accredited by the South African Bureau of Standards (SABS). The sling hygrometer does not need calibration as it is calibrated by the manufacturer, but does need to be tested for accuracy (26). The accuracy and functionality of the sling hygrometer will be assessed by a reputable organisation before usage and a certificate stating this, will be attained from the organisation. The sling hygrometer will be used for research purposes only.

Data will be collected in the cardiac, paediatric, orthopaedic and obstetric OT rooms. Daily measurements of the OT room temperatures and relative humidity levels will be made for a 30 day period in the summer (4 December 2017 to 2 February 2018) and in the winter (12 June 2017 to 3 August 2017). Measurements will be made on weekdays only. Emergency OT rooms will be excluded. Time of day that measurement will be taken will be at 07:00 to 08:00. A data collection sheet will be used (Appendix 5).

First the researcher will measure the ambient temperature at the entrance of CMJAH using the sling hygrometer.

In the OT room, the following procedure will be followed:

- identify the presence of a thermometer
- if a thermometer is present, it will be described as follows

- type (electrical, non-electrical)
- placement in the OT room
- condition or maintenance schedule
- readings displayed on the thermometer.

The researcher will measure the OT room temperature and relative humidity as follows:

- the sling hygrometer will be swung in the OT room for one full minute (two to three revolutions per second), while the researcher walks around the theatre table holding the sling hygrometer above her head
- the operating lights will be off and
- there will be no patient on the operating table.

The attending anaesthetist will then be asked their opinion of the appropriateness of the OT room temperature and relative humidity, for patients to be anaesthetised (This will be based on the anaesthetist's subjective opinion of the thermal conditions and not based on actual temperature measurements recorded).

The recorded temperatures will then be disclosed to the attending anaesthetist.

Data analysis

Data will be captured onto a Microsoft® Excel (2013) spread sheet and analysed using descriptive and inferential statistics. The statistical program Statistica version 12 (Statsoft, USA) will be used. Nominal and ordinal variables will be summarised using frequencies and percentages and continuous variables using means and standard deviations or medians and interquartile ranges depending on the distribution of the data.

The concordance between the two measurement methods, the sling hygrometer (wet and dry bulb thermometer) and the OT room thermometers will be done using Bland and Altman analysis to determine the agreement between the two methods, taking the sling hygrometer as the reference. Bland and Altman analysis quantifies agreement by studying the mean difference between the two measurements and constructing limits of agreement (27).

4.8 Significance of the study

The thermal conditions in OT rooms play an important role in maintaining and alleviating thermal stress in the anaesthetised patient. Both patient hypothermia and hyperthermia need to be avoided as the anaesthetised patient loses their ability to thermoregulate and therefore relies on the anaesthetist and theatre staff for preservation of normal thermoregulatory physiology. Patients with specific physiological variations and needs, such as paediatric, geriatric, obstetric (and neonatal) and cardiac patients are a subset of the surgical population that need strict normothermic conditions. It has been shown that "up to 70% of surgical patients develop hypothermia perioperatively" (7) and that a cold OT room contributes to the inadvertent hypothermia seen in patients (7).

By describing the current thermal conditions in the OT rooms at CMJAH, it can be determined whether corrective measures need to be employed to prevent inadvertent perioperative hypothermia and hyperthermia. Currently, it is not known whether the CMJAH OT rooms have all the necessary instruments in place to accurately measure the room temperature and relative humidity; not knowing this information usually results in the attending anaesthetist having to subjectively decide whether the thermal conditions are appropriate for surgical procedures to commence. The consequences of having to subjectively decide on the appropriate thermal conditions, or decide on this based on (possibly) inaccurate instruments, could lead to the erroneous conclusion that it is appropriate to allow for the commencement of an elective surgical list. Inappropriate OT room relative humidity levels can contribute to theatre fire hazard (due to increasing electrostatic shock level) and can also cause interferences with the electronic monitoring devices. Furthermore, inappropriate relative humidity levels can compromise infection control practices in OT rooms by interfering with the sterility of surgical equipment and by increasing the number of microbes circulating in the OT room (5). For the delivery of a safe anaesthetic and surgical service to patients, it is clear that OT room temperature and relative humidity levels cannot be neglected.

4.9 Validity and reliability of the study

This study will ensure validity and reliability by the following measures:

- selecting an appropriate study design;
- collecting data at the stipulated times and within the defined OT rooms in a standard manor, by one researcher;
- using a sling hygrometer that complies with the industry regulatory standards (ASHRAE 41.1-1986) and only used for research purposes throughout the data collection period;
- applying the measurements to an ASHRAE approved relative humidity conversion chart /table and
- consulting a biostatistician for all data analysis.

4.10 Potential limitations

According to Burns and Grove (28), the potential study limitations are “the aspects of the study that decrease the generalizability of the findings” they can also diminish the credibility of the study findings and need to be addressed upfront as that could result in unearthing further research questions (28).

As this study will be conducted contextually at CMJAH, the results may not be generalizable to other OT rooms and hospitals. Furthermore, data collection in a quantitative, contextual study could take time and in particular the data collection in this study will be seasonal (one summer and one winter month).

The selection of a specified number of OT rooms creates the potential limitation of sampling bias, as it may not represent the general population being studied (29).

4.11 Project outline

4.11.1 Time frame

	Nov 2016	Dec 2016	Jan 2017	Feb 2017	July 2017	August 2017	Sept 2017	Oct 2017	Nov 2017
Proposal									
Literature review									
Proposal submission									
Ethics committee submission									
Postgraduate committee submission									
Data collection									
Data analysis									
Draft article									
Editing									
Submission									

4.11.2 Budget

The Department of Anaesthesiology at the University of the Witwatersrand will bear the cost of the printing and paper for the study.

Additional funding may be needed to purchase a sling hygrometer; however there is potential to receive a loaned sling hygrometer from the Council for Scientific and Industrial Research.

	Price per page	Number of pages	Total
Printing	R1	1000	R1000
Binding	R200	3	R600
Psychometric hygrometer	-	-	R1200
Completed report	R1	100	R400
			R1456

The Wits Department of Anaesthesiology will incur the costs of paper and printing.

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4.13 Appendices

Appendix 1: Ethics waiver

Human Research Ethics Committee (Medical)

Golden Jubilee: October 1966 – October 2016

Research Office Secretariat: Faculty of Health Sciences, Phillip Tobias Building, 3rd Floor, Office 301,
29 Princess of Wales Terrace, Partktown, 2193 Tel +27 (0)11-717-1252 /1234/2656/2700
Private Bag 3, Wits 2050, email: zanele.ndlovu@wits.ac.za
Office email: hrec-medical.researchoffice@wits.ac.za
Website: www.wits.ac.za/research/about-our-research/ethics-and-research-integrity/

Ref: W-CJ-161129-4 29/11/2016

***TO WHOM IT MAY CONCERN*:**

Waiver: This certifies that the following research does not require clearance from the Human Research Ethics Committee (Medical).

Investigator: **Dr Phyllis Phukubye (Student No 0301488M).**

Project title: **Operating theatre room temperatures and relative humidity levels at a central hospital.**

Reason: This study will measure temperature and relative humidity in operating theatre rooms using a sling pyschrometer. There are no human participants

UNIVERSITY OF THE WITWATERSRAND
PROF PE CLEATON-JONES
HREC (MEDICAL)
2016 -11- 29
JOHANNESBURG

Professor Peter Cleaton-Jones

Chair: Human Research Ethics Committee (Medical)

Copy – HREC (Medical) Secretariat: Zanele Ndlovu, Rhulani Mkansi.

Appendix 2: CMJAH CEO Approval.

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL

Enquiries:
Mr. J. Maepa
Office of the Clinical Director
Tell: (011): 488-3365
Email:Johannes.maepa@gauteng.gov.za
14 August 2017

NHRD Ref: W-CJ-161129-4

Dear Dr. Phyllis Phukubye

STUDY TITLE: Operating theatre room temperatures and relative humidity levels at central hospitals.

Permission is granted for you to conduct the above recruitment activities as described in your request provided:

1. Charlotte Maxeke Johannesburg Academic Hospital will not anyway incur or inherit costs as result of the said study.
2. Your study shall not disrupt services at the study sites.
3. Strict confidentiality shall be observed at all times.
4. Informed consent shall be solicited from patients participating in your study.

Please liaise with the HOD and Unit Manager or sister in charge to agree on the dates and time that would suit all parties.

Kindly forward this office with the results of your study on completion of the research.

Supported / ~~not supported~~

Dr. M.I. Mofokeng
Clinical Director
DATE: 18/8/2017

Approved/not approved

Ms G. Bogoshi
Chief Executive Officer
Date: 16.08.2017

Appendix 3: Sling hygrometer calibration certificate

Mon-Cal

sanas Calibration Laboratory 371 1571

Montech Calibration Services (Pty) Ltd
Tel : 011 465 4522
Email : info@moncal.co.za
Fax : 086 767 6091
Web : www.moncal.co.za
Corner Galaxy Ave & Electron Street
Linbro Business Park
Postnet Suite 266, Private Bag X21
Bryanston
2021

CALIBRATION CERTIFICATE

Calibration Certificate No: **SG2042** Page 1/2

UUT:	**Wet and Dry Bulb**
Type:	**Thermometer**
Serial No.:	**Not Marked**
Asset No.:	**Not Marked**
Manufacturer:	**Brannan**
Condition of Instrument:	**Good**
Customer :	**Dr Phyllis Charlotte Maxeke Hospital Johannesburg**
Date of calibration:	**08-14 June 2017**
Date of issue:	**20 June 2017**

Montech Calibration Services laboratory is accredited by SANAS (South African National Accreditation System).Measurements are traceable to the National Laboratory and thus traceable to the national measurement standards maintained by the NMISA for the realisation of the physical units according to the International Systems of Units (SI).The measurement results recorded in this certificate were correct at the time of calibration and only relates to the equipment detailed on this certificate. The subsequent accuracy will depend on factors such as care, handling and frequency of use. It is recommended that recalibration be undertaken at an interval that will ensure that the instrument remains within the desired limits. This calibration certificate may not be reproduced without prior permission of Montech Calibration Services Pty Ltd and SANAS. Calibration certificates without signature are not valid. The results given relate only to the item (s) calibrated and can only be guaranteed at the time of issue. The SOUTH AFRICAN NATIONAL ACCREDITATION SYSTEM (SANAS) is a member of the International Laboratory Accreditation Cooperation (ILAC) mutual recognition Arrangement (MRA). This arrangement allows for the mutual recognition of Technical Test and calibration data by member accreditation bodies. For more information on the arrangement please contact www.ilac.org

Technical Signatory

Seola Mashamaite

Appendix 4: RH conversion table

Name Date

Relative Humidity Table

STUDENT RESOURCE PAGE **2.3**
INFORMATION SHEET

To determine relative humidity:

1. Subtract the wet-bulb temperature from the dry-bulb temperature.
2. Find this number—the difference in degrees—at the top of the chart and place your finger on it.
3. Find the dry-bulb temperature in the first column on the left. Place your finger on it.
4. Bring your fingers down the column and across the row. The relative humidity percentage appears where column and row intersect on the chart.

Dry Bulb (ºC)	**Number of degrees difference between the wet- and dry-bulb readings (ºC)**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
10	88%	77	66	56	45	35	26	16	7	--
11	89	78	67	57	47	38	28	19	11	2
12	89	79	68	59	49	40	31	22	14	5
13	89	79	69	60	51	42	33	25	16	9
14	90	80	70	61	52	43	35	27	19	11
15	90	80	71	62	54	45	37	29	22	14
16	90	81	72	63	55	47	39	31	24	17
17	91	82	73	64	56	48	41	33	26	19
18	91	82	73	65	57	50	42	35	28	21
19	91	82	74	66	58	51	44	37	30	24
20	91	83	75	67	59	52	45	38	32	26
21	91	83	75	68	60	53	47	40	34	27
22	92	84	76	69	61	54	48	41	35	29
23	92	84	77	69	62	56	49	43	37	31
24	92	84	77	70	63	57	50	44	38	32
25	92	85	77	71	64	57	51	45	40	34
26	92	85	78	71	65	58	52	46	41	35
27	93	85	78	72	65	59	53	47	42	37
28	93	86	79	72	66	60	54	49	43	38
29	93	86	79	73	67	61	55	50	44	39
30	93	86	80	73	67	61	56	50	45	40
31	93	86	80	74	68	62	57	51	46	41
32	93	87	80	74	68	63	57	52	47	42
33	93	87	81	75	69	63	58	53	48	43
34	93	87	81	75	69	64	59	54	49	44

Appendix 5 Data collection sheet

OT room : CARDIAC / PAEDIATRIC / ORTHOPAEDIC / OBSTETRIC							
OT wall thermometer : Yes / No			Condition: Good/ poor		Other comments:		
Season : Summer / Winter							
Date	**Ambient temperature**		**OT wall thermometer**		**Sling hygrometer**		**Anaesthetist's perception**
	Ambient temperature (˚C)	**RH (%)**	**OT room temperature (˚C)**	**RH (%)**	**OT room temperature (˚C)**	**RH (%)**	**"Too cold"/"Too hot"/"Appropriate"**
Day 1							
Day 2							
Day 3							
Day 4							
Day 5							
Day 6							
Day 7							
Day 8							
Day 9							
Day 10							
Day 11							
Day 12							
Day 13							
Day 14							
Day 15							
Day 16							
Day 17							
Day 18							
Day 19							
Day 20							
Day 21							
Day 22							
Day 23							
Day 24							
Day 25							
Day 26							
Day 27							
Day 28							
Day 29							
Day 30							

Annexures

4.14 Ethics approval

Human Research Ethics Committee (Medical)

Golden Jubilee: October 1966 – October 2016

Research Office Secretariat: Faculty of Health Sciences, Phillip Tobias Building, 3rd Floor, Office 301,
29 Princess of Wales Terrace, Partktown, 2193 Tel +27 (0)11-717-1252 /1234/2656/2700
Private Bag 3, Wits 2050, email: zanele.ndlovu@wits.ac.za
Office email: hrec-medical.researchoffice@wits.ac.za
Website: www.wits.ac.za/research/about-our-research/ethics-and-research-integrity/

Ref: W-CJ-161129-4 29/11/2016

***TO WHOM IT MAY CONCERN*:**

Waiver: This certifies that the following research does not require clearance from the Human Research Ethics Committee (Medical).

Investigator: **Dr Phyllis Phukubye (Student No 0301488M).**

Project title: **Operating theatre room temperatures and relative humidity levels at a central hospital.**

Reason: This study will measure temperature and relative humidity in operating theatre rooms using a sling pyschrometer. There are no human participants

UNIVERSITY OF THE WITWATERSRAND
PROF PE CLEATON-JONES
HREC (MEDICAL)
2016 -11- 29
JOHANNESBURG

Professor Peter Cleaton-Jones

Chair: Human Research Ethics Committee (Medical)

Copy – HREC (Medical) Secretariat: Zanele Ndlovu, Rhulani Mkansi.

4.15 Graduate Studies Committee approval

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
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Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

12 June 2017
Person No: 0301488M
PAG

Dr PM Phukubye
P O Box 1886
Fourways
2055
South Africa

Dear Dr Phukubye

Master of Medicine: Approval of Title

We have pleasure in advising that your proposal entitled *Operating theatre room temperatures and relative humidity levels at a central hospital* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

4.16 Turnitin report