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MEASUREMENT OF TEMPERATURE CHANGE IN PAEDIATRIC PATIENTS UNDERGOING MRI EXAMINATIONS UNDER GENERAL ANAESTHESIA

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Masters of Medicine in Anaesthesia Johannesburg, 2014

I, Phelisa Miti, declare that this thesis is my own work. It is submitted for admission to the degree of Masters of Medicine by the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

Signed at Johannesburg.....

Signature.....

Date 11 July 2014.....

ABSTRACT

Background and objectives of study: Paediatric patients undergoing Magnetic Resonance Imaging (MRI) procedures are at risk of hypo- or hyperthermia. This study was aimed at determining if there is a change in core temperature in paediatric patients undergoing MRI examinations under general anaesthesia. The objectives included describing the change in temperature during MRI scans, and correlating temperature change with age, weight and MRI scan duration.

Method: This study followed a prospective, contextual and descriptive research design. The study population was paediatric patients who presented for MRI scans under general anaesthesia at Chris Hani Baragwanath Academic Hospital. A convenience, consecutive sampling method was employed and 29 patients aged 6 months to 5 years whose baseline temperatures were below 37.5℃ participated in the study.

Tympanic temperature was measured using an infrared thermometer before induction of general anaesthesia. Inhalational general anaesthesia was induced with incremental concentrations Sevoflurane in a mixture of Nitrous oxide and Oxygen (70:30 %) using an MRI compatible anaesthesia machine. General anaesthesia was maintained with spontaneous inhalation of Sevoflurane in a mixture of O_2 and Air (60:40 %) via a laryngeal mask airway. Tympanic temperature was measured again on completion of the MRI scan within 2 minutes of emergence from general anaesthesia. The change between pre and post scan temperatures was tested for significance using the paired t-test. Correlations were made using the Pearson correlation coefficient.

Results: The mean age of the participants was 31 months and the median 24 months. The mean weight was 13.2 kg, the median 12 kg, and the range 5 to 29 kg. The mean MRI scan duration was 51 minutes, the median 50 minutes and range 30 minutes to 80 minutes. All participants experienced some loss of temperature (0.1 – 2.3 ℃). The mean temperature loss was 0.93℃ and was statistically significant (p=0.001). The 95% confidence interval for temperature change was 0.70 – 1.15 ℃. No statistically significant correlations were found between temperature loss and age (r=-0.028), weight (r=-0.042) and scan duration (r=-0.041).

Conclusion: Heat loss in the harsh MRI environment is an underestimated problem. In addition, the ferromagnetic environment precludes continuous temperature monitoring. This study has shown that temperature does drop in paediatric patients undergoing MRI examinations under general anaesthesia. This change in temperature did not correlate with age, weight, and duration of the MRI scan.

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ABBREVIATIONS

ASA - American Society of Anaesthesiologists

BP - Blood pressure

CHBAH - Chris Hani Baragwanath Academic Hospital

GA - General anaesthesia

IV - Intravenous

kg - Kilograms

MR - Magnetic resonance

MRI - Magnetic Resonance Imaging

N_2O - Nitrous Oxide

O_2 - Oxygen

PACU - Post anaesthesia care unit

RF - Radiofrequency

RFR - Radiofrequency radiation

SAR - Specific absorption rate

TIVA - Total intravenous anaesthesia

TVMF - Time-varied magnetic field

USA - United States of America

W/kg - Watts per kilogram

CHAPTER ONE

OVERVIEW OF THE STUDY

In this chapter the problem statement, aim and objectives, research assumptions and demarcation of study field will be presented. The ethical considerations, research methodology, data analysis, significance of the study and report outline will also be presented.

1.1 INTRODUCTION

Magnetic Resonance Imaging (MRI) is a diagnostic imaging procedure that offers excellent anatomical detail and precise tissue characterisation by generating images from magnetic fields and radiofrequency pulses (1). Cool temperatures and low humidity are required for proper magnet function (2). MRI has been used for paediatric imaging for about 35 years (1).

The radiofrequency radiation (RFR) generated by the MRI scanner is absorbed by the patient and transformed into heat within the patient's tissues. This may increase the patient's core temperature (3). MRI is not painful, but to acquire quality images, patient immobility over long procedure times is paramount. This poses a challenge when it comes to paediatric patients, and general anaesthesia (GA) or deep sedation is usually required for successful imaging. (1-3)

The MRI environment poses a challenge to the anaesthetised patient. GA induces impairment of thermoregulatory control (4). This, in addition to the low ambient temperatures, predisposes patients to hypothermia. The strength of the static magnetic field of the Magnetic Resonance (MR) system can easily create electromagnetic interference of the conventional monitoring devices. Physiological monitors must therefore be specially adapted for use in the MR environment. (5) It is not easy to monitor temperature during MRI because of MRI incompatibility of standard temperature probes. The ferromagnetic component in these thermometers makes them both hazardous and impractical. (6, 7)

Two international studies have reported increases in body temperature in paediatric patients undergoing MRI scans under oral (2) and IV (3) sedation, where patients with lower pre scan temperatures showed larger increases. This increase was attributed to RFR absorption (3, 4). Two further studies, one done in the United States of America (USA) (8) and one done in Turkey (9), in which inhalational GA was employed in children, showed a drop in temperature during MRI scans in most of their patients (8).

The first study of human thermal response to RFR was conducted in 1960 (5). This and subsequent studies indicated that there were no excessive temperature elevations or other deleterious

physiological effects related to RFR. There was no indication of the ages of the patients in these studies and whether they were awake, sedated or under GA. (5, 10-12) There have been no national studies found on this subject. The importance of monitoring temperature during MRI scans has however been emphasised both nationally (6) and internationally (2, 3, 5, 8, 13).

1.2 PROBLEM STATEMENT

Paediatric patients undergoing MRI procedures under anaesthesia are at risk of hypo- or hyperthermia (3, 13). At Chris Hani Baragwanath Academic Hospital (CHBAH) it has been observed that some paediatric patients are cold and shiver post MRI. Temperature is currently not being monitored due to the unavailability of MRI compatible temperature probes and financial constraints. It is therefore not known whether patients experience temperature loss or gain during MRI and thus there is no intervention to ensure that temperature is maintained.

1.3 AIM AND OBJECTIVES

1.3.1 Aim

The aim of the study was to determine if there is a change in core temperature during MRI scans in paediatric patients undergoing MRI examinations under GA at CHBAH.

1.3.2 Objectives

The primary objectives of the study were to:

- determine the tympanic temperature pre MRI scan
- determine the tympanic temperature immediately post MRI scan
- determine the difference between pre scan and post scan temperature
- determine if any thermoregulatory intervention was performed after the MRI scan.

The secondary objectives were to:

- correlate temperature change with the age
- correlate change in temperature with weight
- correlate change in temperature with the duration of the MRI scan.

1.4 RESEARCH ASSUMPTIONS AND DEFINITIONS

The following definitions were used in the study:

Hypothermia – Tympanic temperature less than 36.5℃;
Hyperthermia – Tympanic temperature more than 37.5℃;

Normothermia – Tympanic temperature in the range of 36.5℃- 37.5℃ (4);

Participants – Paediatric patients aged 6 months to 5 years;

Caregiver – The adult accompanying and is responsible for the participant.

1.5 DEMARCATION OF STUDY FIELD

The study took place at CHBAH, Gauteng Province. CHBAH is the biggest academic hospital in South Africa and is a referral centre for many surrounding regional hospitals.

1.6 ETHICAL CONSIDERATIONS

Ethical approval for the study was sought from the Human Research Ethics Committee (Medical) (Appendix I) and the Postgraduate committee (Appendix II) of the University of the Witwatersrand, as well as the appropriate authorities. Informed (Appendix V), written consent (Appendix VI) requested and obtained from caregivers. Anonymity and confidentiality was assured.

Participants found to have hypothermia after the scans were actively rewarmed by covering them with an extra blanket with or without a Bair Hugger in the PACU. None of the participants were found to be hyperthermic but plans were in place to actively cool them by removal of clothing and tepid sponging in the PACU.

The research was conducted according to the Declaration of Helsinki and adhering to good clinical research practice (49)

1.7 RESEARCH METHODOLOGY

1.7.1 Research design

This study followed a prospective, contextual and descriptive research design

1.7.2 Study population

The study population was paediatric patients presenting for MRI examinations under GA at CHBAH.

1.7.3 Study sample

Sample size

In consultation with a biostatistician, it was calculated that when a sample size is 25, a two-sided 95.0% confidence interval for a single mean will extend 0.200 from the observed mean, assuming

that the standard deviation is known to be 0.500 and the confidence interval is based on the large sample z statistic (nQuery Advisor 7).

Sampling method

A convenience, consecutive sampling method was used in this study. Participants for the study were identified from a list of patients who were pre booked for MRI under GA at CHBAH.

Inclusion criteria

The following inclusion criteria were used for the study:

- paediatric patients between the ages of 6 months and 5 years presenting for diagnostic MRI under GA;
- patients whose ears were not obstructed by wax or any other space occupying lesions.

Exclusion criteria

The following patients were excluded from the study:

- patients for whom consent could not be obtained;
- patients whose pre scan temperatures were above 37.5 ℃.

1.7.4 Description of data collection

Potential participants were identified and the caregivers were approached and invited to the study. Informed consent was requested and obtained. All participants were changed into a hospital gown and a single cotton blanket was used to cover each participant.

Tympanic temperature was measured before and immediately after the MRI scans using an infrared ear thermometer (BRAUN ThermoScan®, IRT 4520 ExacTemp), following the manufacturer's instructions.

1.7.5 DATA ANALYSIS

Data collected was captured using an Excel Spread sheet and interpreted using descriptive and inferential statistics. Categorical variables were summarised by frequency counts and percentage calculations. Continuous variables were summarised by sample size, mean, standard deviation, median and range. The difference between pre scan and post scan temperatures was tested for significance by the two-sided paired t test. The 95% confidence interval for temperature change

was used where appropriate. Correlations were determined using the Pearson correlation coefficient. P values ≤ 0.05 were considered significant.

1.8 SIGNIFICANCE OF THE STUDY

This study was significant as it is unknown what happens to paediatric patients' temperatures during MRI scanning. MRI has the potential to increase core temperature whereas the cold MRI environment and GA have the potential to decrease it. This study therefore:

highlighted the importance of monitoring temperature during MRI examinations under GA;

encouraged drawing up of protocols on management of thermal challenges in the MRI suite.

1.9 REPORT OUTLINE

An outline of this research report is as follows:

Chapter one: Overview of the study.

Chapter two: Literature review.

Chapter three: Research methodology.

Chapter four: Results and data analysis.

Chapter five: Conclusion and further recommendations.

1.10 SUMMARY

In this chapter the introduction of the study, problem statement, aim and objectives, research assumptions, demarcation of study field, ethical considerations, methodology, data analysis, significance and report outline were presented. In the next chapter the literature review will be presented.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Anaesthesia is sometimes required for paediatric MRI because the quality of images depends partly on the patient remaining immobile. Knowledge about MRI, its hazards and complications is essential for the attending anaesthetist. This chapter is a review of the literature that addresses the physiology of thermoregulation, the effects of anaesthesia on thermoregulation, and temperature monitoring. The history and physical principles of MRI as well as its challenges, particularly to the anaesthetised child, will also be addressed. Lastly indications for anaesthesia for MRI, safety guidelines and the different techniques of anaesthesia will be addressed, with emphasis on GA for MRI.

2.2 TEMPERATURE REGULATION

Temperature is tightly controlled within 0.2 ℃ - 0.4 ℃ of its set point of 37.0 ℃. The limits of the interthreshold range, which defines the range over which no thermoregulatory response is triggered(4), are 36.7 ℃ - 37.1℃. (16) Temperatures of as low as 13.7 ℃ have been reported to be compatible with life, whereas protein denaturation has resulted in death within 7 ℃ above normality (4).

2.2.1 PHYSIOLOGY OF THERMOREGULATION

The principal site of temperature regulation is the hypothalamus (4, 17). Processing and regulation occurs in three stages:

- afferent thermal sensing
- central regulation
- efferent response. (4, 17, 18)

Afferent thermal sensing

Thermo-sensitive receptors located in the skin, in close proximity to great vessels, viscera and abdominal wall, as well as the brain and spinal cord convey information to the pre-optic area in the anterior hypothalamus (4). Cold sensitive receptors transmit information by A-delta fibres, with a peak discharge rate at 25 - 30 ℃. Warm peripheral receptors transmit information by unmyelinated C-fibres and have their peak discharge rate at 40 – 50 ℃. (4, 17-19) Most ascending thermal information traverses the spinothalamic tracts in the anterior spinal cord (4, 17).

Central regulation

In the hypothalamus, thermal inputs are integrated and compared with threshold (triggering) temperatures (4, 17). Thermal deviations from either side of the interthreshold range trigger heat loss or gain in order to maintain body temperature within the narrow limits of its set point. The anterior hypothalamus integrates afferent thermal information while the posterior hypothalamus controls the descending pathway effectors. (19)

Efferent response

This response is triggered in the posterior hypothalamus. It includes behavioural and vasomotor responses, as well as shivering and non-shivering thermogenesis. Behavioural responses are aimed at escaping forthcoming thermal insult and depend more on peripheral temperature. They include warming or cooling the environment and putting on or removing clothes. (4, 19)

Vasomotor responses involve the sympathetic neural control of skin blood flow. Temperatures lower than 36.7 ℃ trigger vasoconstriction and piloerection in the skin. This reduces cutaneous blood flow and thus heat loss. Temperatures greater than 37.1 ℃ trigger vasodilation. This can increase cutaneous blood flow to 6 - 8 litres per minute, as well as sweating, to dissipate heat. (4, 17, 19) Shivering and non-shivering thermogenesis are metabolically driven responses (4) and will be discussed below.

2.2.2 PAEDIATRIC THERMOREGULATION

Infants and children have a large surface area compared to their body mass (4, 20, 21). In infants particularly, the head comprises up to 20% of the skin's total surface area and shows the highest regional heat flux ability (4, 21). The thin skull bones and usually sparse scalp hair in close proximity to the highly perfused brain accounts for about 85% of body heat losses. There is only a thin layer of fat and reduced keratin content which results in increased thermal conductance and increased heat loss. (4)

In adults the lower ambient temperature limit of thermal regulation is 0 ℃ whereas in the new-born it is 22 ℃. The ambient temperature range over which temperature regulation is achieved through vasoconstriction or vasodilation is the thermo-neutral zone. Within the thermo-neutral zone O_2 demand is minimal as temperature regulation is achieved through non-metabolic processes. Its upper limit, where sweating is triggered, is called the upper critical temperature. Below the lower critical temperature shivering and non-shivering thermogenesis are activated. (4, 22)

For an unclothed adult in a draft-free environment, the thermo-neutral zone is approximately 28 ℃ whereas in a neonate this zone is in the range of 32 ℃ - 35 ℃ (4, 22). The capabilities and the functional range of the paediatric thermoregulatory system are significantly limited and easily overwhelmed by environmental factors. Therefore when compared to adults in similar environments, neonates lose more heat through their skin. (4)

2.2.3 HEAT LOSS MECHANISMS

Four mechanisms contribute to heat loss:

- conduction
- radiation
- convection
- evaporation. (4, 19)

Conduction describes heat transfer between two surfaces in direct contact. The amount of heat transferred depends on the temperature difference between the two objects. The physiologic factors controlling conductive heat loss are cutaneous blood flow and the thickness of the subcutaneous tissue. Patients usually lose heat to metallic surfaces. (4, 19)

Radiation describes transfer of heat between two objects of different temperature that are not in contact with each other. Heat transfer occurs in the infrared light spectrum and is unaffected by air movement or the distance between the two surfaces. (4, 19) In both awake and anaesthetised infants, radiation is the major factor for heat loss under normal conditions (4, 17, 19).

Convection describes heat transfer to moving molecules, such as air or liquids. The thin layer of air adjacent to the patient's skin is warmed by conduction and then lost by convection. The rate and direction of convective heat exchange depends on the velocity and the temperature difference between the air and the skin surface. (4, 19)

Evaporation occurs through the skin and the respiratory system. Its driving force is the vapour pressure difference between the body surface and the environment. Evaporative losses include sensible and insensible water loss, and evaporation of liquids applied to the skin. Respiratory loss occurs if a patient breathes cool, dry air and hypothermia is more likely if the patient's skin is wet or is in contact with wet drapes. (4, 19)

2.2.4 HEAT GENERATING MECHANISMS

Heat can be generated actively by the body through four mechanisms:

- voluntary muscle activity

- non-shivering thermogenesis
- shivering thermogenesis
- dietary thermogenesis. (4)

Voluntary muscle activity is the behavioural part of heat production but is not functional in the peri-anaesthetic period (4). Non-shivering thermogenesis is an increase in metabolic heat production that is not associated with muscle activity and is triggered at 36 ℃. It is the major heat generating mechanism in the new-born and occurs through the metabolism of brown fat. Brown fat is highly specialised tissue, abundant in mitochondria in the cytoplasm of its multinucleated cells. (4, 19)

Brown fat is highly vascularised with rich sympathetic innervation and its mitochondria are responsible for uncoupling oxidative phosphorylation. This results in heat production instead of generating adenosine triphosphate. Activation of brown fat metabolism diverts as much as 25% of the cardiac output through it, facilitating direct warming of the blood. Clinically significant non-shivering thermogenesis persists up to two years of age. (4, 19)

Shivering thermogenesis is involuntary and irregular muscle activity triggered at 35.5 ℃ and usually begins in the upper body. With increasing age, it takes over a more prominent role in thermogenesis. Shivering occurs in two different patterns: a basal, continuous shivering with low intensity and bursts of high intensity which are superimposed in the basal pattern. (4, 16)
Shivering has a number of deleterious effects. It causes:

- discomfort to the patient (4, 16);
- an increases O_2 consumption up to 400% (4, 16, 23);
- an increases carbon dioxide production (16);
- excessive sympathetic nervous system stimulation with increases in cardiac output, pulse rate and blood pressure (BP) (16, 24) which may cause decompensation in patients with limited cardiopulmonary reserve (23, 24).

Dietary thermogenesis refers to stimulation of energy expenditure and thermogenesis by certain nutrients (i.e. proteins, amino acids, caffeine and fructose). Infusion of small amounts of amino acids results in up to five fold increase in heat generation, even in anaesthetised patients. (4)

2.2.5 ANAESTHESIA AND THERMOREGULATION

GA widens the interthreshold range from ±0.4 ℃ to ±4 ℃ (4, 16-18, 25). The vasoconstriction and shivering thresholds may be lowered by up to 3.5 ℃ whereas the vasodilatation and sweating thresholds are only 1.0 ℃ to 1.4 ℃ higher than in awake patients (25)

Anaesthesia and hypothermia

GA decreases heat production by inhibiting muscular activity and non-shivering thermogenesis (4). Heat loss during GA occurs in three phases:

- internal redistribution
- thermal imbalance
- plateau or rewarming. (4, 17, 19)

Internal redistribution of heat occurs with induction of anaesthesia. A reduction in the vasoconstriction threshold results in peripheral vasodilatation and heat is thus distributed from the central to the peripheral compartment. The decrease in core temperature during the first hour is approximately 0.1 ℃ to -1.5 ℃ as heat is mainly redistributed, not lost. (4, 19)

During the thermal imbalance phase, heat loss to the environment exceeds metabolic heat production. It results in a linear decrease in core temperature and lasts about two to three hours. Radiation, convection, evaporation and conduction all contribute to heat loss. (4, 18, 19)

The plateau or rewarming phase reflects a thermal steady state in which heat loss equals heat production as thermoregulatory vasoconstriction is activated, between 34 ℃ and 35.5 ℃ (4, 19). Unlike adults, this third phase in infants and children is a rewarming rather than a plateau. This is due to marked vasoconstriction which results in the shrinkage of the central compartment volume, resulting in a higher core temperature. (4)

Consequences of hypothermia

Mild core hypothermia ranges over 36.4 ℃ to 33.0 ℃ and this is the approximate temperature at which organ dysfunction may begin to develop (16). Hypothermia reduces the basal metabolic rate along with the risk of tissue hypoxia and ischaemia but the deleterious effects of even mild hypothermia outweigh the potential benefits. (4, 16)

In the cardiovascular system mild hypothermia leads to increased sympathetic activity with an increase in vasoconstriction, heart rate and cardiac output. Further hypothermia causes a drop in the heart rate and cardiac output. Below 28 ℃, bradycardia is accompanied by decreased cardiac contractility. At 25 ℃ spontaneous ventricular fibrillation occurs and at 21 ℃ there is asystole. (19)

The respiratory centre is stimulated by mild hypothermia leading to an increased respiratory rate. Progression causes respiratory depression with impairment of the muco-ciliary functioning and thus an inability to clear secretions. (19) The level of consciousness drops progressively with a

drop in cerebral metabolic rate. Increased O_2 consumption and metabolic acidosis occur as a result of decreased tissue perfusion and shivering. (4)

Prolonged drug metabolism as a result of hepatic and renal dysfunction may delay recovery from anaesthesia. Platelet dysfunction occurs, leading to coagulopathy. Impaired immune function and delayed wound healing prolong hospitalisation. A negative nitrogen balance results from increased breakdown and decreased synthesis of proteins. Protein loss leads to impaired immune function. General protein reserves are depleted resulting in slowed wound healing. (4, 16, 17)

Anaesthesia and hyperthermia

Hyperthermia is an increase in body temperature that exceeds the body's ability to lose heat. It is uncommon under anaesthesia. It can be caused by endogenous heat production or exogenous heat exposure. (19) Normal physiologic response is more aggressive to hyperthermic than to hypothermic threats. These responses seem to be well preserved during GA. (25) Anaesthetic agents can induce malignant hyperthermia in susceptible individuals (26). Differentials of hyperthermia under anaesthesia include fever from an underlying infection, neuroleptic malignant syndrome and anticholinergic poisoning (19).

Consequences of hyperthermia

The effects of hyperthermia range from a minor heat illness to life threatening heat strokes. Cramps, oedema, exhaustion and syncope are symptoms of minor heat illness. Heat stroke occurs when thermoregulatory mechanisms fail and is potentially fatal. Core temperature can rise above 40 ℃ with subsequent haemorrhagic necrosis of the lungs, heart, liver, gastrointestinal tract, kidneys and brain. (19)

2.3 TEMPERATURE MONITORING

Body temperature varies widely within the body. Core tissues (deep thoracic, abdominal and central nervous system) tend to maintain a constant temperature due to their high perfusion rates. Peripheral tissues (arms and legs) have significantly lower temperatures that may vary markedly and are highly influenced by ambient temperature. Core temperature is the best indicator of thermal status in humans. Skin temperatures offer little as a reflection of core temperature. (4, 18, 27)

2.3.1 Thermometers

For decades, mercury-in-glass thermometers were standard methods of measuring temperature, but recently thermocouples, thermistors and infrared sensors have become common (17). A

thermocouple consists of two different metals with a small current being produced where these meet. The voltage magnitude of this current not only depends on, but can also be used to measure, temperature. (4, 17) Thermistors are temperature-sensitive semi-conductors whose resistance drops exponentially as temperature increases (19).

Most electronic thermometers are thermocouples and thermistors. These have to be in contact with the surface of the tissue in question in order to measure the temperature (17) and are suitable for continuous monitoring (19). Infrared thermometers measure the radiant heat emitted by all surfaces above absolute zero degrees. When signals are obtained from the tympanic membrane, the result is comparable with core temperature. Infrared thermometers are ideal as they dispense with the need to insert thermistors and thermocouples into the ear. (17, 27)

2.3.2 Core temperature measuring sites

Measuring sites recommended for clinical use are the tympanic membrane, nasopharynx, distal oesophagus, pulmonary artery, bladder and rectum (4). These sites usually provide equal readings in both awake and anaesthetised humans undergoing non-cardiac surgery (28).

Tympanic membrane temperature measurement is used because it is the closest one can get to the temperature regulating site, the hypothalamus, without surgery (27). It is accessed via the external auditory canal which needs to be sealed by the infrared temperature probe to allow the air column trapped between the tympanic membrane and the probe to reach a steady state temperature (4, 17). Errors are often encountered when the probe cannot “visualise” the tympanic membrane. These temperature probes are popular due to the diminished risk of perforating the ear drum and fast response time but are not suitable for continuous monitoring. (17, 27)

Nasopharyngeal temperature provides a good estimate of core temperature. For the probe to accurately reflect core temperature, the tip needs to be placed in the posterior nasopharynx, close to the soft palate. Slight and self-limiting bleeding from the nose may occur, especially in children with large adenoids. (4)

Oesophageal temperature can be measured using probes that are combined with an oesophageal stethoscope, which makes this site attractive for the paediatric population. Central temperature is measured only if the tip of the probe is placed in the distal third of the oesophagus at the point where heart sounds are loudest. (4, 17) Rectal probes, bladder and pulmonary artery catheters give even more accurate estimates of core temperature but have the disadvantage of being invasive and are therefore less desirable for the paediatric population (4).

2.3.3 Temperature monitoring during MRI

The decision on which body site to use is based on accuracy and accessibility. Hard wire thermistors and thermocouples are not practical during MRI because of their ferromagnetic content. (6, 7) Intermittent temperature monitoring is advised during prolonged scanning (7). Skin temperature strips that use a liquid crystal display can be used but accuracy is limited (6, 7) and they do not reflect core temperature.

Fiberoptic temperature probes are MRI compatible. They employ flouroptic optical sensor technology which is based on the fluorescence decay time of a special thermo sensitive phosphorescent sensor, located at the end of a fiberoptic cable. The measured decay time is converted into temperature by the instrument's software using a calibrated conversion table. One limitation of this probe is that it is not suitable for insertion into a body cavity and is therefore usually placed in the axilla. (29) The result is peripheral and not core temperature; therefore it is not the gold standard for use in MRI.

Core temperature measurement during MRI employs minimally invasive thermometers which require additional setup time. Two of the most prevalent temperature measurement sites are the rectum and oesophagus. These thermometers are invasive and therefore less desirable for diagnostic MRI examinations, especially in the paediatric population. There is also a delay in response that is caused by thermal inertia from tissues intervening between the measuring site and the hypothalamus. As a result, the patient can become hyperthermic or hypothermic for an extended period without this being recognised by the clinician. (26)

2.4 MAGNETIC RESONANCE IMAGING

MRI is a diagnostic imaging procedure that offers excellent anatomical detail and precise tissue characterisation by generating images in cross section and in three-dimension from magnetic fields and radiofrequency pulses (1, 29, 30). It is indicated in the diagnosis and management of many neurological, cardiovascular, oncological and musculoskeletal conditions (30).

2.4.1 History

The origins of MRI can be traced back for over a century (31). Nikola Tesla (1856-1943), the man behind the magnetic field unit which is the Tesla (T), discovered the rotating magnetic field (32). In 1946 Bloch and Purcell found that when certain nuclei were placed in a magnetic field they absorbed energy in the electromagnetic spectrum, and re-emitted it when the nuclei returned to their original state (6, 31, 33). MRI has evolved significantly over the past 35 years. In 1974 Paul and Mansfield described the use of magnetic field gradients for spatial localisation of nuclear

magnetic resonance signals, laying the foundation for MRI. The first images of a human finger, wrist and chest were reported in the 1970's. (31, 34)

2.4.2 Physical principles

MRI relies on the fact that some atoms within the human body possess an odd unpaired proton. Proton nuclei of hydrogen atoms are the most abundant examples, being major constituents of water which forms 60% of the human body. (7, 22, 30) These nuclei possess a spin, which may be visualised as a rotation of the nuclei about their own axes. This spin results in a local magnetic field that allows protons to act like small magnets. (6, 30)

When a strong electromagnetic field is applied to the body, these nuclei align themselves parallel to that field. These nuclei can be turned out of alignment (creating an "energised" state), by applying brief RF pulses, creating an electromagnetic field perpendicular to the first magnetic field. When the RF pulse is removed, these nuclei slowly recover their original alignment and the RF energy taken up is released again. Each proton will emit an RF signal which is proportional to the difference between the original alignment and the energised state. (6, 29, 30)

Tissue contrast develops as a result of different rates of realignment. The signal from the protons is collected by a set of three orthogonal gradient coils which surround the patient (6). A computer then analyses the data and transforms it into two or three-dimensional images (6, 7).

The magnet is the largest and most expensive component of the scanner. MRI requires strong magnetic fields between 0.2 and 4.0 T (35). This strength is provided by superconducting electromagnets. To minimise electrical resistance, the coils around the superconducting magnets are immersed in liquid Helium and cooled to below -269℃. (35) This results in cool ambient temperatures in the scanner room (30).

2.4.3 The MRI suite

The MRI suite is a challenging environment for the anaesthetist and it carries risks. Understanding the implications of the MRI environment will ensure safety of both the patient and personnel. (6) The MRI suite is divided into four zones:

- Zone I – public zone with free access;
- Zone II – MRI suite and public zone interface;
- Zone III – induction area, ferromagnetic objects should not be allowed in this zone;
- Zone IV – scanner room with the magnet. (7)

2.4.4 Challenges of the MRI environment

The strong magnetic field

This is the most important hazard related to anaesthesia and patient care in the MRI suite. The magnetic field is able to exert large forces on any ferromagnetic materials in close proximity, induce currents in metallic objects causing local heating and interfere with monitoring equipment. (7, 30) Conversely, ferromagnetic objects and electrical fields in the vicinity of the magnet degrade the quality of the images produced (5, 30).

Magnetic interference

The attraction of ferromagnetic objects into the magnet increases significantly as the objects are brought closer to it, resulting in rapid acceleration of these into the magnetic field (6, 30). Objects that are not fixed down risk being dangerous projectiles that may injure anyone in their path, damage equipment and interfere with the images generated. Magnetic media such as credit cards, pass keys, mobile sim cards, floppy discs and video tapes may be erased in the magnetic field. (6, 7, 30) Newer MRI machines are shielded, allowing use of ferromagnetic equipment (7).

Ferromagnetic materials inside the body are subject to similar forces and can move, malfunction, or heat up significantly with potentially fatal consequences. Absolute contraindications to MRI include the presence of cochlear implants, ferromagnetic arterial or aneurysm clips, and cardiac pacemakers. (30) The human body is conductive and movement of the blood around the body results in generation of electrical potentials and current (35). Time varied magnetic field (TVMF), which enables the computer to spatially encode RF emitted to construct images, can induce electrical eddy currents in biological tissues (6). These currents can cause symptoms such as seizures, ventricular fibrillation, nausea, vertigo and flashing lights (30).

Radio magnetic interference

Two large RF coils which transmit and emit RF energy surround the patient. Television transmitters, radios and beeper paging systems may interfere with this transmission and reception of RF. Cables and leads can behave as antennae for the RF and RF pulses can induce electrical eddy currents, short circuiting electrical equipment. The MRI suite must be shielded by lining the walls and windows with thin, continuous copper sheets and cables can be wrapped with a thin layer of aluminium foil. (6, 7)

Temperature variation in the MRI scanner

Exposure to RF radiation may result in radiofrequency induced heating during MRI. The majority of RF power transmitted for imaging is transformed into heat within the patient's tissues as a result of resistive losses, resulting in increases in body core temperatures. (5) The thermoregulatory and physiological changes displayed depend on the amount of energy absorbed. Absorption of RF radiation is described as the Specific Absorption Rate (SAR), measured in Watts per kilogram (W/kg) (12). International guidelines limit SAR values to a whole body average of 4 W/kg over 15 minutes. (3)

The actual increase in tissue temperature caused by RFR is dependent on the individual's thermoregulatory system and the surrounding environment. If the thermoregulatory effectors are not capable of dissipating the heat load, then there is accumulation of heat along with an elevation in overall tissue temperatures. (5)

The first study of human thermal response to RFR was conducted in 1960 (5). This and subsequent studies indicated that there were no excessive temperature elevations or other deleterious physiological effects related to RFR. There was no indication of the ages of the patients who participated in these studies and whether they were awake, sedated or under GA. (5, 9-11) There have been no national studies found on this subject.

A study conducted in children who underwent brain MRI scans under oral sedation showed that low pre scan temperatures may lead to larger temperature increases than those who begin their scans with normal temperatures. This might be due to triggered intrinsic heat generating mechanisms coupled to the extrinsic radiofrequency energy. (2) Exposure to powerful static magnetic fields may also cause temperature changes (5). Machata et al (3) documented a significant increase in body core temperature in infants and children under IV sedation during 1.5 T and 3.0 T examinations, with a more profound increase during 3.0 T MRI.

The cool temperatures and low humidity required for proper magnet function predispose patients to radiant and convective heat loss (2, 5). Core body temperature also decreases in GA due to thermoregulatory impairment (4). Although absorption of RFR from the MRI machine may partially offset heat loss (5), the harsh MRI environment poses a significant challenge to the anaesthetised child (2). Two recent studies were conducted in paediatric patients undergoing MRI scans under inhalational anaesthesia. Only 24% (8), and 26.7% (9) of the patients experienced an increase in temperature. The rest experienced a drop in temperature (8, 9).

2.5 EQUIPMENT

All equipment in the MRI room should be MRI compatible. An important distinction exists between MRI safe and MRI compatible equipment. MRI safe refers to an object or device which when used in the MRI suite will not harm the patient or staff but may interfere with imaging and lose its functionality. MRI compatible equipment is both safe and will operate normally within the MRI environment without interfering with imaging. (7, 29)

The MRI scanner is designed to place the patient in the centre of the magnetic field within the bore of the magnet, which extremely limits access to the patient (30). Central wall gases should be installed in consultation with a biomedical engineer (6, 7). Electrical power can cause electrical noise artefacts and interfere with images therefore it should consist of isolated circuits with filtered alternating current (6, 7).

Wave guides, which are copper shielded pipes fitted into the walls to shield cables and wires from RF interference, are necessary to prevent leakage of RF pulses and the antenna effect of electrical wires and cables (6). Anaesthetic machines require modification by replacement of the ferromagnetic components, mainly the back bars and vertical supports, with brass, aluminium and plastic (6, 30)

Medical gas cylinders must be constructed from aluminium (30). Breathing circuits require additional lengths of tubing (30). Plastic, battery operated laryngoscopes may be used (6, 30). Standard IV infusion pumps malfunction in this environment due to ferromagnetic circuitry (6). Total intravenous anaesthesia (TIVA) is most easily managed with infusion pumps. MRI compatible pumps are available. It is important to remember that these must be supported on non-ferromagnetic poles. (36)

2.6 MONITORING ISSUES

Magnetic Resonance (MR) system can easily create electromagnetic interference with the conventional monitoring devices. Physiological monitors must therefore be specially adapted for use in the MR environment (5). High levels of ambient noise caused by the rapid switching of the gradient coils may mask monitor alarms (37).

Average noise levels of 95 decibels have been measured in a 1.5 TMRI scanner. This is comparable with the noise of heavy traffic. Exposure to this level is only safe if it is limited to two hours a day. (37) As the field strength increases, so does the noise. Earplugs are essential for both the patient and the anaesthetist for noise reduction. (4) Noise may also mask the sound of partial airway obstruction therefore vigilance is essential (30).

Electrocardiography (ECG)

According to Faraday's law, a current is induced in any conducting fluid when the fluid flow is at 90 ° to the field. This effect applies to blood flowing in the aorta and is maximal in the transverse aorta. Spike artefacts that mimic R waves are often produced and make it impossible to reliably monitor for ischemia and arrhythmias. (38) MRI compatible ECG systems utilise carbon graphite electrodes to lower resistance, eliminate ferromagnetism and minimize RF interference. Cables are coaxialised to avoid coiling and subsequent skin burning. (6, 7, 30, 38) As an extra precaution, a towel should be placed on the patient's chest to prevent cables from touching the skin (6).

Blood Pressure monitoring

Non-invasive automated oscillometric BP monitoring is possible if connections are changed to plastic. Invasive pressure monitoring is possible if MR compatible transducers are used with the transducer cabling passing through the waveguides. (29, 30)

Pulse oximetry

MRI compatible pulse oximeters use heavy fiberoptic cables which do not overheat and cannot be looped. Severe burns to extremities have been reported with standard non-compatible pulse oximeters. (6, 30)

Capnography

Main stream capnography is not recommended as the sensor within the magnet bore may interfere with imaging even if it is not ferromagnetic (6). Longer than normal sample tubing is required, resulting in an approximately 20 second delay which should always be taken into consideration (30).

Oxygen sensors

These are essential within the MRI suite for episodes of quenching of superconducting magnets. This is a process that involves evaporation of the liquid Helium that causes an immediate loss of superconductivity. This may occur as a result of system errors, services, power ups, or deliberate shutdown of the magnetic field. Helium leakage within the scanning room could result in precipitous falling of O_2 levels, leading to hypoxia. O_2 sensors within the MRI suite recognise and alert the staff to a hypoxic environment. (7, 30)

2.7 CONTRAST

Some patients require IV contrast to enhance images. Gadolinium was approved in 1998 as the contrast agent of choice for MRI because it does not contain Iodine and therefore does not produce an osmotic load. (4) Its elimination half-life is 1.3 to 1.6 hours. It is excreted via the kidneys after forming a complex with chelating agents, with 95% excreted within 72 hours in both adults and children. (39) Patients with advanced renal failure are at risk of developing nephrogenic systemic fibrosis after gadolinium-based contrast agents. There are no reports of nephrogenic systemic fibrosis in patients with normal kidney function. (4)

2.8 ANAESTHESIA DURING MRI

MRI examinations require patients to stay still for a variable time of up to a few hours in a magnetic, closed, claustrophobic and noisy environment (40). GA is administered to patients who require monitoring and support during MRI procedures. These patients include those who are:

- physically or mentally challenged
- unable to communicate
- neonatal and paediatric patients
- critically ill or high-risk patients (26)
- very anxious or frightened despite reassurance (40).

2.8.1 Safety guidelines

The foremost goal is to optimise patient safety and minimise complications (1). Safe conduct requires close collaboration and prompt coordination between anaesthesiologists, radiologists, MRI technologists, and nurses. A task force composed of anaesthesiologists and radiologists with MRI expertise created a document which was published in March 2009. This established important recommendations for safe practice and consistency of anaesthesia care in the MRI environment. (41)

All anaesthesiologists should:

- have general safety education on the unique physical environment of the MRI scanner (41);
- ensure that all anaesthesia team personnel and patients entering zone III or IV have been screened for the presence of ferromagnetic materials (41-43);
- take a complete pre-procedural history, including age, weight, allergies relevant past medical history and history of previous anaesthetics (43);

- physically examine all patients, including a focused airway examination (42, 43);
- ensure that appropriate fasting guidelines appropriate have been followed (43);
- obtain appropriate informed consent from the parent or caregiver, explaining the risks involved with the drugs administered (44);
- collaborate with all participants to determine how the patient will be managed during the MRI procedure (41);
- prepare a plan for emergency situations, ensuring that emergency equipment, drugs, communication and an evacuation plan are in place (41, 42);
- ensure that all monitors used in zone IV are MRI compatible and a monitor should be available to view vital signs from zone III (41);
- ensure that for patients receiving sedation or GA, monitoring and equipment should mirror what is available in other anaesthetising locations (41);
- have an advanced plan in place to deal with common airway problems (41, 43);
- ensure that anaesthetised patients are recovered in a post-anaesthesia care unit that is properly equipped and staffed (42);
- discharge patients with oral and written discharge instructions (42);
- ensure that all events are documented including patient demographics, history, physical examination, prescriptions along with their times and adverse events, procedures undertaken, as well as time and condition of the patient at discharge (44).

2.8.2 Anaesthetic techniques

Anaesthesia for MRI is poorly standardised and varies from one institution to another, despite identical guidelines and goals (42). The different anaesthetic techniques are:

- verbal assurance
- analgesia
- sedation
- general anaesthesia.

Verbal assurance involves staying with the patient throughout the procedure, explaining events as they occur and reassuring them. This technique is only useful in calm, older children. Oral or parenteral analgesia is necessary when there is a painful underlying condition. These techniques can be carried out by a nurse, with the anaesthetist on standby. (7)

The American Society of Anaesthesiologists (ASA) Guidelines clearly separate deep sedation (responding purposefully to painful stimulus) from GA (not aroused by painful stimulus) (45). As

MRI examination is not painful, deep sedation alone is considered sufficient (1). The borders between the states of deep sedation and GA are indistinct and form part of a continuum (40).

It is the anaesthetist who must make the choice while taking into account both the type of exploration to be carried out and the patient's individual characteristics (1). The first case ever reported on anaesthesia for MRI was in a hyperactive child with Downs syndrome. She was induced with intramuscular Methohexital and maintained on an IV infusion with spontaneous ventilation. (46)

Sedation may be simple or advanced. Simple sedation employs the use of one agent, e.g. an oral benzodiazepine or inhalation of N_2O in at least 50% O_2. Advanced sedation employs a combination of agents and is induced by one of the following:

- any combination of drugs via any route;
- IV sedation using a bolus or an infusion;
- inhalational sedation, except N_2O, used as a sole agent in a concentration of less than 50% O_2. (47)

Failure to produce adequate sedation to complete the examination often happens and repeat scans under GA are sometimes required (6, 7).

Sedative agents: Midazolam is used via the oral, intramuscular or IV routes (7). The duration of action ranges from 20 to 120 minutes, depending on the dose and administration route (47). **Ketamine** is both sedative and analgesic. It can be given orally, intramuscularly, rectally or IV. The duration of action is longer after the oral versus parenteral routes (47).

Propofol is an IV agent with many advantages for MRI anaesthesia. Its rapid onset and recovery, effective anaesthesia, as well as its antiemetic properties, make it the agent of choice for busy sedation services (42). Children are quite sensitive to Propofol and deep sedation, airway obstruction and apnoea occur rapidly and unpredictably (47).

Some institutions perform **inhalational** sedation. A study performed on 640 infants showed that Sevoflurane is an ideal sedative for MRI procedures. The addition of 50% N_2O lowers the required concentrations of Sevoflurane and thus the risk for hypotension. (1) Entonox, a 1:1 mixture of N_2O and O_2 is available for older children and has an excellent safety profile (47).Other sedatives include Clonidine, Dexmedetomidine, Chloral hydrate, Trimeprazine, Droperidol and some opioids (47).

General anaesthesia has the advantages of a controlled and rapid onset and guaranteed immobility (38). Induction should occur in a child friendly environment (22). This can be zone IV where there is an MRI compatible anaesthesia machine. A room close to the scanner where standard equipment is used should be employed so that an anaesthetised patient can be quickly transferred. (38) Drugs should be prepared before the child arrives. Pulse oximetry is the minimum monitoring acceptable pre-induction (22).

Sevoflurane is the agent of choice for inhalational induction as it acts rapidly, giving a smooth induction with less cardiovascular depression than halothane. It is not odourless but unlike Isoflurane it is relatively non-irritant. Sevoflurane is administered via face mask in 50% O_2 and N_2O. Once consciousness is lost, monitors must be applied and IV access secured. (22)

Airway management is vital during GA. Small infants less than 5 kg, patients with head injuries and cardiac MRI patients where there is a need for breath hold, are best managed by intubation and mechanical ventilation (30, 47). The airways of older children may be managed by spontaneous ventilation with a harnessed face mask or a laryngeal mask airway (4, 30, 48).

Once anaesthesia is achieved and the airway secured, the patient is positioned in accordance with the intended examination (1). Earplugs are placed on all patients imaged in the 3T MRI scanner (4). Maintenance of anaesthesia may be either inhalational or IV. Vaporisers should be MRI compatible. TIVA is an acceptable technique if standard infusion pumps are kept in zone III and connecting lines are passed through waveguides. (30)

Monitoring requires the use of MRI compatible equipment. Routine monitoring includes ECG, pulse oximetry, capnography and non-invasive BP. (1, 42) Anaesthesia impairs thermoregulation and predisposes the patient to hypothermia (4). Additionally, anaesthesia may trigger malignant hyperthermia in susceptible individuals which requires diagnosis and intervention (26). Body temperature can increase from RF heating or decrease from the superconductor-protective cool environment (7). Therefore it would be ideal to monitor temperature during MRI.

Continuous temperature monitoring can be accomplished by liquid crystal display or fiberoptic temperature probes. There is currently limited means of monitoring core temperature due to the risk of heat generation and burns. (4) Measuring core temperature before and after the scan can direct post scan intervention. Care must be taken to avoid hypothermia in all patients. Airflow directed through the scanner can cool the child rapidly. Most active warming devices are MRI-incompatible. Warmed bags of IV fluids, thermal packs, airway humidification and covering the patient are ways of avoiding excessive heat loss. (48)

On emergence, earplugs are removed and patients are then recovered in a suitable recovery room (1, 22, 30). It is important to transfer the patient out of the cool environment of zone IV as soon as possible. Discharge occurs once patients meet the normal discharge criteria (30, 47).

2.9 SUMMARY

Continuous monitoring of temperature during MRI examinations under GA is important because of potential hyperthermia from RFR absorption (5, 13) and anaesthetic agent induced malignant hyperthermia (26) as well as hypothermia from GA and the cool MRI environment (4). Skin temperature strips and fiberoptic probes are MRI compatible but these are not gold standard as they do not reflect core temperature (7, 29).

In the next chapter the problem statement, aim, objectives, ethics, research methodology, validity and reliability of the study will be addressed.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

In this chapter the problem statement, aim, objectives, ethical considerations, research methodology, validity, as well as reliability of the study will be addressed.

3.2 PROBLEM STATEMENT

Paediatric patients undergoing MRI procedures under anaesthesia are at risk of hypo- or hyperthermia (3, 13). At CHBAH it has been observed that patients shiver post MRI examinations. Temperature is currently not being monitored due to the unavailability of MRI compatible temperature probes and financial constraints. It is therefore, not known whether patients experience temperature loss or gain during MRI and thus there is no intervention to ensure temperature is maintained.

3.3 AIM AND OBJECTIVES OF THE STUDY

3.3.1 Aim

The aim of this study was to determine if there is a change in core temperature during MRI scans in paediatric patients undergoing MRI examinations under GA at CHBAH.

3.3.2 Objectives

The primary objectives of the study were to:

- describe the tympanic temperature pre MRI scan
- describe the tympanic temperature immediately post MRI scan
- describe the difference between pre scan and post scan temperatures
- describe if any thermoregulatory intervention was performed after the MRI scan.

The secondary objectives were to:

- correlate temperature change with the age
- correlate temperature change with weight
- correlate temperature change with the duration of the MRI scan.

3.5 ETHICAL CONSIDERATIONS

Ethical approval for the study was sought from the Human Research Ethics Committee (Medical) (Appendix I) and the Postgraduate committee (Appendix II) of the University of the Witwatersrand, as well as the Medical Advisory Committee of CHBAH (Appendix III). Approval was also obtained from the head of the department of Radiology (Appendix IV). A comprehensive information letter containing a clear explanation of the study (Appendix V) was given to the caregivers of all participants, with translation where necessary, and written consent (Appendix VI) requested and obtained.

Anonymity and confidentiality was assured. Participants found to have hypothermia after the scans were actively rewarmed by covering them with an extra blanket and a Bair Hugger in the PACU. None of the participants were found to be hyperthermic but plans were in place to actively cool them by removal of clothing and tepid sponging in the PACU.

The research was conducted according to the Declaration of Helsinki and adhering to good clinical research practice (49).

3.6 RESEARCH METHODOLOGY

3.6.1 Research design

This study followed a prospective, contextual, descriptive research design.

Prospective study

In prospective studies, variables occur during the course of the study whereas in retrospective studies, variables have already occurred when the study takes place (14). This was a prospective study measuring the difference in temperature before and after MRI scans in paediatric patients undergoing MRI examinations under GA at CHBAH.

Contextual study

This study was contextual as it was conducted in one hospital only.

Descriptive study

Descriptive designs focus on measurable aspects of human behaviour and provide a picture of a phenomenon as it naturally occurs (14).

This study described the change in temperature during MRI scans in paediatric patients undergoing MRI examinations under GA.

3.6.2 Study population

The study population was paediatric patients presenting for MRI examinations under GA at CHBAH.

3.6.3 Study sample

Sample size

In consultation with a biostatistician, it was calculated that when a sample size is 25, a two-sided 95.0% confidence interval for a single mean will extend 0.200 from the observed mean, assuming that the standard deviation is known to be 0.500 and the confidence interval is based on the large sample z statistic (nQuery Advisor 7).

Sampling method

A convenience, consecutive sampling method was used in this study. Convenience sampling employs the use of the most readily accessible subjects in a study. Consecutive sampling is a version of convenience sampling where every available individual within an accessible population is chosen. It is the best choice of non-random sampling (15). Participants for the study were identified from a list of patients who were pre-booked for MRI under GA at CHBAH.

Inclusion criteria

The following inclusion criteria were used for the study:

- paediatric patients between the ages of 6 months and 5 years presenting for diagnostic MRI under GA;
- patients whose ears were not obstructed by wax or any other space occupying lesions.

Exclusion criteria

The following patients were excluded from the study:

- patients for whom consent could not be obtained;
- patients whose pre scan temperatures were above 37.5 ℃.

3.6.4 Description of data collection

Patients were pre-booked by their respective disciplines with the Radiology Department. Appropriate fasting guidelines were explained to their caregivers by the booking doctors. Most patients presented as outpatients to the Radiology Department on the morning of the scan. The anaesthetist met the patients for the first time in the MRI suite.

Potential participants were identified and the caregivers approached and invited to take part in the study using the information letter (Appendix V). The letter was translated verbally to non – English speaking caregivers with the aid of the anaesthetic nurse. Informed consent was requested and obtained from caregivers.

A thorough history was obtained, ensuring that the appropriate fasting guidelines were followed. This included the age and gender of the participant. A full physical examination was done in zone II of the MRI suite. This included the weight and otoscopic examination to ensure patency of the external auditory canal. Standard patient screening for any ferrous material was done. All participants were changed into a hospital gown and covered with a single cotton blanket.

Tympanic temperature was measured from the right ear using an infrared thermometer (BRAUN ThermoScan®, IRT 4520 ExacTemp) following the manufacturer's instructions which were as follows:

- a single-use lens filter was placed on the temperature probe tip for hygienic purposes;
- the temperature probe tip was placed in the ear canal, sealing its opening;
- the scan button was pressed for one second, released and a reading acquired.

Participants were transferred to the magnet room with an MRI compatible anaesthetic machine. An O_2 saturation monitor was attached to the patient. The researcher gave the anaesthetic following a standard anaesthetic protocol. Participants were induced with incremental concentrations of Sevoflurane in a 30:70 percent mixture of O_2 and N_2O. After loss of consciousness, the rest of the monitors were applied.

IV access was obtained and the airway secured with a laryngeal mask airway. Participants were continually monitored with ECG, pulse oximetry, non-invasive BP and capnography. GA was maintained with spontaneous inhalation of Sevoflurane in a mixture of O_2 and Air (60:40%). A standard fluid regimen was used for all patients. This comprised of Ringer's lactate with 1% Dextrose to a maximum of 10 ml per kg, which was ensured by using a Buretrol®. The fluid was stored in a trolley in Zone II of the MRI suite and used at room temperature.

After positioning, the ambient temperature and time were recorded, on commencement of each scan. The time and tympanic temperature were recorded on completion, at the door of magnet room where the temperature probe could be used safely. This was within two minutes of emergence.

The participants were then transferred to the PACU where the following participants were to receive thermoregulatory intervention as follows:

- participants with post scan temperatures $>$ 36.5 ℃ $<$ 37 ℃ - blanket only;
- shivering participants, regardless of post scan temperatures – blanket and Bair Hugger;
- participants with post scan temperatures $>$ 37.5 ℃ - clothing removal and tepid sponging;
- sweating participants, regardless of post scan temperatures – clothing removal and tepid sponging.

Hypothermic participants were thus actively rewarmed. None of the participants were found to be hyperthermic but plans were in place to actively cool them.

The following data was collected and entered onto a data capture sheet (Appendix VII):

- patient demographics – Hospital number, age, gender and weight
- ASA Classification
- ambient temperature
- pre scan tympanic temperature
- starting time
- finishing time
- post scan tympanic temperature
- thermoregulatory intervention.

3.6.5 Data Analysis

All data collected was captured using an Excel Spread sheet. Data was then interpreted using descriptive and inferential statistics. Categorical variables were summarised by frequency counts and percentage calculations. Continuous variables were summarised by sample size, mean, standard deviation, median and range. The difference between pre scan and post scan temperatures was tested for significance by the two-sided paired t test. The 95% confidence interval for temperature change was used where appropriate. Correlations were determined using the Pearson correlation coefficient. P values ≤ 0.05 were considered significant.

3.7 VALIDITY AND RELIABILITY

Pre scan and post scan temperature measurements were made by the same observer in all participants. The same infrared thermometer was used for all participants, following the same technique. The thermometer was pre calibrated by the manufacturer and thus no calibration was required. Temperature was measured from the right ear on all participants.

3.8 SUMMARY

In this chapter the following were addressed: research assumptions, ethical considerations, research methodology, as well as validity and reliability of the study. In the next chapter, the results and discussion will be presented.

CHAPTER FOUR

STATISTICAL ANALYSIS AND DISCUSSION OF RESULTS

4.1 INTRODUCTION

This chapter contains results and discussion of the data that was collected. These results are presented according to the objectives which were as follows:

The primary objectives of the study were to:

- describe the tympanic temperature pre MRI scan
- describe the tympanic temperature immediately post MRI scan
- describe the difference between pre scan and post scan temperatures
- describe if any thermoregulatory intervention was performed after the MRI scan.

The secondary objectives were to:

- correlate temperature change with the age
- correlate temperature change with weight
- correlate temperature change with the duration of the MRI scan.

4.2 RESULTS

The temperature in the MRI scan room was set at 18 ℃ for all participants. This is standard practice at CHBAH. Participants' temperatures were measured using an infrared thermometer (BRAUN ThermoScan®, IRT 4520 ExacTemp) and measurements were taken from the right ear in all participants. All participants were dressed in a hospital gown and covered with a single cotton blanket.

4.2.1 Sample realisation

Data was collected over a period of 9 months (August 2012 to May 2013). This includes a 3 month interruption period over which no MRI scans were performed under GA as the MRI anaesthesia machine was out of commission. Thus half the data was collected in 2012 and the other half in 2013. During this period a total of 30 participants were enrolled (n=30). One participant was excluded due to the development of malignant hyperthermia. Therefore this data analysis includes 29 participants (n=29).

4.2.2 Data analysis

All data collected was captured using an Excel Spread sheet. Data was then interpreted using descriptive and inferential statistics. Categorical variables were summarised by frequency counts and percentage calculations. Continuous variables were summarised by sample size, mean, standard deviation, median and range. The difference between pre scan and post scan temperatures was tested for significance by the two-sided paired t test. The 95% confidence interval for temperature change was used where appropriate. Correlations were determined using the Pearson correlation coefficient. P values ≤ 0.05 were considered significant.

4.2.3 Sample demographics

Nineteen (65.5%) of the 29 participants were male and 10 (34.5%) were female. The mean age of the participants was 31 months, median 24 months, and range 6 to 60 months. The mean weight of the participants was 13.2 kg, median 12 kg, and range 5 to 29 kg. Twelve (41.4%) participants were classified as ASA 1, 15 (51.7%) as ASA 2 and 2 (6.9%) as ASA 3 (illustrated in Table 4.1).

Table 4.1 ASA Classification of the participants

ASA	Number of participants (%)
1	12 (41.4)
2	15 (51.7)
3	2 (6.9)
Total	29 (100)

4.2.4 Primary objective: to describe the tympanic temperature pre MRI scans

The mean pre-scan temperature of the participants was 37.12 ℃ with a standard deviation of 0.266. The minimum temperature measured was 36.5 ℃ and the maximum was 37.5 ℃ (illustrated in Table 4.2).

4.2.5 Primary objective: to describe the tympanic temperature immediately post MRI scans

The mean post-scan temperature of the participants was 36.19 ℃ with a standard deviation of 0.633. The minimum post-scan temperature was 34.7 ℃ and the maximum was 37.4 ℃ (illustrated in Table 4.2).

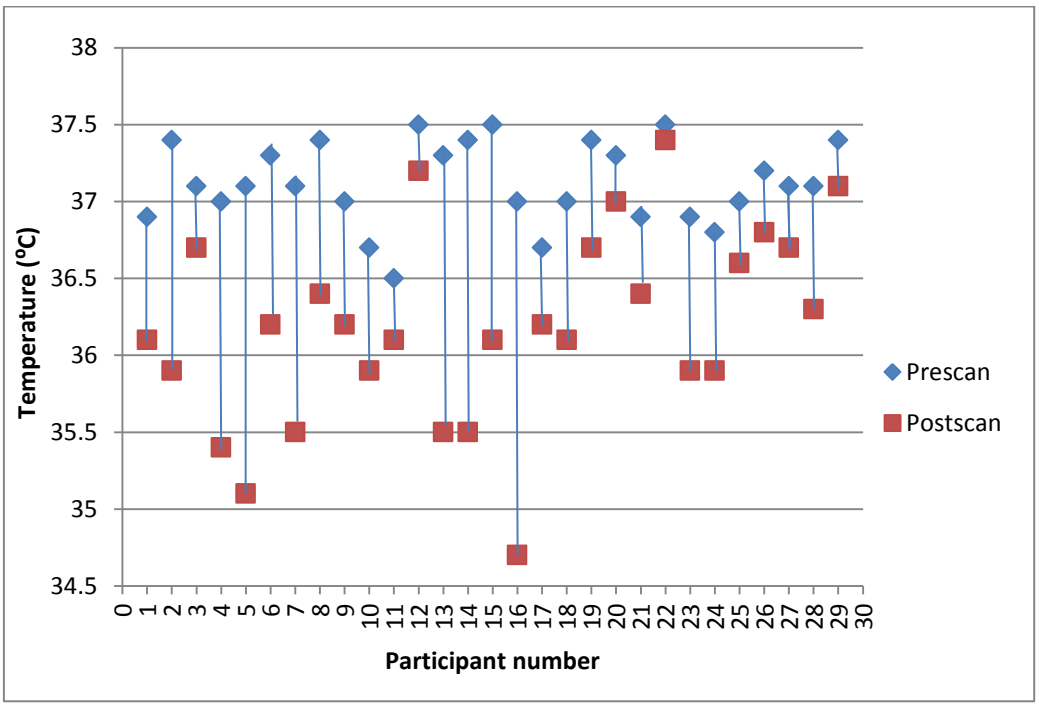
4.2.6 Primary objective: to describe the difference between pre scan and post scan temperatures

The mean change between pre scan and post scan temperatures of the participants was 0.93 ℃, with a standard deviation of 0.597. The minimum temperature change was 0.1 ℃ and the maximum temperature change was 2.3 ℃. Using the paired t-test, a statistically significant difference was found between the pre and post scan temperatures (p=0.001). The 95% confidence interval for the temperature change was 0.70 - 1.15℃. A summary of the pre and post scan temperatures with temperature change is illustrated Table 4.2 and temperature changes per participant in Figure 4.1.

Table 4.2 Summary of pre and post scan tympanic temperatures with temperature change.

Variable	Sample size	Mean	Standard deviation	Minimum/ Maximum
Tympanic temperature pre scan (℃)	29	37.12	0.266	36.5/37.5
Tympanic temperature post scan (℃)	29	36.19	0.633	34.7/37.4
Temperature change (℃)	29	0.93	0.597	0.1/2.3

Figure 4.1 Pre and post scan temperatures of each participant



4.2.7 Primary objective: to determine if any thermoregulatory intervention was performed

A blanket and Bair Hugger were placed on twenty one (72.5%) participants. An extra blanket only was placed on 5 (17.2%) participants while 3 (10.3%) participants required no warming intervention (illustrated in Table 4.3). No cooling was required for any of the participants.

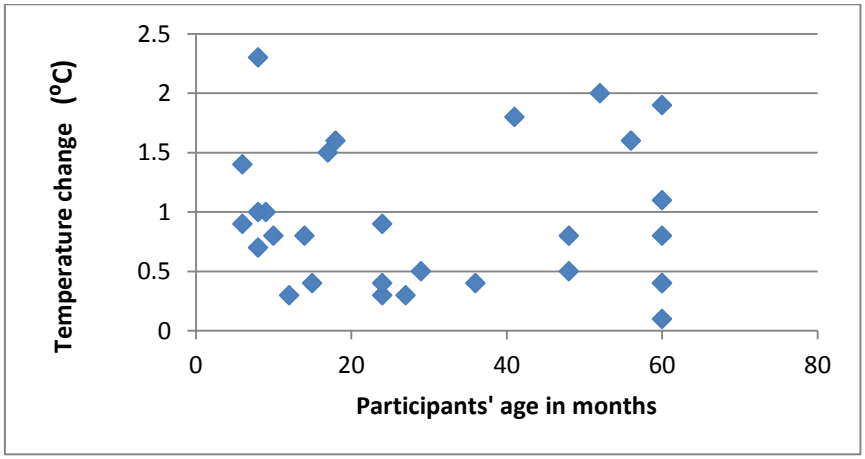
Table 4.3 Intervention administered to participants

Intervention	Number of participants (%)
Bair Hugger + blanket	21 (72.5)
Blanket only	5 (17.2)
None	3 (10.3)
Total	29 (100)

4.2.8 Secondary objective: to correlate temperature change with age

The correlation between temperature change and age was not statistically significant (r = -0.028, p = 0.885) as illustrated in Figure 4.2 and Table 4.4.

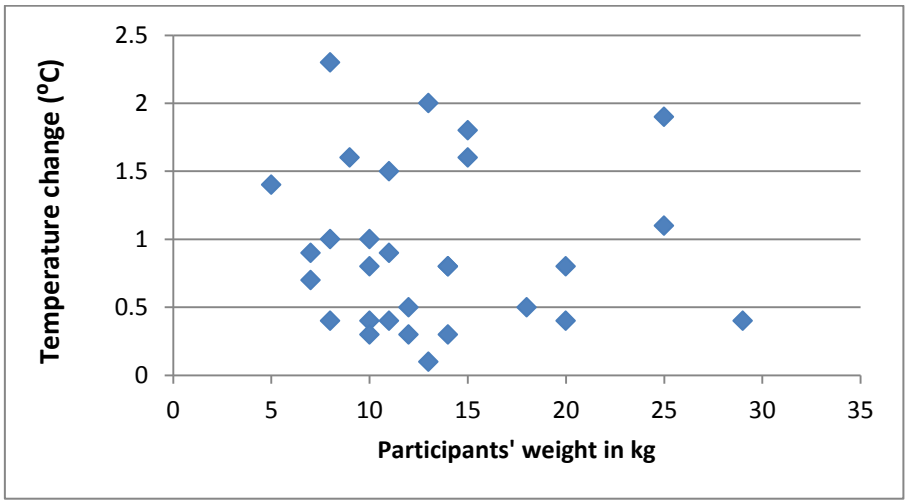
Figure 4.2 Temperature change correlated with age of each participant



4.2.9 Secondary objective: to correlate temperature change with weight

The correlation between temperature change and weight was not statistically significant (r= -0.042, p = 0.829) as illustrated in Figure 4.3 and Table 4.4.

Figure 4.3 Temperature change correlated with weight of each participant



4.2.10 Secondary objective: to correlate temperature change with the duration of the MRI scan

The mean scan duration was 51 minutes, the median 50 minutes and the range 30 minutes to 80 minutes. The correlation between temperature change and duration of the MRI scan was not statistically significant (r= -0.041, p = 0.833) as illustrated in Figure 4.4 and Table 4.4.

Figure 4.4 Temperature change correlated with duration of MRI scan

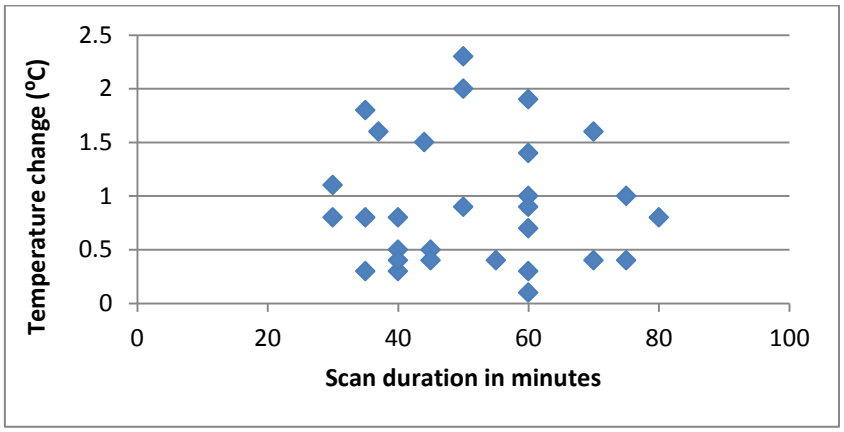


Table 4.4 Correlations of temperature change with age and weight of participants, and the duration of the MRI scan

	Change in temperature
	Pearson correlation coefficient
Age	-0.028 (0.885)
Weight	-0.042 (0.829)
Duration of MRI scan	-0.041 (0.833)

4.3 DISCUSSION

The importance of monitoring temperature during MRI scans has been emphasised both nationally (6) and internationally (2, 3, 5, 8, 13). The aim of this study was to determine if there is a change in core temperature during MRI scans in paediatric patients undergoing MRI examinations under GA at CHBAH. All the patients who participated in this study (n=29) experienced some loss of temperature (0.1 – 2.3℃). The mean temperature loss was 0.93 ℃ which was statistically significant ($p<0.001$). The greatest temperature loss (2.3 ℃) was described in an 8 month old participant who weighed 8 kg and was in the scanner for 51 minutes. This participant's pre scan temperature, weight, age and scan duration had absolute values which were lower than their respective group means.

Two similar studies conducted in the USA (8) Turkey (9) both employed inhalational GA in children aged 6 months to 8 years(8), and 0 to 7 years(9) . These studies showed a drop in temperature during MRI scans in most of their participants. Davidson et al showed that the mean pre scan temperature was 37.2 ℃ and the mean post scan temperature was 36.2 ℃ (8). Acar et al found the mean temperature loss to be 0.4 ℃ ($p<0.001$) (9).

Bryan et al (2) and Machata et al (3) reported increases in body core temperature in paediatric patients undergoing MRI scans under oral (2) and IV (3) sedation respectively. Patients with lower pre scan temperatures showed larger increases in body temperatures in both of these studies. This increase was attributed to RFR absorption. (3, 4) During MRI the majority of RFR power transmitted for imaging is transformed into heat within the patient's tissues as a result of resistive losses. This sometimes results in increases in body core temperatures. (5) None of the participants in our study experienced an increase in core temperature.

It appears that there is a tendency for temperatures to drop under GA compared to sedation. Both sedation and GA result in thermoregulatory impairment but the pattern of heat loss in sedated patients is different from patients under GA (2). The depth of sedation influences the degree of thermoregulatory impairment. Patients who are not anaesthetised completely show residual intrinsic thermoregulatory responses consistent with heating. (3) GA decreases heat production by inhibiting muscular activity and non-shivering thermogenesis (4).

Various factors that contributed to temperature loss in the participants in this study:

- patients were subjected to low ambient temperatures of 18 ℃;
- GA-induced vasodilatation resulting in redistribution of heat from the core to the peripheral compartment (4, 19);
- GA-induced thermoregulatory impairment (2);
- the limited and easily overwhelmed capabilities and functional range of the paediatric thermoregulatory system (4).

Although it was not an objective of this study to determine the incidence of post anaesthetic shivering, the researcher noticed that the majority of participants shivered on the way to PACU. MRI procedures are less invasive than surgery where there is a breach of the skin which normally forms a protective barrier against heat loss. This makes the effects of hypothermia after MRI less deleterious. However, the discomfort and heightened energy requirements imposed by hypothermia are enough to warrant precautionary measures. The level of consciousness drops progressively as the cerebral metabolic rate drops. Increased O_2 consumption and metabolic acidosis occur as a result of decreased tissue perfusion and shivering .(4)

Participants whose post scan temperatures were under 36.5 ℃ and those who shivered, regardless of their temperature, were covered with an extra blanket with or without a Bair Hugger. Twenty six (89.6%) of the participants thus received an intervention based on temperature loss and shivering. Twenty one (72.5%) of the participants were covered with a blanket and Bair Hugger while 5 (17.2%) required only an extra blanket before discharge from the PACU. Only three (10.3%) of the 29 participants with temperature loss required no intervention as their temperatures remained within the normal range (36.5 – 37.5℃) despite a drop in temperature and they were not shivering.

Patients at CHBAH are usually covered with their own blanket if they bring one. This may lead to some patients being inadequately warmed and some excessively warmed. It was not part of the aim of this study to determine what proportion of participants was inadequately or excessively

warmed. Participants were therefore covered with a single cotton blanket over a hospital gown for standardization.

Heat loss under GA occurs in three phases:

- redistribution which occurs during the first hour of GA, where core temperature decreases 1-2℃
- thermal imbalance during which there is a more gradual decline over 3 to 4 hours
- plateau, where heat loss equals compensatory heat production.

In infants and children, the third phase is a rewarming rather than a plateau. This is due to marked vasoconstriction which results in the shrinkage of the central compartment volume, resulting in a higher core temperature. (4)

No statistically significant correlations were found between loss of temperature and age, weight or duration of the scan as all correlations (Pearson) had p values > 0.05. However, the Pearson correlation coefficient was negative. This inverse correlation, although very weak, indicates that an increase in temperature loss is associated with a decrease in each of the variables of age, weight and duration of scan.

The weakest correlation was found between temperature loss and the duration of the scan. The longest duration of scan in this study was 80 minutes, which confines the data to the first two phases of heat loss under GA. This should have resulted in a positive correlation, but, since all correlations were negative, it explains why the weakest correlation was found between temperature loss and the duration of scan. Davidson et al (8) also found no statistically significant correlation between loss of temperature and age, gender, body surface area or scan duration (8).

4.4 SUMMARY

In this chapter the results and discussion of the results were presented. In the following and final chapter the summary, limitations and recommendations will be addressed.

CHAPTER FIVE

SUMMARY, LIMITATIONS, RECOMMENDATIONS AND CONCLUSION

5.1 INTRODUCTION

This chapter will include a summary and main findings of the study. The limitations of the study will be addressed, and recommendations for clinical practice and further research made. A conclusion will also be presented.

5.2 SUMMARY OF THE STUDY

5.2.1 The aim of the study

The aim of this study was to determine if there was a change in core temperature during MRI scans in paediatric patients undergoing MRI examinations under GA at CHBAH.

5.2.2 Objectives of the study

The primary objectives of the study were to:

- describe the tympanic temperature pre MRI scan
- describe the tympanic temperature immediately post MRI scan
- describe the difference between pre scan and post scan temperatures
- describe if any thermoregulatory intervention was performed after MRI scan.

The secondary objectives were to:

- correlate temperature change with the age
- correlate temperature change with weight
- correlate temperature change with the duration of the MRI scan.

5.2.3 Summary of the methodology used in the study

This study followed a prospective, contextual, descriptive research design and described the change in temperature during MRI scans in paediatric patients undergoing MRI examinations under GA. The study population was paediatric patients presenting for MRI examinations under GA at CHBAH. A convenience, consecutive sampling method was used in this study and participants for the study were identified from a list of patients who were pre-booked for MRI under GA.

Included in the study were paediatric patients between the ages of 6 months and 5 years presenting for diagnostic MRI under GA, whose ears were not obstructed by wax or any other space occupying lesions. Excluded from the study were patients for whom consent could not be obtained and those whose pre scan temperatures were above 37.5 ℃.

Potential participants were identified and caregivers approached using an information letter (Appendix V), which was verbally translated where necessary. Informed consent was requested and obtained. A thorough history was obtained, ensuring that the appropriate fasting guidelines were followed. A physical examination was done in zone II of the MRI suite. Standard patient screening for any ferrous material was done.

All participants were changed into a hospital gown and a single cotton blanket was used to cover each. Tympanic temperature was measured from the right ear using an infrared thermometer. Participants were transferred to the magnet room with an MRI compatible anaesthetic machine. The researcher gave the anaesthetic following a standard anaesthetic protocol.

The ambient temperature and time were recorded on commencement of each scan. On completion the time and tympanic temperature were recorded, within two minutes of emergence. Participants were then transferred to the PACU. Hypothermic and shivering participants were actively warmed by covering them with an extra blanket, with or without a Bair Hugger. None of the participants were found to be hyperthermic but plans were in place to actively cool them by removal of clothing and tepid sponging.

5.2.4 Main findings of the study

All the patients who participated in this study (n=29) experienced some loss of temperature (0.1 – 2.3℃). The mean temperature loss was 0.93 ℃ and was statistically significant ($p<0.001$). The greatest temperature loss (2.3 ℃) was described in an 8 month old participant who weighed 8 kg and was in the scanner for 51 minutes.

Twenty six (89.6%) of the participants received an intervention based on temperature loss and shivering. Twenty one (72.5%) of the participants were covered with a blanket and Bair Hugger while 5 (17.2%) required only an extra blanket before discharge from the PACU. Only three (10.3%) of the 29 participants with temperature loss required no intervention as their temperatures remained within the normal range (36.5 – 37.5℃) despite a drop in temperature and they were not shivering.

No statistically significant correlations were found between loss of temperature and age, weight or duration of the MRI scan as all correlations had p values > 0.05. A very weak inverse correlation

was found, indicating that an increase in temperature loss is associated with a decrease in each of the variables age, weight and duration of scan. The weakest correlation was found between temperature loss and the duration of the scan.

5.3 LIMITATIONS OF THE STUDY

The study is contextual as participants received their MRI examinations at one hospital. These results may not be generalised to other institutions as conditions may be different. There may be no or better provision of blankets, or patients may be routinely done under sedation and not GA. However, these results do have a potential to improve clinical practice at CHBAH.

The information letter was not compiled in any African language. This posed as a problem with non-English speaking caregivers understanding the aims of the study. This was overcome by verbal translation to the caregiver's home language. The translator was a proudly South African, multilingual anaesthetic nurse.

5.4 RECOMMENDATIONS FROM THE STUDY

5.4.1 Recommendations for clinical practice

Monitoring core temperature in the MRI environment is a challenge due to electromagnetic interference. However, even in light of this challenge, undetected and thus untreated hypothermia has deleterious effects.

Pre-warming with a Bair Hugger for 30 minutes before GA will offset phase I heat loss during the first hour of GA (18). Radiation heaters in Zone II of the MRI suite where examination and change of clothing takes place will prevent heat loss and optimise the thermal status of patients before they enter Zone III. Patients should remain covered with their own blankets as a source of both comfort and warmth. Hospital cotton blankets can then be layered on top of the patients' own blankets, covering the body and more importantly, the head. The experienced technicians in the MRI suite at CHBAH reassured that these neither pose as artefacts nor alter the quality of the images.

Pre-preparing the MRI suite before the patients are taken into the magnet room minimises the time that patients spend in the cold environment and reduces heat loss. At CHBAH patients are recovered in a general PACU. This is distant from the MRI suite and patients are exposed to cold as they are wheeled to the PACU. Using Zone II of the MRI suite as both a receiving and PACU will minimise this distance and limit exposure to cold. This may prevent temperature loss and thus the need for thermoregulatory intervention.

5.4.2 Recommendations for further research

Should the above recommendations be implemented at CHBAH, it is recommended that their impact be followed up. A follow up study can be conducted, using the results in this study as the control, to evaluate the effect of the heat loss preventing measures. This will help appreciate the difference made by precautionary measures and thus change practice.

5.5 CONCLUSION

Heat loss in the harsh MRI environment is an underestimated problem. In addition, the ferromagnetic environment precludes continuous temperature monitoring. This study has shown that temperature does drop in paediatric patients undergoing MRI examinations under general anaesthesia. This change in temperature did not correlate with age, weight, and duration of the MRI scan.

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APPENDIX I: ETHICS APPROVAL

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Dr Phelisa Miti

CLEARANCE CERTIFICATE	**M120101**
PROJECT	Measurement of Temperature Change in Paediatric Patients undergoing Magnetic Resonance Imaging (MRI) Examinations under General Anaesthesia
INVESTIGATORS	Dr Phelisa Miti.
DEPARTMENT	Department of Anaesthesiology
DATE CONSIDERED	27/01/2012
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 27/01/2012 **CHAIRPERSON** .....
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor : Mrs Juan Scribante

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...

APPENDIX II: POSTGRADUATE COMMITEE APPROVAL

Faculty of Health Sciences
Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172040

Reference: Ms Thokozile Nhlapo
E-mail: thokozile.nhlapo@wits.ac.za

18 January 2014
Person No: 675596
PAG

Dr P Miti
760 Cilantro Estate
Honeydew Manor
2170
South Africa

Dear Dr Miti

Master of Medicine: Approval of Title

We have pleasure in advising that your proposal entitled *Measurement of temperature change in paediatric patients undergoing Magnetic Resonance Imaging (MRI) examinations under general anaesthesia* 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.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

APPENDIX III: MEDICAL ADVISORY COMMITTEE APPROVAL

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

MEDICAL ADVISORY COMMITTEE

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

PERMISSION TO CONDUCT RESEARCH

Date: 17th January 2014

TITLE OF PROJECT:

Measurement of Temperature Change in Paediatric Patients Undergoing MRI Examinations Under General Anaesthesia

UNIVERSITY: Witwatersrand

Principal Investigator: Dr P Miti

Department: Radiology

Supervisor : Ms Juan Scribante \ Dr Lee

Permission Head Department (where research conducted): **Yes**

The Medical Advisory Committee recommends that the said research be conducted at Chris Hani Baragwanath Academic Hospital. The CEO / management of Chris Hani Baragwanath Academic Hospital is accordingly informed and the study is subject to:-

- Permission having been granted by the Committee for Research on Human Subjects of the University of the Witwatersrand.
- The Hospital will not incur extra costs as a result of the research being conducted on its patients within the hospital
- The MAC will be informed of any serious adverse events as soon as they occur
- Permission is granted for the duration of the Ethics Committee Approval.

.....
Recommended
(On behalf of the MAC)
Date: 17/01/2014.

.....
Approved/Not Approved
Hospital Management
Date: 21/01/14

APPENDIX IV: RADIOLOGY APPROVAL

I ..... A RAUF .....

Designation/Rank ..... Acting HoD .....

Hereby grant

Dr Phelisa Miti

Student number : 675596

permission to conduct her MMed research of

MEASUREMENT OF TEMPERATURE CHANGE IN PAEDIATRIC PATIENTS UNDERGOING MRI EXAMINATIONS UNDER GENERAL ANAESTHESIA.

Permission granted: YES / NO

Signature .....

DEPARTMENT OF DIAGNOSTIC IMAGING
AND INTERVENTIONAL RADIOLOGY

CHRIS HANI BARAGWANATH HOSPITAL
SOWETO

P O BERTSHAM
2013
SOUTH AFRICA

TEL: (011) 933-8411
933-8289
933-8850

APPENDIX V: EXPLANATION OF THE STUDY TO CAREGIVER

Dear Caregiver

I am Phelisa Miti. I am one of the doctors that will put your child to sleep for the MRI examination. In order for the MRI machine to take good pictures, a child must stay still for 10 minutes to an hour. It is necessary therefore for him/her to be put to sleep during the examination. This sleep is called general anaesthesia. We induce this sleep with a mask and gasses then we connect the child to a machine that will deliver Air/Oxygen and the gas that will keep them asleep for the duration of the examination.

Some children can get cold during the examination because the MRI room is quite cold and GA can also make them cold. Some children can get hot because the rays the machine uses to take pictures are absorbed into the body. We cannot measure the child's temperature in the MRI machine because of a magnet the machine uses. This magnet interferes with the thermometers we use to measure temperature and the thermometers can in turn reduce the quality of the pictures. We do not know therefore whether children get hot or cold during MRI examinations.

I hereby request your permission for your child to participate in a study where I will measure his/her temperature before and after the MRI examination. Temperature will be measured from one ear before GA, after GA and after the MRI examination. It will take only a few seconds and it will be painless. If your child is cold, we will warm him/her and if your child is hot, we will cool him/her.

If you understand my explanation and grant me permission, I will need for you to sign a consent form. If your child is six years of age or older, I will explain the study to them as well and request them to sign an assent form.

Please understand that you are under no obligation to agree for your child to take part in this study. You can also pull your child out of the study at any moment without having to give reasons and this will not disadvantage your child in any way.

Thank you

Phelisa Miti
Anaesthetic doctor – CHBAH
011 933 1843

APPENDIX VI: CONSENT FORM

Research title: Measurement of temperature change in paediatric patients undergoing MRI under general anaesthesia

I …… grant permission for my child to take part in the above study. I understand that my child's temperature will be measured from one ear before GA, after GA and after the MRI examination. I understand the reasons for the study and my questions have been answered. I understand that I can withdraw from the study without notice and my child will not be disadvantaged.

……
Parent/Caregiver name

……
Parent/Caregiver signature

……
Date

……
Researcher name

……

Researcher signature……
Date

APPENDIX VII: DATA COLLECTION SHEET

MEASUREMENT OF TEMPERATURE CHANGE IN PAEDIATRIC PATIENTS UNDERGOING MRI UNDER GENERAL ANAESTHESIA

Participant number	
Hospital number	
Age	
Gender	
Weight	
ASA Classification	
Ambient Temperature	
Pre scan temperature	
Scan time - Start	
Scan time – Finish	
Post scan temperature	
Thermoregulatory intervention	