

**AN AUDIT OF THE ANAESTHETIC GAS SCAVENGING  
SYSTEMS IN SELECTED HOSPITALS AFFILIATED TO THE  
UNIVERSITY OF THE WITWATERSRAND**

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degree

of

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## **Declaration**

I, Morongoa Hazel Mogodi, declares that this research report is my own work. It is being submitted for the degree of Master of Medicine in the branch of Anaesthesiology in the University of the Witwatersrand, Johannesburg. It has never been submitted before for any degree or examination at this or any other University.

.....

Morongoa Hazel Mogodi

Signed on the 13<sup>th</sup> of January 2016 at Johannesburg

## **Dedication**

To my family and friends who are always supporting me every step of the way.

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## **Abstract**

The American Society of Anaesthesiologists recommends that in any location in which inhalational anaesthetic agents are administered, an adequate and reliable system for scavenging waste anaesthetic gases should be in place. The aim of this study was to describe the functioning, use and maintenance of the anaesthetic gas scavenging systems at Charlotte Maxeke Johannesburg Academic Hospital, Chris Hani Baragwanath Academic Hospital, Helen Joseph Hospital and Rahima Moosa Mother and Child Hospital.

The research design was prospective, contextual and descriptive. An audit of the anaesthetic gas scavenging systems and the maintenance records at Charlotte Maxeke Johannesburg Academic Hospital, Chris Hani Baragwanath Academic Hospital, Helen Joseph Hospital and Rahima Moosa Mother and Child Hospital was done. A total of 59 operating theatres and 12 venues of remote anaesthesia were included in this study, i.e. a total of 71 areas.

The number of fully functional anaesthetic gas scavenging systems was 32 (45,07%) in the operating theatres and none in the venues of remote anaesthesia. The receiving hoses were available in 42 (71,19%) operating theatres. The receiving hose was connected to the terminal unit in 39 (66,10%) operating theatres, of which 7 (11,86%) were assisted by sleek tape. Sleek tape was used in 8 (11,27%) operating theatres to “patch” the receiving hose.

Medical gas pipeline system personnel were available in each hospital but they were not solely dedicated to the anaesthetic gas scavenging system. No manufacturer’s recommendations could be found in any of the study hospitals. Records of maintenance were not available and quarterly maintenance is not undertaken by any of the study hospitals.

The small number of the fully functional anaesthetic gas scavenging systems and the maintenance thereof did not conform to the South African National Standards 7396-2 which was concerning.

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## List of Abbreviations

AGSS	: Anaesthetic Gas Scavenging System
CMJAH	: Charlotte Maxeke Johannesburg Academic Hospital
CHBAH	: Chris Hani Baragwanath Academic Hospital
HJH	: Helen Joseph Hospital
MGPS	: Medical Gas Pipeline System
NIOSH	: National Institute of Occupational Safety and Health
OSHA	: Occupational Safety and Health Administration
RMMCH	: Rahima Moosa Mother and Child Hospital

# Chapter 1

## Overview of the study

### 1.1 Introduction

In this chapter, a brief overview of the study will be presented. Included is the background of the study, problem statement, aim, objectives, research assumptions, demarcation of the study field, ethical considerations, research methodology, significance of the study, validity and reliability, and an outline of the research report.

### 1.2 Background of the study

“Waste anaesthetic gases are small amounts of volatile anaesthetic gases that leak from the patient’s anaesthetic breathing circuit into the air of the operating rooms during delivery of anaesthesia” (1). The exposure to these gases has been linked to the possible development of unwanted health effects in health care providers (2, 3).

Anaesthesia has markedly evolved. The days of “open drop” anaesthesia are in the past. Even though previous methods seem simple, a price was paid as theatre pollution led to drastic consequences. (4)

The use of volatile agents in the operating theatre may contaminate the environment. Prolonged exposure to these agents has been associated with a number of adverse health effects in theatre personnel. (5) Exposure to high concentrations of waste anaesthetic gases even for a short time may cause headache, irritability, fatigue, nausea, drowsiness, difficulties with judgment and coordination, hepatic and renal disease. Long term exposure to low concentrations of waste anaesthetic gases may cause miscarriages, genetic damage and cancer. (1, 6) The negative health effects are dependent on the level of contamination. In principle, some contamination by waste anaesthetic gases is unavoidable, but the amount of contamination is dependent on factors such as the air-conditioning, availability of the Anaesthetic Gas Scavenging System (AGSS), type of airway used and method of conducting anaesthesia. (7)

The National Institute for Occupational Safety and Health (NIOSH) recommends that an AGSS should be used in all environments that provide anaesthesia. The institution is responsible to organise and document a maintenance program of the AGSSs. (8)

The AGSS is comprised of the disposal system, receiving system and transfer system (9). The gas disposal system may be active or passive (3). The use of an optimally functional AGSS should reduce the amount of waste anaesthetic gases in the operating theatre to the levels that are appropriate for NIOSH recommendation (8).

Several methods of sampling are available to sample minute amount of waste anaesthetic gases in the operating theatre atmosphere. The types of sampling methods described are grab sampling, time-weighted average sampling and continuous sampling. (8)

Continuous sampling is the most convenient method to monitor operating theatre ambient air. A portable infrared analyser samples and analyses the trace levels of volatile agents continuously. The device provides a continuous readout of the results. Time-weighted average concentration value can be displayed if used for a prolonged period. (8) Unfortunately this technology is costly.

Although the AGSS is known to be effective in preventing air pollution in the operating theatre, it is vital to ascertain whether the system is adequately functioning. Assessing the integrity of the system encompasses inspection as well as negative and positive pressure relief valve checks. (5)

A study was performed in an academic hospital in Thailand, where a number of AGSSs were investigated. The authors found that 26% of the systems were assembled incorrectly irrespective of successful negative pressure leak test. Positive pressure leak test was failed by 45% of the machines due to malfunction of the adjustable pressure limiting valve. (5)

No South African literature could be identified, that assessed the functioning and efficiency of the AGSSs in the operating theatre.

### **1.3 Problem statement**

“The exposure to trace concentrations of waste anaesthetic gases in the operating theatre and the possible development of adverse health effects has concerned health care professionals for many years” (2, 3).

There are AGSSs in place at the hospitals affiliated to the Department of Anaesthesiology at the University of the Witwatersrand. However several problems have been observed including:

- drainage of foul smelling material from the terminal unit
- receiving hose connected to disposal system with sleek tape
- disconnection of the receiving hose from the disposal system
- disconnection of the receiving system from the receiving hose.

It is not known if these AGSSs are functioning, used optimally and maintained appropriately in the operating theatres and venues of remote anaesthesia in:

- Charlotte Maxeke Johannesburg Academic Hospital (CMJAH)
- Chris Hani Baragwanath Academic Hospital (CHBAH)
- Helen Joseph Hospital (HJH)
- Rahima Moosa Mother and Child Hospital (RMMCH).

### **1.4 Aim**

The aim of this study was to describe the functioning, use and maintenance of the AGSSs at CMJAH, CHBAH, HJH and RMMCH.

### **1.5 Objectives**

The objectives of this study were to:

- document the presence of the gas disposal system interface and the terminal unit
- describe if the terminal unit generates negative pressure

- describe the connection of the receiving hose to the terminal unit
- describe the presence and condition of the receiving hose
- describe the connection of the receiving hose to the receiving system
- document the presence of a flow indicator and describe the reading on the flow indicator
- document the number of fully functional AGSSs
- audit the maintenance records of the AGSS at each hospital.

## 1.6 Research assumptions

The following definitions were used in this study.

**Waste anaesthetic gases:** small amounts of volatile anaesthetic gases that leak from the patient's anaesthetic breathing circuit into the air of the operating theatre during delivery of anaesthesia (1).

**Venue of remote anaesthesia:** these are areas where anaesthesia is administered for procedures outside the operating theatre for example, computerized tomogram unit, magnetic resonant imaging unit and angiography suite.

**Authorized medical gas pipeline system (MGPS) person:** this is the person responsible for the maintenance of the AGSS in a hospital.

**Maintenance records:** this included the identification of the presence of an authorized MGPS person, the recommendations from the manufacturers of AGSSs and documentation of the maintenance done.

**Functional operating theatre:** an operating theatre with an anaesthetic work station.

**Sleek tape:** a waterproof adhesive strapping tape. The term "sleeked" refers to the use of sleek tape to repair defects.

**Fully functional AGSS:** in this study will be if all the components of the AGSS are present, not "sleeked" and connected irrespective of the pressure generated.

## **1.7 Demarcation of the study field**

The research was conducted at two central hospitals, CMJAH and CHBAH and two regional hospitals, HJH and RMMCH.

## **1.8 Ethical considerations**

Approval to conduct this study was obtained from the relevant authorities. As no data were collected from humans or animals in this study an ethics waiver was received from the Human Research Ethics Committee (Medical) of the University of Witwatersrand (Appendix B).

This study was conducted by adhering to the Declaration of Helsinki (10) and the South African Good Clinical Practice Guidelines (11).

## **1.9 Research methodology**

### **1.9.1 Study design**

The research design was prospective, contextual and descriptive.

### **1.9.2 Study population**

The study population was the AGSSs and the maintenance records at CMJAH, CHBAH, HJH and RMMCH.

### **1.9.3 Study sample**

The sample size will be determined by the number of functional operating theatres and venues of remote anaesthesia in the study hospitals and the maintenance records of these hospitals. Purposive sampling was used and eligibility criteria were adhered to.

### **1.9.4 Data collection procedures**

The selected hospitals were visited on different days convenient to the researcher. Most of the data was collected by visual inspection of the AGSSs, while the

operating theatre or venue of remote anaesthesia was functional. An indirect measurement of the negative pressure generated in the terminal unit was done. An audit of the maintenance records was done.

### **1.10 Significance of the study**

As previously mentioned, “exposure to trace concentrations of waste anaesthetic gases in the operating theatre and the possible development of adverse health effects has concerned health care professionals for many years” (2, 3).

Assessment of the functioning, use and maintenance of AGSSs is an indirect measure to determine the exposure of the operating theatre personnel to waste anaesthetic gases. The results of this study may contribute to a safer working environment at the study hospitals.

### **1.11 Study Outline**

The following chapters are presented in this study.

Chapter 1 : Overview of the study

Chapter 2 : Literature review

Chapter 3 : Research design and methodology

Chapter 4 : Results and discussion

Chapter 5 : Limitations and recommendations

### **1.11 Summary**

This chapter provided a brief overview of this study. In the following chapter the literature regarding the AGSSs is reviewed.

## **Chapter 2**

### **Literature Review**

#### **2.1 Introduction**

In this chapter, various concepts regarding the AGSS are reviewed. A brief historical background on the development of the anaesthetic gas scavenging techniques is provided. This is followed by a full description of the components and functioning of the AGSS. The South African National Standards regarding the AGSS are summarised. Recommendations from the NIOSH are covered. Details with regard to monitoring of efficiency and maintenance of the AGSS are elaborated upon. The potential hazards, previous studies on the AGSS and environmental implications of waste anaesthetic gases are discussed.

#### **2.2 Historical background**

##### **2.2.1 Early concerns**

Anaesthesia has markedly evolved. The days of “open drop” method anaesthesia are in the past. Even though the previous methods seem simple, a price was paid by theatre pollution which led to drastic consequences such as headache, fatigue and irritability. (4)

The first awareness of excess waste anaesthetic gases and its associated side effects was documented in 1889 by Prof. G van Overbeek de Meyer, a microbiologist. (12)

And a few weeks later, a detailed description of the side-effects, was elucidated by an ophthalmologist, Prof. von Eversbusch at the University of Erlangen. The symptoms noted were headache, eye discharge, rhinorrhoea and coughing which occurred after prolonged exposure to the polluted air in the operating theatre. The best method of prevention was proposed to be intensive ventilation of the operating theatre. A second preventative method was the production of high humidity, allowing absorption of the polluting molecules. (12)

In the decades that followed the problem of theatre pollution seemed to recede due to the tremendous progress of local anaesthetic techniques. However, two surgeons from Berlin, Unger and Bettman were concerned about the possible hazards of theatre pollution and revived the concept. (12)

### **2.2.2 Attempts to decrease pollution**

Various problems caused by the waste anaesthetic gases were reported in a surgical journal by a Dresden surgeon, Kelling, in 1918. He designed a specially shaped anaesthetic mask for effective removal of the waste anaesthetic gases. (12)

In 1925, Perthes described a specially designed exhaust fan with an inlet close to the patient's head. It completely renewed the air in the theatre within five minutes. In the same year, Kirschner suggested the use of fans to dissipate the anaesthetic gases away from the surgeon within the operating theatre. (12)

Another invention to eliminate waste anaesthetic gases was done by Wieloch, an obstetrician in the 1920s. A specially shaped box was designed in which the patient's head was positioned during anaesthesia. The purpose of this box was to collect the anaesthetic vapours which are denser than air. An exhaust system was attached to this box and waste anaesthetic gases were eliminated outside the theatre complex. (12)

The piping system was described in the late 1920s. Zaaijer invented a waste gas system that led to a hall in the theatre suite. Killian suggested the use of water powered extraction systems, with a minimum performance of 40 l/min. (12)

In 1946, a German surgeon known as Wertmann revived the concept of theatre pollution. A definitive technical solution was called for at the time when war-damaged hospitals were reconstructed. His proposal was not carried through. (12)

In the 1980s, the design and functional characteristics of four anaesthetic scavenging devices were described in South Africa. The devices were Carstens system, Stellenbosch Valve, Ventex System and the Gardner Box. The former three were designed in South Africa and the latter was designed in England. (13)

The Carstens system was designed by Carstens at Baragwanath Hospital. A negative pressure chamber that contained an open bag and a two-way valve. The waste anaesthetic gases from the patient, enters into the open bag and the negative

pressure generated by the vacuum system extracts the waste anaesthetic gases to the outside. An excessive negative pressure will cause the bag to collapse. Inadequate vacuum will result in an increase in the positive pressure and therefore a positive blow-off through the two-way valve. (13)

The Stellenbosch Valve was designed by Foster of the University of Stellenbosch. It was made up of a compartment that housed two valves which were held against their seats by a common spring, and which opened to admit air into the compartment. There was a differential opening pressure of 0,5 cmH<sub>2</sub>O between the two valves. A reservoir bag and a controlled suction port opened into the compartment. Application of a suction pressure resulted in the opening of the lower pressure valve and entrained atmospheric air until a pressure of 0,5 cmH<sub>2</sub>O developed across the other valve which was connected to the expiratory valve of the breathing circuit. The admitted waste anaesthetic gases passed into the reservoir bag and were removed by the scavenge line. Movement of the reservoir bag indicated that the system was functional. (13)

The Ventex System was designed by Cornish of Allan Cornish (Pty) Ltd, Johannesburg. The waste anaesthetic gases flowed into a reservoir bag and were extracted into the main suction via a variable spindle valve. An increase in the pressure caused the bag to distend and the positive disc valve to open. An excessive suction pressure caused the bag to collapse and air was entrained via the negative disc valve. (13)

The Gardner Box was designed by Gardner of Gardner Co. from Oxford. It consisted of a compartment containing a bag that opened into the atmosphere. Waste anaesthetic gases from the hooded valve passed into the compartment and was extracted by the main suction. If the suction was not adequate, the bag collapsed and the positive pressure valve opened and gas would spill. With excessive suction pressure, the bag will expand and air will be entrained through the inlet valve. (13)

In the 1990s, Corn designed an Anaesthetic Scavenging Hood. This was a gas-impermeable flexible fabric bag which enclosed the patient's head. The bottom portion of the Anaesthetic Scavenging Hood was fastened around the patient's neck without compromising the safety of the patient. An exhaust port was incorporated

into the other end of the Anaesthetic Scavenging Hood and was connected to the suction hose. An opening for the endotracheal tube or laryngeal mask airway was present on the hood. The idea behind this development was to minimize the level of waste anaesthetic gases in the paediatric operating theatre, with the use of uncuffed endotracheal tubes. (14)

### **2.2.3 Absorption technique**

During the mid-1940s, the advantages of absorption of gases by charcoal filters was documented by the surgeon, Holscher. These filters were incorporated within the expiratory valves or fitted to the top of a specially designed mask. (12)

Canisters filled with activated charcoal has been used for anaesthetic waste gas disposal by directing gases from the gas disposal tubing through them. They effectively absorb halogenated volatile agents and not the nitrous oxide. The rate of gas flow determines the efficiency of these canisters. The disadvantages of using this method is the cost and must be changed on regular basis. (15)

### **2.2.4 Possible future methods**

Under developments are new methods of capturing waste anaesthetic gases for reuse rather than releasing them into the environment. A recycling system called the Dynamic Gas Scavenging System collects and reuses 99% of waste anaesthetic gases without altering the chemical structure. The system is designed to work with any anaesthesia machine. (16)

Another method of capturing the waste anaesthetic gases into a canister system before release into the environment is described. This system is called Deltasorb and it incorporates zeolite filters. The Deltasorb selectively captures the volatile agents through a filtration process, which are then liquefied and used as raw material to produce a bulk of volatile agent. (16, 17)

## **2.3 Definition of the waste anaesthetic gases**

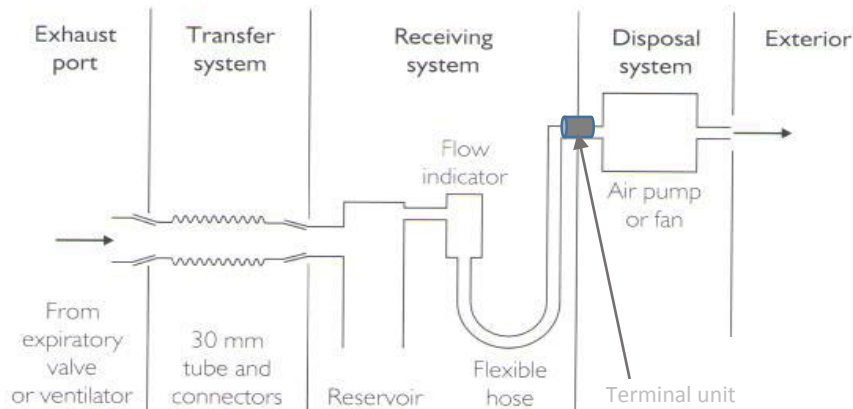
“Waste anaesthetic gases are small amounts of volatile anaesthetic gases that leak from the patient’s anaesthetic breathing circuit into the air of the operating rooms during delivery of anaesthesia” (1).

## 2.4 Description of the AGSS

AGSS dispose of gases that have been vented from the breathing circuit by the adjustable pressure limiting valve and ventilator spill valve (18). They are used to reduce occupational exposure to waste anaesthetic gases (9). The presence of leaks in the breathing circuit or AGSS will lead to the pollution of the operating theatre atmosphere by the waste anaesthetic gases. An excessive amount of waste anaesthetic gases delivered to the AGSS might decrease the efficiency of the system. It is of paramount importance to include the AGSS in the pre-use checkout procedure of the anaesthetic machine, to ascertain that it functions optimally. (8)

The AGSS is comprised of the disposal system, receiving system and transfer system (see Figure 2.1) (9). The waste anaesthetic gases are vented from the anaesthesia machine through the adjustable pressure limiting valve or the ventilator's relief valve. The transfer system collects waste anaesthetic gases from the adjustable pressure limiting valve and ventilator's relief valve to the receiving system. The transfer system refers to a wide-bore, 30 mm diameter tubing with its male and female conical connectors. The 30 mm diameter is distinctly different from the airway accessories making misconnections improbable. (19) The tubing should be sufficiently rigid and as short as possible to minimize inadvertent occlusion by kinking. The receiving system consists of a reservoir, air break, flow indicator and a filter. (20) The receiving hose connects the reservoir to the disposal system, which is connected to the vacuum system. This tubing should be collapse-proof and should run overhead to minimize the chance of occlusion. (21, 22)

The gas disposal system may be active or passive. The advantage of the active system is that they are more efficient in removing waste anaesthetic gases as compared to the passive systems, due to the incorporated vacuum system. The disadvantage of active systems is that they require calibration and are costly to operate. Passive systems rely on positive pressure gradient to function optimally for removal of waste anaesthetic gases. (3)



**Figure 2.1:** Components of the AGSS adapted from Basic Physics and Measurement in Anaesthesia (21).

An interface with a negative-pressure relief valve is mandatory because the pressure within the system is negative (22). The recommended pressures are described in the general requirements of the system compiled by the South African National Standard (see Table 2.1), and they depend on the type of terminal unit installed.

## 2.5 South African National Standards 7396-2 for the AGSS

The South African National Standards are drafted in accordance with the rules given in the International Standard Organization (ISO). The objectives of these standards regarding the AGSS are as follows:

- “avoidance of cross connections between different pipeline systems;
- continuity of function of the system;
- use of suitable materials;
- cleanliness of components;
- correct installation;
- provision of indicating system(s);
- correct marking of the pipeline system and components;
- testing, commissioning and certification;
- correct operational management” (9).

The South African National Standards 7396-2 for the AGSS will be briefly discussed.

### **2.5.1 General requirements**

The general requirements of the AGSS from the South African National Standards 7396-2 are summarized in Table 2.1

### **2.5.2 Information to be supplied by the manufacturer as recommended by the South African National Standards 7396-2**

The manufacturer of the complete system or the manufacturers of each component of the AGSS, shall provide the healthcare facility with instructions for use (9).

The instructions for use shall contain the following:

- “name and address of the manufacturer;
- year of manufacture, lifetime of the system and its components, any special storage and handling conditions;
- special operating instructions;
- any warnings and/or precautions to be taken, in particular the danger of fire or explosion due to the use of oil or grease in oxygen enriched atmospheres or the use of flammable anaesthetic agents;
- batch or serial number;
- technical specification including the performance of the system and how to connect or disconnect detachable parts and accessories;
- description of the indicating system;
- position in normal condition of all shut-off valves, if fitted;
- instructions for recommended periodic checks of function of the system;
- instructions for recommended maintenance tasks and their frequency, and a list of recommended spare parts if applicable;
- adequate information regarding which anaesthetic gases and vapours the system is compatible with;
- instruction for the disposal of components or consumables” (9).

**Table 2.1: General requirements of the AGSS as summarized from the South African National Standards 7396-2 (9).**

<b>Requirement</b>	<b>Elaboration</b>
Safety	Installations, extensions, modifications, commissioning, operation and maintenance in accordance with instructions of the manufacturer.
Alternative construction	The use of materials different from the International Standard Organization (ISO) must have equivalent degree of safety and evidence thereof shall be provided by the manufacturer.
Materials	Materials must be corrosion resistant and compatible with anaesthetic gases and vapours. Durability of non-metallic pipes must be evaluated after exposure to volatile anaesthetic agents.
Continuity of operation	Two sources of air supply must be available to drive exhaust ejectors.
Testing, commissioning and certification	Tests carried out after installation must be documented and certified by the manufacturer. All devices used must be appropriate and calibrated.
Inspection and leakage	Visual inspection to assess integrity of all connections.
Marking	The pipeline shall be marked "AGSS" or national equivalent and arrows to denote the direction of flow.
Mechanical function and cleanliness	Appropriate probe can be inserted, captured and released. Inspection for absence of visible particulate matter.
Cross connection	No cross connection to any pipeline system.
Functioning of power devices	Power devices must function in accordance with the manufacturer's specifications.
Pressure and flow terminals	Type 1L terminal unit: -1 kPa at 50 l/min or -2 kPa at 25 l/min. Type 1H terminal unit: -1 kPa at 80 l/min or -2 kPa at 50 l/min.
Indicating system	Means shall be provided to indicate to the user that the anaesthetic gas scavenging system is operating.
Anaesthetic gas scavenging disposal system	Exhaust from the disposal system shall be connected to a conduit of a non-circulating ventilation system. Entry of insects, debris and precipitation must be prevented.
Identification	Correct labelling and identification of each terminal unit.
Durability	Test for durability of markings and colour coding, shall be carried out at ambient temperature and using a rag soaked in distilled water followed by isopropanol.
Certification	Undertaken before the system is put to use. Certified in writing. Results of the tests done should be part of the permanent record of the health care facility.
Extensions and modifications	Appropriate tests and inspections as described above shall be carried out after modification of the system.

### **2.5.3 Operational management information**

The manufacturer of each component of the AGSS, shall provide operational management information to the healthcare facility. This will enable the health facility to draft an operational management document. Instructions for recommended maintenance tasks and their frequency and a list of spare parts shall be provided. (9)

### **2.5.4 “As-installed” drawings**

A separate set of “as-installed” mechanical drawings which show the actual locations of the pipelines, the diameters, shut-off valves and all other components shall be maintained during construction. It shall be brought up to date if changes are made. These drawings shall include details which will enable concealed pipelines to be located. A complete set of “as-installed” drawings shall be presented to the healthcare facility, for inclusion as part of the permanent record keeping of the pipeline system. (9)

### **2.5.5 Electrical diagrams**

Electrical diagrams of the components supplied shall be provided by the system manufacturer to the health care facility (9).

## **2.6 Maintenance of the AGSS**

### **2.6.1 Occupational Safety and Health Administration**

The OSHA is one of the agencies concerned with potential dangers associated with exposure to waste anaesthetic gases (8).

The responsibilities of the OSHA are as follows:

- “adopt and mandate job safety and health standards;
- establish rights and responsibilities for employers and employees for the implementation of safe occupational conditions;
- require record keeping on all employees to assess job-related injuries;
- evaluate work-related safety practices by entering and inspecting any workplace to determine compliance with mandatory standards;

- cite violations of standards in the workplace and apply punitive measures if necessary” (8).

### **2.6.2 Measurement of trace levels of waste anaesthetic gases in the operating theatre**

“Sampling procedures for evaluating waste anaesthetic gas concentrations in air should be conducted for nitrous oxide and halogenated compounds on a quarterly basis in each anaesthetising location. Monitoring should include leak testing of equipment, sampling air in the worker’s personal breathing zone and room air monitoring using gas-bag sampling on real-time sampling. Ventilation and air conditioning systems used, should be inspected and tested at regular intervals to ensure that complete room air exchange occur at a rate of 15 times per hour or more. The central vacuum system should be inspected and tested on a quarterly basis.” (8)

Several methods are available for sampling minute levels of waste anaesthetic gases in the operating theatre atmosphere. The types of sampling described are grab sampling, time-weighted average sampling and continuous sampling. (8)

Grab sampling is useful to monitor steady state levels of trace waste anaesthetic gases caused by a leak from high pressure systems. The sample of air is collected when the operating theatre is not in use, into a container that is then sealed and sent to the laboratory for analysis. The disadvantages of grab sampling are that the levels of trace anaesthetic gases measured do not represent the levels when the operating theatre is in use and the results are delayed. (8)

Time-weighted average sampling is another method used to evaluate the exposure of operating theatre personnel to waste anaesthetic gases. It is defined as the average atmosphere concentration reached over an eight hour period. A sample of the operating theatre air is continuously collected by a pump into a bag over eight hours and then analysed. The results indicate an average exposure over time. Monitoring of nitrous oxide can be done by passive dosimeters. These devices are worn in the breathing zone by the operating theatre personnel, with a minimum sampling duration of 15 minutes and can function for 168 hours. At the onset of the exposure period, the dosimeters are uncapped and recapped at the end of the

exposure period. The wearer keeps the record of the exposure period. When sampling is complete, the dosimeter is labelled with the employee's name and the total time of exposure. It is then sent to the laboratory for analysis. (8, 15)

Continuous sampling is the most convenient method to monitor operating theatre ambient air. A portable infrared analyser continuously samples and analyses the trace levels of volatile agents. The device provides a continuous readout of the results and therefore the effectiveness of the control measures can be determined. Time-weighted average concentration values can be displayed if used for a prolonged period. (8, 15)

The recommendations of trace elements of waste anaesthetic gases as adapted from the NIOSH are shown in Table 2.2.

**Table 2.2: Recommendations of trace levels of waste anaesthetic gases adapted from NIOSH (22).**

<b>Anaesthetic gas</b>	<b>Maximum time-weighted average concentration (ppm)</b>
<b>Either agent alone</b>	
Halogenated agent	2
Nitrous oxide	25
<b>Combined halogenated agent and nitrous agent</b>	
Halogenated agent	0.5
Nitrous oxide	25

### **2.6.3 Waste anaesthetic gas management**

The anaesthetic equipment should undergo quarterly services to maintain minimum leakage, these should be done by a qualified technician. Training should be provided to the operating theatre personnel to ensure that they recognize the occupational practices that decrease unnecessary exposure to trace elements of waste anaesthetic gases. (8) The OSHA has found that appropriate work practices can aid in reducing the exposure of theatre personnel to waste anaesthetic gases.

Inappropriate anaesthetic techniques can contribute to increased levels of waste anaesthetic gas levels. (23) These techniques include improper size of face masks, insufficiently inflated tracheal tube cuffs, uncuffed tracheal tubes, improper

positioning of laryngeal mask airways, flushing of the circuit, paediatric circuits, careless filling of the vaporizers and turning on the vaporizers when not in use (8, 23, 24).

#### **2.6.4 Medical surveillance**

A complete history with regards to medical and prior occupation shall be obtained from each member of the personnel prior to employment and this information will be retained in the employee's medical record. Physical examinations of the employees are carried out prior to employment and every year thereafter. The employees must be informed and trained with regards to the potential and unwanted effects resulting from the exposure of waste anaesthetic gases. It is vital that this information is provided at the time of initial employment. Any undesirable pregnancy outcome affecting the employees or their spouses shall be documented in the employee's medical record. The medical records shall be retained for the entire time of employment and an additional 20 years thereafter. (8)

#### **2.6.5 Failure of the AGSS**

Failure of the AGSS results in spillage of the waste anaesthetic gases into the operating theatre. This will result in exposure levels exceeding the NIOSH recommendations. A local alarm "system fail" warning and failure of the receiving system flow indicator will indicate failure of the system. These should be inspected on a regular basis. (25)

The authorised person of the medical gas pipeline system (MGPS) and the theatre manager will be informed of the failure and attempts should be made to reduce staff exposure if operations continue with a failed system. When repairs have been completed, the theatre staff should be notified that the system is in good working order. (25)

### **2.7 Occupational exposure to waste anaesthetic gases**

Significant improvements to control waste anaesthetic gas pollution in the operating theatres has been made over the years. However, exposure of the operating theatre personnel still takes place. (26) The relationship between exposure to the waste

anaesthetic gases in the operating theatre and the possibility to develop adverse health effects has concerned operating theatre personnel for several years, even though the results from studies have been conflicting (2).

Boivin (27) in a meta-analysis concluded that the epidemiological data generally indicate an increased risk of spontaneous abortion in females of child bearing age exposed to waste anaesthetic gases. In 1967, Vaisman (8) from the Soviet Union published results of a survey of male and female anaesthesiologists. During the time, the commonly used agents were diethylether, halothane and nitrous oxide. A high incidence of general symptoms like headache, fatigue, irritability were reported. It was also noted that 58% of pregnancies ended in spontaneous abortion. However, Byhahn (28) drew attention to the fact that Vaisman did not report the concentration and the duration of exposure to the waste anaesthetic gases.

In 1974, Cohen (29) published a large epidemiological study, focusing on the occupational related health risks in exposed operating theatre personnel. The study group of 49 585 operating theatre personnel was compared to a control group of 23 911 people without prior exposure to occupational waste anaesthetic gases. A conclusion was reached that exposed female personnel had a higher rate of spontaneous abortion than non-exposed women (17-20% vs 9-15%). Again, there were no data with regards to the concentration of waste anaesthetic gases and duration of exposure. The author concluded at the time that epidemiological studies that had valid methodology with regards to health risk caused by the waste anaesthetic gases do not exist.

In the early 2000s, Chandrasekhar (26) evaluated genotoxic effects on operating theatre personnel occupationally exposed to anaesthetic gases in India. Ninety subjects divided into two groups were included in this study. The first group (the study group) was made up of 45 operating theatre personnel and the control group (45 subjects) was selected from the general population with no prior occupational exposure to anaesthetic agents. Venous blood samples were collected from the study and control groups using heparinized syringes. These samples were conveyed to the lab on ice, and were processed within two hours. The damage to the genetic material was assessed by the comet assay, micronucleus test and chromosomal aberration assay. The results of this study revealed a significant increase in the level

of genotoxicity in the subjects that were occupationally exposed to anaesthetic agents, even though the mechanism of DNA damage is still unclear.

A study published in 2012 by Kaymac (30) from Turkey investigated the genotoxic effects of 4 halogenated anaesthetic agents (desflurane, halothane, isoflurane and sevoflurane) on human peripheral blood lymphocytes and sperm cells in-vitro by alkaline comet assay. Human peripheral blood lymphocytes and sperm cells obtained from healthy individuals, were exposed to different concentrations of the halogenated anaesthetic agents (0.1 mM, 10 mM and 100 mM) and 1% dimethyl sulfoxide or phosphate buffered saline as controls. The genotoxic effect referred to the DNA strand breaks and alkali-labile sites which were measured as percentage tail intensity with the comet assay. The results of this study revealed that all the halogenated anaesthetic agents were capable of causing DNA damage in human peripheral blood lymphocytes in a dose dependent manner in-vitro. The results in sperm cells revealed the absence of genotoxic effects with desflurane in any of the exposure concentrations, and the genotoxic effects of halothane was not related to dosage. The above concentrations of the halogenated anaesthetic agents were not equated to the exposure of waste anaesthetic gases in terms of parts per million.

An animal study was carried out by Vieira (31) in South Africa in the 1980s. This study investigated the effects of low intermittent concentrations of nitrous oxide on the developing rat foetus. Five groups of 12 gravid rats were exposed to oil free compressed air (control group), 5000 ppm, 1000 ppm, 500 ppm and 250 ppm of nitrous oxide-air mixtures respectively. The exposure was during their entire gestation, six hours per day and five days a week. The gravid rats were killed on day 19 of their pregnancies and the number of corpora lutea of pregnancy were counted, each uterus was examined for placentation sites and embryonic remnants and detailed examination of the foetuses was done. A significant reduction in the mean litter size occurred in the group exposed to 5000 ppm of nitrous oxide-air mixture. The mean litter size of the control group and the other study groups were comparable. Foetal resorption or skeletal malformations were not found in any group. This study confirmed the increase in the threshold of reproductive effects in rats exposed to nitrous oxide-air mixture intermittently and it is dose dependent.

## 2.8 Potential hazards of AGSS

The AGSS adds complexity to the anaesthetic equipment. It extends the anaesthetic circuit to the disposal interface. Therefore any change in pressure due to unopposed vacuum or blockade can potentially harm the patient. (32)

Gray (33) reported a case of scavenging malfunction in 2003. A patient that was under general anaesthetic was connected to an anaesthetic machine that has been checked. The reservoir bag suddenly collapsed and it was not moving. A leak or disconnection was excluded on the breathing system. Maneuvers to refill the reservoir bag by the oxygen flush failed. The AGSS was suspected to be the cause, as all the fresh gas flow was vented away from the patient. The scavenging pipe was disconnected from the terminal unit and the reservoir bag refilled automatically. The patient was not harmed by this event. The case was completed with the AGSS completely disconnected and waste anaesthetic gases were vented out of the window using an "elephant tubing". Scrutinizing the AGSS revealed an absence of a grille attachment which functions to filter out dust and debris. This resulted in accumulation of dust and particulate matter in the AGSS which led to an increase in negative pressure reaching a critical point and venting the entire fresh gas flow away from the patient through the AGSS. The author recommends the necessity of the anaesthetists to familiarize themselves with the components and function of AGSS in order to identify potential hazards.

Another critical incident occurred in the United Kingdom in 1999. A patient was induced on her bed and had to be transferred to the operating table after induction of anaesthesia. During this time the anaesthetic machine was also moved to accommodate the other operating theatre equipment. When artificial ventilation was started, peak inflation pressure was noted to be 41 cmH<sub>2</sub>O returning to baseline of 17 cmH<sub>2</sub>O, despite the absence of positive end-expiratory pressure. Similar challenges were observed with manual ventilation, even though the adjustable pressure limiting valve was left open. The breathing system was intact on inspection. Disconnection of the scavenging hose from the receiving system relieved the pressure and with close observation, it was found that the wheel of the anaesthetic machine was occluding the scavenging transfer tubing. The AGSS was not defective but the assembly thereof. The author recommended that obstructions of this nature

can be avoided by the use of tubing that is resistant to kinking and caution should be taken when the position of the anaesthetic machine is changed. (34)

## **2.9 Previous studies on AGSSs**

Despite the success of the AGSS, it is crucial to ascertain that it functions appropriately. Assessing the integrity of the system encompasses inspection as well as negative and positive pressure relief valve checks. (5)

Development of pneumothorax has resulted due to improperly functioning AGSS and this prompted the authors to conduct a study addressing the AGSS. A full text article on this study was not accessible. A study was performed in an academic hospital in Thailand, where 38 active scavenging systems were investigated. Their results revealed that 26% of the systems were incorrectly assembled even though the negative pressure leak test was successful. About 47% of these machines failed a positive pressure leak relief valve check, which was due to a malfunction of an adjustable pressure limiting valve. The author suggested that a routine pre-use check and regular maintenance of equipment should be emphasized and the anaesthetic personnel should be encouraged to learn about safety precautions. (5)

A blinded analysis of anaesthesia machine scavenger system calibration was conducted in an Academic Medical Center in Texas. The aim of the study was to assess the frequency of appropriate scavenger system setup. In this study, every anaesthetic machine in the operating theatre was checked on a weekday morning after the setup has been completed. Similar follow up checks were done a week later. During the initial assessment 15,6% of the machines were improperly calibrated. At the follow up assessment it was found that 25% of the AGSSs were improperly calibrated, of which 75% were low flow AGSSs. The authors concluded that this could result in the increasing risk of operating theatre pollution. (3)

## **2.10 Environmental implications of waste anaesthetic gases**

The inhaled volatile agents are exhaled and scavenged by the anaesthesia machine with no additional degradation, and typically vented into the outside environment.

Nitrous oxide is a greenhouse gas and can play a role in global warming. All volatile anaesthetic agents are halogenated chlorofluorocarbons (halothane, enflurane and isoflurane) or fluorinated hydrocarbons (sevoflurane and desflurane). They have a potential to damage the ozone layer and theoretically they can contribute to global warming. (16, 17, 35)

## **2.11 Summary**

An in-depth discussion on various subjects has been presented in the literature review regarding the AGSS. In the first section, a brief historical background on the development of the AGSS is provided. This was followed by a full description of the components and functioning of the AGSS. The South African National Standards for AGSS were summarized. Recommendations of the NIOSH were mentioned. Details on monitoring of efficiency and maintenance of the AGSS were elaborated. The potential hazards of the AGSS, previous studies on AGSS and environmental implications of waste anaesthetic gases were discussed. In the next chapter the research design and methodology is discussed.

## Chapter 3

### Research design and methodology

#### 3.1 Introduction

In this chapter problem statement, aim, objectives, ethics, research methodology, validity and reliability will be presented.

#### 3.2 Problem statement

The exposure to minute concentrations of waste anaesthetic gases in the operating theatre and the possibility to develop adverse health effects has concerned the operating room personnel for many years (2, 3).

There are AGSSs in place at the hospitals affiliated to the Department of Anaesthesiology at the University of the Witwatersrand. However several problems have been observed including:

- drainage of foul smelling material from the terminal unit
- receiving hose connected to disposal system with sleek tape
- disconnection of the receiving hose from the disposal system
- disconnection of the receiving system from the receiving hose.

It is not known if these AGSSs are functioning, used optimally and maintained appropriately in the operating theatres and venues of remote anaesthesia in:

- CMJAH
- CHBAH
- HJH
- RMMCH.

### **3.3 Aim**

The aim of this study was to describe the functioning, use and maintenance of the AGSSs at CMJAH, CHBAH, HJH and RMMCH.

### **3.4 Objectives**

The objectives of this study were to:

- document the presence of the gas disposal system interface and the terminal unit
- describe if the terminal unit generates negative pressure
- describe the connection of the receiving hose to the terminal unit
- describe the presence and condition of the receiving hose
- describe the connection of the receiving hose to the receiving system
- document the presence of a flow indicator and describe the reading on the flow indicator
- document the number of fully functional AGSSs
- audit the maintenance records of the AGSS at each hospital.

### **3.5 Ethical considerations**

Approval to conduct this study was obtained from the Postgraduate Committee of the University of the Witwatersrand (Appendix A). As no human beings were involved in this study an ethics waiver was granted from the Human Research Ethics Committee (Medical) of the University of Witwatersrand (Appendix B). Approval from the Medical Advisory Committee of CHBAH and Chief Executive Officers of CMJAH, HJH and RMMCH was obtained (Appendix C to F respectively). The matrons in charge of theatre complexes were informed of this study.

This study did not involve any drug and therapeutic management and was conducted by adhering to the Declaration of Helsinki (10) and the South African Good Clinical

Practice Guidelines (11). The data from the study will be stored for six years after the completion of the study.

The results of this study will be communicated to the Head of the Department of Anaesthesiology, University of the Witwatersrand as this could impact on the safety of the work environment.

## **3.6 Research methodology**

### **3.6.1 Study design**

The research design was prospective, contextual and descriptive.

In a prospective study, the researcher collects data and the outcome is measured (36). This study was prospective as data was collected at the time of study taking place.

A contextual study takes place in a specific location (37). Specific hospitals affiliated to the University of the Witwatersrand were included in this study.

A descriptive study describes a phenomenon. The researcher searches for accurate information about the characteristics of a sample, but does not manipulate the variables. (36) In this study the functioning, use and maintenance of AGSSs were described.

### **3.6.2 Study population**

The study population was the AGSSs and the maintenance records at CMJAH, CHBAH, HJH and RMMCH.

### **3.6.3 Study sample**

#### **Sample size**

The sample size was determined by the number of functional operating theatres and venues of remote anaesthesia in the study hospitals and the maintenance records of these hospitals.

## **Sampling method**

Purposive sampling was used in this study. Purposive sampling is nonprobability sampling in which a researcher selects the sample based on personal judgment about which ones are most informative. (38)

## **Inclusion and exclusion criteria**

All functional operating theatres and the remote venues of anaesthesia in the study hospitals were included.

## **Data collection procedures**

Most of the data was collected by visual inspection of the AGSSs, while the operating theatre or venue of remote anaesthesia was functional. An indirect measurement of the negative pressure generated in the terminal unit was done. An audit of the maintenance records was done.

## **Pressure monitoring device**

The ideal device as recommended by the South African National Standards 7396-2 is a two way pressure gauge, which measures pressure and flow simultaneously (9). This device was not available at the study hospitals. The person authorised for MGPS at CMJAH uses a business card to indirectly assess the negative pressure in the terminal unit. The business card is applied to the terminal unit, and should remain in situ if the negative pressure is adequate. The manufacturer of the AGSS was consulted and mentioned that they do not have the two way pressure gauge. They assess the terminal unit pressure by application of a business card, it is common practice to use this method in the operating theatre. An adequate negative pressure is indicated if the business card remains in situ. Therefore in this study a business card was used.

The development of the data collection sheet was guided by the South African National Standards 7396-2 (9) and validated by two experienced anaesthesiologists. (Appendix G)The following data was collected:

- presence of disposal system interface

- type of terminal unit
- description of the connection of receiving hose to the terminal unit
- subjective negative pressure measured
- condition of the receiving hose
- connection of the receiving hose to the receiving system
- describe the reading on the flow indicator.

An audit of record keeping (Appendix H) was undertaken at each hospital. The following information was collected:

- determine if the hospital had an authorised MGPS person
- is the manufacturer recommendations on file
- records of maintenance available
- is quarterly maintenance done.

All data will be collected by the researcher and entered into Microsoft Excel 2013 spreadsheets.

### **3.7 Data analysis**

Analysis of data will be done using Microsoft Excel 2013 spreadsheets. Descriptive statistics will be done. Categorical variables will be described using frequencies and percentages.

### **3.8 Validity and reliability**

Measures were taken to ensure the validity and reliability of the study.

Validity indicates whether the conclusions drawn from a study are justified based on the design and interpretation. Reliability represent the consistency of the measure achieved. (39)

Validity and reliability of this study will be ensured by:

- using an appropriate study design

- having a representative sample
- a single researcher collecting all the data
- data was collected on days convenient for the researcher and this also ensured that routine practice is not changed
- the development of the data collection sheet was guided by the South African National Standards 7396-2 (9) and validated by two experienced anaesthesiologists
- pressure in the terminal unit was measured with the same business card.

### **3.9 Summary**

A detailed explanation of the research methodology has been presented under the headings of study design, study population and study sample (including sample size, sampling method, inclusion and exclusion criteria), description of data collection procedures and the planned statistical analysis of data. In the following chapter the results and discussion of this study are presented.

## **Chapter 4**

### **Results and discussion**

#### **4.1 Introduction**

In this chapter the results of the study according to objectives are presented followed by a discussion of the results.

The objectives of the study were to:

- document the presence of the gas disposal system interface and the terminal unit
- describe if the terminal unit generates negative pressure
- describe the connection of the receiving hose to the terminal unit
- describe the presence and condition of the receiving hose
- describe the connection of the receiving hose to the receiving system
- document the presence of a flow indicator and describe the reading on the flow indicator
- document the number of fully functional AGSSs
- audit the maintenance records of the AGSS at each hospital.

#### **4.2 Sample realisation**

The sample size was determined by the number of functional operating theatres and venues of remote anaesthesia in the study hospitals and the maintenance records of these hospitals.

Due to renovations that were taking place at HJH, there were only three operating theatres that were functional at the time of data collection. A total of 59 operating theatres and 12 venues of remote anaesthesia were included in this study, i.e. a total of 71 areas. A breakdown of the AGSSs per hospital is shown in Table 4.1.

**Table 4.1: AGSSs per hospital**

<b>Hospital</b>	<b>Number of functional operating theatres</b>	<b>Number of venues of remote anaesthesia</b>	<b>Total</b>
<b>CMJAH</b>	24	5	29
<b>CHBAH</b>	28	6	34
<b>HJH</b>	3	1	4
<b>RHMMC</b>	4	0	4
<b>Total</b>	59	12	71

### **4.3 Results**

Data was collected over four days. Each hospital's data was collected in one day. Numbers and percentages are used to describe the findings. Percentages are rounded off to 2 decimal places.

#### **4.3.1 Objective: to document the presence of the gas disposal system interface and the terminal unit**

The gas disposal system interface and the terminal unit were present in 59 (100%) operating theatres, however 2 of the gas disposal interfaces were covered by sleek tape. The type of terminal unit was not marked in any of the operating theatres. A gas disposal system interface and a terminal unit were not available in any of the venues of remote anaesthesia and these areas are therefore excluded from further analysis.

#### **4.3.2 Objective: to describe if the terminal unit generates negative pressure**

A business card was placed over the terminal unit to assess if it generated negative pressure. The business card remained in situ if negative pressure was generated. The ability to generate negative pressure was observed in 13 (22,81%) terminal units and inadequate pressure to hold the business card in place was generated in 44 (77,19%). However 2 of the gas disposal interfaces were covered by sleek tape and therefore negative pressure generation was not assessed. The number and percentage of terminal units that generated negative pressure per hospital is shown in Table 4.2.

**Table 4.2: Terminal units that generated negative pressure per hospital**

<b>Hospital (n)</b>	<b>Number generating pressure</b>	<b>Percentage</b>
<b>CMJAH (23)</b>	1	4,35
<b>CHBAH (27)</b>	10	37,04
<b>HJH (3)</b>	0	0
<b>RMMCH (4)</b>	2	50,00
<b>Total (57)</b>	13	22,81

**4.3.3 Objective: to describe the connection of the receiving hose to the terminal unit**

The receiving hose was connected to the terminal unit in 39 (66,10%) operating theatres, of which 7 (11,86%) were assisted by sleek tape. The receiving hose was not connected to the terminal unit in 20 (33,90%) operating theatres. The number and percentage of receiving hoses that were connected to the terminal units in the operating theatres per hospital is shown in Table 4.3.

**Table 4.3: Connection of the receiving hoses to the terminal units per hospital**

<b>Hospital (n)</b>	<b>Number</b>	<b>Percentage</b>
<b>CMJAH (24)</b>	16	66,67
<b>CHBAH (28)</b>	17	60,71
<b>HJH (3)</b>	2	66,67
<b>RMMCH (4)</b>	4	100
<b>Total (59)</b>	39	66,10

**4.3.5 Objective: to describe the presence and condition of the receiving hose**

The receiving hoses were available in 42 (71,19%) operating theatres. The number and percentage of receiving hoses that were present in the operating theatres per hospital is shown in Table 4.4.

**Table 4.4: Receiving hoses per hospital**

<b>Hospital (n)</b>	<b>Number</b>	<b>Percentage</b>
<b>CMJAH (24)</b>	16	66,67
<b>CHBAH (28)</b>	19	67,86
<b>HJH (3)</b>	3	100
<b>RMMCH (4)</b>	4	100
<b>Total (59)</b>	42	71,19

The receiving hose was intact in 34 (80,95%) operating theatres. The number and percentage of receiving hoses that were intact in the operating theatres per hospital is shown in Table 4.5.

**Table 4.5: Intact receiving hoses per hospital**

<b>Hospital (n)</b>	<b>Number</b>	<b>Percentage</b>
<b>CMJAH (16)</b>	13	81,25
<b>CHBAH (19)</b>	17	89,47
<b>HJH (3)</b>	0	0
<b>RMMCH (4)</b>	4	100
<b>Total (42)</b>	34	80,95

Sleek tape was used in 8 (19,05%) operating theatres to “patch” the receiving hose. The number and percentage of the receiving hose “patched” with sleek tape per hospital is shown in Table 4.6.

**Table 4.6: Receiving hoses “patched” with sleek tape per hospital**

<b>Hospital (n)</b>	<b>Number</b>	<b>Percentage</b>
<b>CMJAH (16)</b>	3	18,75
<b>CHBAH (19)</b>	2	10,53
<b>HJH (3)</b>	3	100
<b>RMMCH (4)</b>	0	0
<b>Total (42)</b>	8	19,05

#### **4.3.6 Objective: to describe the connection of the receiving hose to the receiving system**

The receiving hose was connected to the receiving system in 44 (74,58%) operating theatres, and not connected in 15 (25,42%) operating theatres. The number and percentage of receiving hoses connected to the receiving system per hospital is shown in Table 4.7.

**Table 4.7: Connection of the receiving hose to the receiving system in the operating theatres**

<b>Hospital (n)</b>	<b>Number</b>	<b>Percentage</b>
<b>CMJAH (24)</b>	16	66,67
<b>CHBAH (28)</b>	21	75,00
<b>HJH (3)</b>	3	100
<b>RMMCH (4)</b>	4	100
<b>Total (59)</b>	44	74,58

#### **4.3.7 Objective: to document the presence of a flow indicator and describe the reading on the flow indicator**

The flow indicator was available in 21 (35,59%) operating theatres and all of them had a low reading including the ones that generated negative pressure. A flow indicator was not available in 38 (64,40%) operating theatres. The number and percentage of flow indicators present in the operating theatres per hospital is shown in Table 4.8.

**Table 4.8: Flow indicators per hospital**

<b>Hospital (n)</b>	<b>Number</b>	<b>Percentage</b>
<b>CMJAH (24)</b>	7	29,17
<b>CHBAH (28)</b>	13	46,43
<b>HJH (3)</b>	0	0
<b>RMMCH (4)</b>	1	25
<b>Total (59)</b>	21	35,59

#### **4.3.8 Objective: to document the number of fully functional AGSSs**

The 12 venues of remote anaesthesia were included in the analysis. The number fully functional AGSSs was 32 (45,07%) in the operating theatres and venues of remote anaesthesia. Only 14 AGSSs had the flow indicators incorporated in the anaesthetic workstation. The number and percentage of the fully functional AGSSs in the operating theatres and venues of remote anaesthesia per hospital is shown in Table 4.9.

**Table 4.9: The number fully functional AGSSs in the operating theatres and venues of remote anaesthesia**

<b>Hospital (n)</b>	<b>Number</b>	<b>Percentage</b>
<b>CMJAH (29)</b>	13	44,83
<b>CHBAH (34)</b>	15	44,12
<b>HJH (4)</b>	0	0
<b>RMMCH (4)</b>	4	100
<b>Total (71)</b>	32	45,07

#### **4.3.9 Objective: audit of the maintenance records of the AGSS at each hospital**

MGPS personnel were available in each hospital but they were not solely dedicated to the AGSS. The manufacture's recommendations and maintenance records were not available. According to the MGPS personnel, quarterly maintenance was not undertaken at any of the hospitals included in the study.

### **4.4 Discussion**

The literature on the AGSSs was limited and therefore the discussion of results was mainly compared with the South African National Standards 7396-2, referred to as "the regulation" and other relevant guidelines where appropriate.

The American Society of Anaesthesiologists recommends that in any location in which inhalational anaesthetic agents are administered, an adequate and reliable system for scavenging waste anaesthetic gases should be in place (40). The gas disposal interface and the terminal unit were present in 59 (100%) operating

theatres, however 2 of the gas disposal interfaces were covered by sleek tape and therefore were not functional. Interestingly the gas disposal interface and the terminal unit were not available in any of the venues of remote anaesthesia. The terminal unit is essentially the core of the AGSS and the rest of the system is futile if the terminal unit is not available or dysfunctional.

The different types of terminal units cater for different flow rates and the pressure generated by the AGSS. The regulation differentiate between two different terminal units namely, Type 1L terminal unit: -1 kPa at 50 l/min or -2 kPa at 25 l/min and Type 1H terminal unit: -1 kPa at 80 l/min or -2 kPa at 50 l/min, these pressures are regarded as appropriate for the use of AGSS. The regulation further states that the terminal unit must be correctly labeled and identified. (9) The type of terminal unit was not marked in any of the operating theatres.

The ability to generate negative pressure was assessed by the use of a business card. Although this method is not scientific, it is commonly used in practice. A business card was placed over the terminal unit and if it remained in situ then negative pressure was generated. The ability to generate negative pressure was observed in 13 (22,81%) terminal units and no negative pressure was generated in 44 (77,19%). The negative pressure generated by the terminal unit is not known and therefore optimal functioning of the AGSS could not be ascertained.

The receiving hoses were available in 42 (71,19%) operating theatres. The receiving hose was connected to the terminal unit in 39 (66,10%) operating theatres, of which 7 (11,86%) were assisted by sleek tape. The receiving hose was not connected to the terminal unit in 20 (33,90%) operating theatres, resulting in deposition of the waste anaesthetic gases directly into the theatre atmosphere. The receiving hose was connected to the receiving system in 44 (74,58%) areas. The above components must be available and connected in order for the AGSS to be functional.

Visual inspection to assess the integrity of the connections should be undertaken according to the regulation. Regarding alternative construction, the use of materials different from the regulation must have an equivalent degree of safety and evidence thereof shall be provided by the manufacturer. (9) The receiving hose was intact in 34 (80,95%) operating theatres. Sleek tape was used in 8 (19,05%) operating

theatres to “patch” the receiving hose. Slick tape was not designed to repair the defects that occur on the AGSS.

The regulation states that an indicating system must be in place to show that the AGSS is functional. The flow indicator was available in 21 (35,59%) operating theatres and all of them had a low reading including the ones that generated negative pressure. It is therefore difficult to ascertain if the pressure that was generated in the terminal unit was optimal for the functioning of the AGSS.

There were 32 (45,07%) fully functional AGSSs in the operating theatres and the venues of remote anaesthesia. Previously studies have been conducted on the AGSSs, however they were not directly comparable to our study since their focus was on different variables. However, their results were not good. A study conducted in Thailand found that 26% of the AGSS was assembled incorrectly and 47% failed a positive pressure leak relief valve check, due to a malfunction of the adjustable pressure limiting valve (5). A blinded analysis in Texas showed that 15,6% of their AGSSs were not properly calibrated at the follow up assessment their results were worse, with 25% of AGSSs improperly calibrated (3) .

According to the regulation, the manufacturer of each component of the AGSS shall provide operational management information to the healthcare facility. This will enable the health facility to draft an operational management document. Instructions for recommended maintenance tasks and their frequency and a list of spare parts shall be provided. (9) MGPS personnel were available in each hospital but they were not solely dedicated to the AGSS. No manufacturer’s recommendations could be found in any of the study hospitals. Records of maintenance were not available in the study hospitals. Quarterly maintenance is not undertaken by any of the study hospitals. Litigation can be avoided if the AGSS is functioning optimally and well maintained.

Significant improvements to control waste anaesthetic gas pollution in the operating theatre has been made over the years. However, occupational exposure still occurs. (26) The relationship between exposure to the waste anaesthetic gases in the operating theatre and possible development of adverse health effects such as headache, eye discharge, rhinorrhoea and coughing, has concerned the operating

room personnel for several years, even though the results from studies have been conflicting (2).

## **4.5 Summary**

In this chapter, the sample realisation, the results of the study according to the objectives and a discussion of the results were presented. In the following chapter the recommendations for further study, recommendations for practice and limitations will be discussed.

## **Chapter 5**

### **Limitations and recommendations**

#### **5.1 Introduction**

In this final chapter, a summary of the study, the limitations of the study, the recommendations and conclusion are presented.

#### **5.2 Study summary**

The American Society of Anaesthesiologists recommends that in any location in which inhalational anaesthetic agents are administered, an adequate and reliable system for scavenging waste anaesthetic gases should be in place (40).

The aim of this study was to describe the functioning, use and maintenance of the AGSSs at CMJAH, CHBAH, HJH and RMMCH. A total of 59 operating theatres and 12 venues of remote anaesthesia were included in this study, i.e. a total of 71 areas.

The research design was prospective, contextual and descriptive. An audit of the AGSSs and the maintenance records at CMJAH, CHBAH, HJH and RMMCH was conducted.

The number fully functional AGSSs was 32 (45,07%) in the operating theatres and venues of remote anaesthesia. The receiving hoses were available in 42 (71,19%) operating theatres. The receiving hose was connected to the terminal unit in 39 (66,10%) operating theatres, of which 7 (11,86%) were assisted by sleek tape. Sleek tape was used in 8 (19,05%) operating theatres to “patch” the receiving hose.

MGPS personnel were available in each hospital but they were not solely dedicated to the AGSS. No manufacturer’s recommendations could be found in any of the study hospitals. Records of maintenance were not available in the study hospitals. Quarterly maintenance is not undertaken by any of the study hospitals.

### **5.3 Limitations of the study**

The following are the limitations that were encountered during the study:

- the two-way pressure device was not available in order to accurately measure the negative pressure and flow in the terminal unit
- this was a contextual study and therefore the results may not be extrapolated to other hospitals.

### **5.4 Recommendations from this study**

The following are recommendations for clinical practice:

- management should be informed that the functioning, monitoring and maintenance of the AGSSs is suboptimal
- a program for monitoring and maintenance should be drafted
- education of operating theatre personnel regarding the assembly of the system in order to decrease the waste anaesthetic gases and therefore the potential side effects on the personnel
- annual medical examination of the theatre personnel to ascertain if they are presenting with any symptoms of exposure to waste anaesthetic gases.

The following are recommendations for future research:

- do medical personnel in these hospitals suffer from any of the symptoms associated with exposure to waste anaesthetic gases
- a similar study can be done in other public and private sector hospitals within South Africa
- the sampling of the operating theatre atmosphere to assess the efficiency of the AGSSs
- a follow up audit to evaluate if a change of practice has been implemented.

## **5.5 Conclusion**

The small number of fully functional AGSSs was concerning. This study demonstrated the lack of the essential component of the AGSS namely the terminal unit in the venues of remote anaesthesia. Even though general anaesthesia might not be undertaken on a daily basis in these venues, there is guaranteed exposure to waste anaesthetic gases whenever a patient is anaesthetised with the use of volatile agents. The maintenance of the AGSSs were not conforming to the South African National Standards 7396-2.

This study also demonstrated the tolerance of operating theatre personnel towards improvising, even if it might be detrimental to our health, this is said in the light of the use of sleek to “repair” defects in the AGSSs.

## **5.6 Summary**

In this final chapter, a summary of the study, the limitations of the study, the recommendations and conclusion were be presented.

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## Appendix A: Approval to conduct the study from the Post Graduate Committee of the University of the Witwatersrand



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](mailto:thokozile.nhlapo@wits.ac.za)

26 May 2014  
Person No: 873755  
PAG

Dr MH Mogodi  
P.O.Box 19090  
Sunward Park  
1470  
South Africa

Dear Dr Mogodi

### **Master of Medicine: Approval of Title**

We have pleasure in advising that your proposal entitled *An audit of the anaesthetic gas scavenging systems in selected hospitals affiliated to the University of the Witwatersrand* 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

A handwritten signature in black ink, appearing to read 'S Benn'.

Mrs Sandra Benn  
Faculty Registrar  
Faculty of Health Sciences

Appendix B: Approval to conduct the study Human Research Ethics Committee (Medical) of the University of the Witwatersrand

**Human Research Ethics Committee (Medical)**

Research Office Secretariat: Senate House Room SH 10005, 10<sup>th</sup> floor. Tel +27 (0)11-717-1252  
Medical School Secretariat: Medical School Room 10M07, 10<sup>th</sup> Floor. Tel +27 (0)11-717-2700  
Private Bag 3, Wits 2050, www.wits.ac.za. Fax +27 (0)11-717-1265



Ref: W-CJ-140303-1

03/03/2014

**TO WHOM IT MAY CONCERN:**

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

**Investigator:** Dr M H Mogodi (student no. 873755).

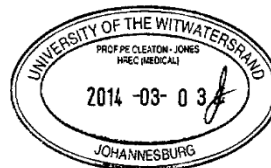
**Project title:** An audit of the anaesthetic gas scavenging systems in selected hospitals affiliated to the University of the Witwatersrand

**Reason:** This study will assess the functioning, use and maintenance of anaesthetic gas scavenging systems in the operating theatres and venues of selected hospitals affiliated with the University of the Witwatersrand and. No patient or medical staff information will be recorded. A list of the hospitals and written permissions to do the study from the hospitals' CEOs must be lodged with the HREC(Medical) Secretariat for the Committee's records.

A handwritten signature in black ink, appearing to read 'Peter Cleaton-Jones'.

Professor Peter Cleaton-Jones

Chair: Human Research Ethics Committee (Medical)



Copy - HREC(Medical) Secretariat : Anisa Keshav, Zanele Ndlovu.

Appendix C: Approval to conduct the study from the Medical Advisory Committee of CHBAH



**GAUTENG PROVINCE**

HEALTH  
REPUBLIC OF SOUTH AFRICA

MEDICAL ADVISORY COMMITTEE  
CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

**PERMISSION TO CONDUCT RESEARCH**

Date: 20 October 2014

TITLE OF PROJECT: An audit of the anaesthetic gas scavenging systems in selected hospitals affiliated to the University of the Witwatersrand

UNIVERSITY: Witwatersrand

Principal Investigator: M H Mogodi

Department: Anaesthesiology

Supervisor (If relevant): J Scribante

Permission Head Department (where research conducted): Yes

Date of start of proposed study: October 2014

Date of completion of data collection: December 2015

The Medical Advisory Committee recommends that the said research be conducted at Chris Hani Baragwanath Hospital. The CEO /management of Chris Hani Baragwanath 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: 20 October 2014

Approved/Not Approved  
Hospital Management

Date: 22/10/14

Appendix D: Approval to conduct the study from the CEO of CMJAH



**GAUTENG PROVINCE**

REPUBLIC OF SOUTH AFRICA

**CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL**

Enquiries:  
Mrs. L. Senyolo  
Office of the Director: Clinical Services  
Tell: (011): 488-3365  
Fax: (011): 488-3753  
14<sup>th</sup> October 2014

Dr. M.H. Mogodi  
Registrar – Anaesthetic Department  
CMJAH

Dear Dr. Mogodi

**RE: "an audit of the anaesthetic gas scavenging systems in selected hospitals affiliated to the University of the Witwatersrand"**

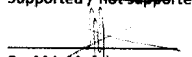
Permission is granted for you to conduct the above recruitment activities as described in your request provided:

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

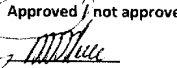
Please liaise with the Head of Department and Unit Manager or Sister in Charge to agree on the dates and time that would suit all parties.

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

~~Supported / not supported~~

  
Dr. M.J. Mofokeng  
Director: Clinical Services  
DATE: 14/10/2014

Approved / not approved

  
Ms. G. Bogoshi  
Chief Executive Officer  
DATE: 2014/10/17

Appendix E: Approval to conduct the study from the CEO of HJH



GAUTENG PROVINCE  
REPUBLIC OF SOUTH AFRICA

**PERMISSION FOR RESEARCH**

DATE: 08.10.14

NAME OF RESEARCH WORKER: MORONGO HAZEL MAGODI

CONTACT DETAILS OF RESEARCH (INCLUDE ALTERNATE RESEARCHER):

072 370 5043

0723705043@vodmail.co.za

TITLE OF RESEARCH PROJECT AN AUDIT OF THE ANAESTHETIC GAS

SCAVENGING SYSTEMS IN SELECTED HOSPITALS AFFILIATED TO THE

UNIVERSITY OF THE WITWATERSRAND

OBJECTIVES OF STUDY (Briefly or include a protocol):

INSPECT THE ANAESTHETIC GAS SCAVENGING SYSTEM

AUDIT OF THE MAINTENANCE OF THE AGSS

METHODOLOGY (Briefly or include a protocol): SEE PROTOCOL

THE APPROVAL BY THE SUPERINTENDENT IS STRICTLY ON THE BASIS OF THE FOLLOWING:

- (i) CONFIDENTIALITY OF PATIENTS MAINTAINED: PATIENTS NOT INVOLVED
- (ii) NO COSTS TO THE HOSPITAL: NO COST TO THE HOSPITAL
- (iii) APPROVAL OF HEAD OF DEPARTMENT: APPROVAL FROM HOD ATTAINED
- (iv) APPROVAL BY ETHICS COMMITTEE OF UNIVERSITY: ETHICS WAIVER ATTAINED

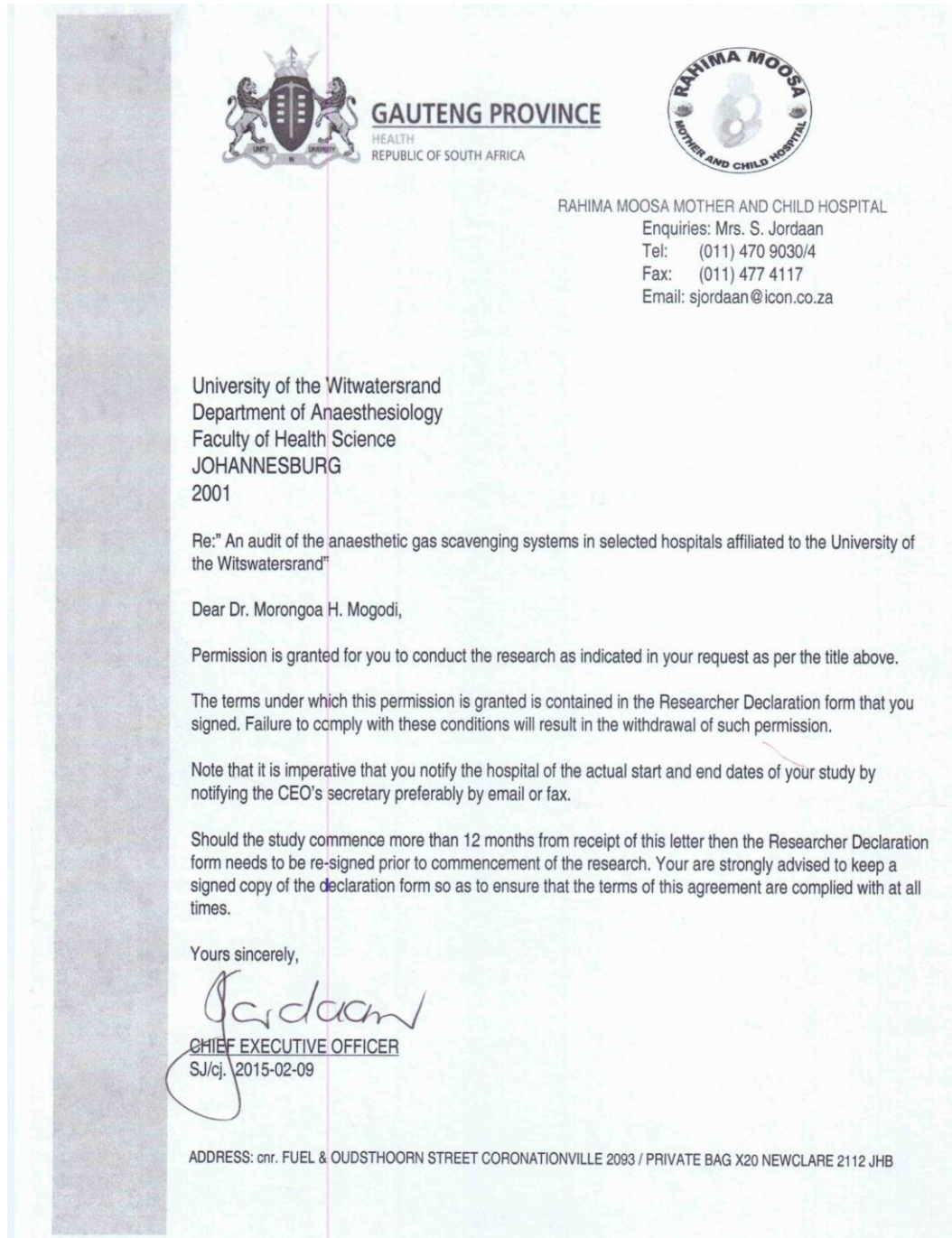
SUPERINTENDENT PERMISSION  
Signature: [Signature] Date: 15/10/2014

SUBJECT TO ANY RESTRICTIONS: Financial impact on the facility

Helen Joseph Hospital  
Perth Road  
Tel: 011 489 1011

Private Bag X47  
Auckland Park  
2006

Appendix F: Approval to conduct the study from the CEO of RMMCH



Appendix G: Data collection sheet

**Data collection sheet:**

Hospital: CMJAH  CHBAH  HJH  RHMMC

Observation:

Operating theatre  Remote anaesthesia venue

Date of assessment:

Receiving system identification number

Presence of disposal system interface: Yes  No

Type of terminal unit: 1L  1H

Placement of business card on terminal unit: Hold  Fall

Condition of receiving hose: Intact  Sleek tape

Connection of receiving hose to terminal unit: Yes  No   
• Assisted connection with sleek tape: Yes  No   
• Other \_\_\_\_\_

Connection of receiving hose to receiving system: Yes  No

Describe reading on flow indicator: High  Normal  Low  Absent

Appendix H: Audit of record keeping

**Audit of record keeping**

Hospital: CMJAH  CHBAH  HJH  RHMMC

Authorised person for MGPS: Yes  No

Manufacture's recommendations: Yes  No

Records for maintenance: Yes  No

Quarterly maintenance: Yes  No