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Knowledge and practices of anaesthetists regarding the disposal of waste anaesthetic gases and sharps in a department of anaesthesiology

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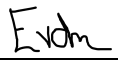
A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg in partial fulfilment of the requirements for the degree of Master of Medicine in the branch of Anaesthesiology.

Johannesburg, 2020

Declaration

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



19 September 2020

Abstract

Background

The operating room has numerous healthcare hazards that can lead to detrimental health effects. The South African legislation, standards and guidelines governs the management of hazardous healthcare waste. It is the responsibility of the individual healthcare worker (HCW) and the hospital authorities to take the necessary steps to reduce the risks associated with healthcare waste. Anaesthetists are often exposed to waste anaesthetic gases (WAG) and sharps and if managed poorly, can lead to an unsafe working environment. The study will assess the knowledge and practices of anaesthetists of WAG and sharps disposal.

Methods

A prospective, contextual, descriptive research design was followed. The study population consisted of anaesthetists working in the Department of Anaesthesiology at the University of the Witwatersrand (Wits). The data were collected through a self-administered questionnaire and analysed using Stata version 15 (StataCorp, USA).

Results

The results indicated that the anaesthetists had inadequate knowledge of the legislation of WAG and sharps disposal, WAG disposal and sharps disposal. However, the knowledge of sharps disposal was greater than the knowledge of WAG disposal. The practices of WAG and sharps disposal varied and only few of the anaesthetists attended training on WAG and sharps disposal.

Conclusion

The knowledge of the anaesthetists of WAG and sharps disposal was poor with the knowledge of sharps being better than the knowledge of WAG. There was low attendance of training of WAG and sharps disposal, with no significant difference between the adequacy of knowledge and those who received training. The results were concerning, especially with anaesthetists in this study working in a high risk environment due to few-functioning scavenging systems and the high incidence of human immunodeficiency virus (HIV) in South Africa.

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Abbreviations

CDC	Centers for Disease Control and Prevention
HCW	Healthcare worker
HIV	Human immunodeficiency virus
NIOSH	National Institute for Occupational Safety and Health
PPM	Parts per million
SANS	South African National Standard
SABS	South African Bureau of Standards
SASA	South African Society of Anaesthesiologists
WAG	Waste anaesthetic gas
Wits	University of Witwatersrand

Statement

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

The formatting of this Research Report complies with the University of the Witwatersrand's Style Guide for Theses, Dissertations and Research Reports. The formatting of the draft article is in keeping with the rest of the Research Report thus may not comply with the author guidelines of the South African Journal of Anaesthesia and Analgesia, the journal to which it is intended to be submitted.

Section 1: Review of the literature

1.1 Introduction

Anaesthesia providers are exposed to numerous occupational hazards that are workplace-related or personal (1). The workplace related hazards are waste anaesthetic gases (WAG), infections transmitted through sharps injuries and bodily fluids, air-borne infections, musculoskeletal injuries, latex allergy, radiation, magnetic resonance imaging, diathermy and laser smoke inhalation and electromagnetic fields. Personal hazards include substance misuse, stress and fatigue (1).

Non-hazardous healthcare waste is waste that does not cause physical, chemical, biological, or radioactive harm (2). Hazardous healthcare waste is “any material or substance that, if handled improperly, has the potential to harm people, property or the environment” (3). According to the South African National Standard (SANS), hazardous healthcare waste includes anatomical, infectious, sharps, chemical, pharmaceutical and radioactive waste. Chemical waste consists of discarded solids, liquids or gaseous chemicals produced by a healthcare facility that has the ability to be a danger to human health, or to have an effect on the environment through pollution (4). Sharps include needles, syringes, blades, clinical glass and any other item used for clinical purposes that can cause a cut or puncture wound (5).

Non-functional scavenging and ventilation systems (6) and poor management of sharps (7) pose a risk to anaesthetists on a daily basis. The history of WAG and sharps, risks to healthcare workers (HCW) and the environment, precautionary practices, the South African legislation, standards and guidelines, scavenging and ventilation systems, monitoring of WAG, alternative methods and relevant studies will be discussed.

1.2 The history of waste anaesthetic gases, scavenging systems, ventilation systems and sharps

1.2.1 Waste anaesthetic gases

Health hazards related to WAG have been a concern since the introduction of inhalational agents (8). The health resorts in the 1700s first used inhalational agents as medical treatment. In 1844, Gardner Quincy Colton managed to manufacture nitrous oxide to “perfection” and presented it in Connecticut. Dr Horace Wells, a dentist, attended the exhibition, decided to use nitrous oxide for a tooth extraction in public, but experienced devastating humiliation. Thereafter, his former student, Mr William T.G. Morton, successfully extracted a tooth, pain free, with the use of ether (9). Dr James Young Simpson, an obstetrician, was dissatisfied with the use of ether for labour pains and tested chloroform with great success at a dinner party at his house in 1847 (10).

In 1951, Charles Suckling, a British chemist, was asked to develop a new anaesthetic agent, which was halothane. A respected anaesthetist, Michael Johnstone, soon realised the potential of halothane and its use rapidly escalated (10). Methoxyflurane followed in the 1960s, but was withdrawn due to dose-related nephrotoxicity. The search continued for an ideal inhalational agent and the two fluorinated liquid anaesthetic agents, enflurane and isoflurane, were developed in 1963 and 1965, respectively. Sevoflurane and desflurane were developed in the 1960s, but not used clinically. In 1983, the Japanese further developed sevoflurane and in 1995 it was approved for clinical use (10).

Professor G van Overbeek de Meyer, a microbiologist, was the first to mention the side effects associated with WAG in 1889. Later in this same year, an ophthalmologist, Professor von Eversbusch, from the University of Erlangen, described the side effects in more detail; it was then that ventilation strategies were recommended by him to prevent operating room pollution. Another recommendation by him was to produce high humidity in the operating room to be able to absorb polluting molecules (11).

In the 1970s, epidemiological studies documented the associated risks of chronic WAG exposure. The risks included stillbirths, congenital abnormalities, low birth weight, altered sex ratio of male to female, infertility and cancer (12).

In 1977, increased concerns related to the risks associated with WAG, resulted that the National Institute of Occupational Safety and Health (NIOSH) published guidelines to limit exposure to WAG. The recommended exposure limits for nitrous oxide used as a sole agent was 25 parts per million (ppm) measured as a time-weighted average (13). PPM is the form in which concentrations of gases and vapours are measured (14). The American Conference of Governmental Industrial Hygienists reviewed the exposure limits in 1989 and allocated a threshold limit value-time-weighted average for nitrous oxide of 50 ppm over an eight-hour workday. The threshold limit value-time-weighted average assigned to halothane was 50 ppm and for enflurane, 75 ppm (13). The American Conference of Governmental Industrial Hygienists provided threshold limit values of inhalational agents to be used by American authorities as guidelines to set their occupational exposure limits (15).

With the introduction of the guidelines and the increase in awareness, gas pollution in the operating room reduced significantly over the years due to scavenging systems, effective ventilation and a focus on regular maintenance and leak detection of anaesthetic equipment. Changes in anaesthetic practice also contributed to the decrease in exposure. The chronic exposure to low concentrations of WAG remains a concern to NIOSH, despite the conflicting evidence related to the health effects (16).

1.2.2 Scavenging and ventilation systems

In 1918, Dr Kelling, a Dresden surgeon, documented in a surgical journal the potential problems associated with WAG. Dr Kelling designed an anaesthetic mask that was able to remove the excess vapour produced during anaesthesia. Later in 1925, a German named, Perthes, designed an exhaust fan. The exhaust fan had an inlet near the patient’s face to direct WAG away. This method renewed the air in the operating room within five minutes. During the same period, an obstetrician, Dr Wieloch, designed a box that could fit around the patient’s head.

The box had a sophisticated exhaust system to eliminate the WAG to the outside (11). The first piping system to eliminate WAG was described in the late 1920s and Dr Killian, amongst others, suggested that a water-powered extraction system with a minimum performance of 40 litres per minute should be introduced (11).

In the 1980s, four scavenging devices were available in South Africa. The first was the Carsten System designed by Carstens at Baragwanath hospital. The others were the Gardner Box designed in Oxford England, the Stellenbosch Valve, designed by Foster in Stellenbosch and the Ventex System, designed by Cornish of Allan in Johannesburg (17). All four were dependent on efficient high-volume and high-pressure suctioning (17).

1.2.3 Sharps

A Roman scholar, Aulus Cornelius Celsus, described the syringe as early as the first century. Then 800 years later, an Egyptian surgeon, Ammar bin Ali al-Maswili, used hollow glass tubes to remove cataracts, which developed into the modern-day practice of obtaining blood specimens from patients. A Frenchman, Blaise Pascal, invented the first modern syringe in 1655. In 1844, an Irish doctor, Francis Rynd, produced the first hollow needle. The Scottish surgeon, Alexander Wood, combined the hollow needle with the syringe to inject morphine into a patient (18). Reusable needles and glass syringes were used up to the 1950s, and then were replaced by disposable plastic syringes and single use needles (19). After documenting the first needle stick injury in 1981, McCormick and Maki suggested that prevention strategies should be implemented. This included educational programs, avoiding recapping of needles and improved needle disposal. The Centers for Disease Control and Prevention (CDC) introduced universal precautions in 1987 (7).

1.3 Risks of waste anaesthetic gases and sharps to the healthcare worker in the operating room

1.3.1 Waste anaesthetic gases

In the United States of America, it is estimated that more than 200 000 HCWs working in the operating room, post anaesthetic care unit, dental and radiology

departments are chronically exposed to WAG and therefore are at risk for associated occupational illnesses (13). HCWs are more likely to be exposed to high concentrations of WAG in operating rooms where no scavenging or ventilation systems are available (16).

In 2016, Mogodi (20) showed that only 45% of the scavenging systems were functional. Of these, 45% had connections for the hose, but the terminal units were unable to generate the required negative pressures. In the operating rooms that were remote, no gas interface or terminal units were present. Results indicated that functioning, monitoring and maintenance of the anaesthetic gas scavenging systems at the University of the Witwatersrand (Wits) core hospitals were suboptimal (20).

In 2015, a study done at Memorial Hermann Hospital in Houston, showed that the sevoflurane concentrations in the breathing zone of the patients in the post anaesthetic care unit were above the recommended exposure limits. The study also showed that sevoflurane can still be exhaled by the patient for up to 60 minutes after being extubated (21). A common concern in post anaesthetic care units is that the scavenging and ventilation systems are limited or inadequate (22).

Paediatric anaesthetists experience greater WAG exposure in the operating room due to inhalational inductions with masks and the use of un-cuffed tracheal tubes. Obstetric complications and poor pregnancy outcomes, especially spontaneous abortions, have a higher prevalence in anaesthetists whose practice includes more than 75% of paediatrics cases (23).

Headaches, irritability, fatigue, nausea, drowsiness and difficulty with judgement and coordination are some of the side effects associated with the acute exposure of anaesthetic agents. Chronic exposure may lead to congenital abnormalities, genetic damage, and cancer. Nitrous oxide exposure in an acute setting may cause light-headedness, eye irritation, cough or shortness of breath. Chronic exposure can reduce fertility, cause spontaneous abortions in female HCWs, reduce mental performance and cause neurological, liver and renal disease (24). The neurological effects from nitrous oxide may be due to the elevated homocysteine levels produced by the indirect inactivation of methionine synthase

and the inhibition of thymidalate synthetase. Methionine synthase is an important enzyme in folate metabolism, converting homocysteine to methionine (25). This leads to a decreased production of hydrofolate and therefore a decrease in deoxyribonucleic acid synthesis. Nitrous oxide exposure in a person with prolonged vitamin B12 deficiency can lead to the failure of myelin synthesis and therefore peripheral neuropathy (26). Elevated homocysteine levels can also be associated with cardiovascular dysfunction and oxidative stress, which result in cellular damage by forming reactive oxygen species (25).

The potentially harmful effects related to the chronic exposure of low concentrations of sevoflurane and desflurane to the HCW has not yet been thoroughly investigated (13). Possible genotoxic effects related to chronic exposure to low concentrations of sevoflurane are still an ongoing debate (27).

Methoxyflurane, commonly used in Australia, is a self-administered inhaler to provide analgesia to patients in the pre-hospital setting, trauma patients, burns patients and in obstetric and dental practices. Its use outside of the operating room results in the HCWs in these settings being exposed to WAG. Methoxyflurane, also known as Penthrox or the Green Whistle, possesses both hypnotic and analgesic properties (28). Methoxyflurane does not have an occupational exposure limit and a maximum exposure limit of 15 ppm expressed as eight-hour-time-weighted average for medical staff is used. The device has an activated charcoal chamber attached to reduce exposure. Exposure to the HCW depends on the frequency and duration of the device used, the ventilation in the room and if a scavenging system is present. Monitoring for occupational exposure is advised (29). Methoxyflurane remains an occupational risk with rare but significant renal and hepatic side effects (28).

1.3.2 Sharps

“A safe injection is defined as one that does not harm the recipient, expose the health worker to avoidable risk, or result in waste that puts other people at risk” (19). HCWs and patients involved in unsafe practices are at an increased risk to sustain a sharps injury and are regarded as the following: the re-using of disposable needles and syringes, recapping needles, not discarding the needle

after use, allowing someone else to discard contaminated sharps, placing hands in containers of needles for cleaning, sharpening needles for re-use, discarding needles and syringes into general waste and collecting used needles for resale (19). In developing countries, unsafe injection practices are common and place the HCWs, the public, cleaners, waste handlers, and scavengers at disposal sites at risk (19).

The most likely source of infection transmission for the anaesthetist in the operating room is a needle stick injury. Human immunodeficiency virus (HIV), hepatitis B and hepatitis C are the common blood borne viruses transmitted through needle stick injuries. The risk of the transmission of these pathogens is proportional to three factors; the number of exposure to infected blood, prevalence of patients carrying the pathogen and infectivity of the pathogen (1). The prevalence rate of HIV in South Africa in 2018 was 13.1%, an estimated 7,2 million people (30). The risk of HIV transmission after percutaneous exposure in the healthcare setting is 0,3%, for hepatitis B the risk of seroconversion in a non-immune HCW is as high as 40% and hepatitis C carries an estimated seroconversion rate of 2% (1).

Hollow-bore needles are associated with a higher risk of HIV transmission compared to solid sharps (1). Anaesthetists use hollow-bore needles to draw up drugs and to inject into administration ports. The intravenous catheters' introducer needle is a hollow-bore needle. The highest incidence of needle stick injuries occurs during or after the removal of the introducer needle. Other causes for percutaneous injuries from hollow-bore needles are during recapping, passing the needle to another HCW, during a collision with another HCW, when removing the needle from the syringe (11), during local infiltrations, when performing regional techniques or during an accidental fall on the anaesthetist's foot (6).

1.4 Risk of waste anaesthetic gases and sharps to the environment

1.4.1 Waste anaesthetic gases

The volatile anaesthetic agents, especially nitrous oxide, destroy the ozone layer. Nitrous oxide is a known greenhouse- and ozone-depleting gas (31). Nitrous oxide has a 300 times higher global warming potential than carbon dioxide. The other greenhouse gases are carbon dioxide, methane and chlorofluorocarbons. The volatile anaesthetic agents have a similar chemical structure as the chlorofluorocarbons and may have an impact on climate change (32).

The impact of gaseous substances on climate change depends on its atmospheric lifetime, global warming potential and the ozone depletion potential. To replicate the chemistry of the atmosphere is complicated, therefore the effects of volatile agents on climate change is only an estimate. Sevoflurane has the lowest global warming potential and desflurane the highest (32).

1.4.2 Sharps

The sharps that are disposed of, untreated, to landfill sites can lead to the contamination of the drinking water, the surrounding surface or ground areas around these sites (33). Sharps should be disposed of through incineration or buried after microwaving or autoclaving at a designated landfill site (2). The current management of healthcare risk waste in South Africa is incineration, despite other alternative technologies being available. Gauteng has the highest number of incinerators in the country (34). There are different compounds produced during incineration that may be harmful to people and the environment. These compounds include nitric oxide, sulphur dioxide, carbon monoxide, dioxins and furans (35). For example; dioxins are persistent organic pollutants and exist in the environment for many years. Dioxins are resistant to biological and chemical degradation and may have a detrimental effect on human health (36)

1.5 Precautionary practices to reduce hazardous healthcare waste

Ideally, primary prevention measures should be in place to reduce the exposure to hazardous healthcare waste. According to Boiano and Steege (24) an approach to reduce the exposure to hazardous healthcare waste is as follows: if the generation of the waste substance cannot be avoided or eliminated, a systematic plan should be in place that includes the engineering controls, administration controls, work practice controls and personal protective equipment (24).

1.5.1 Precautionary practices for Waste anaesthetic gases

The anaesthetist can avoid or eliminate the use of WAG when using regional or total intravenous anaesthesia (24). The engineering controls for WAG include the scavenging systems, the ventilation systems and the key-filler devices for filling the vaporisers. Examples of administration controls are training and education on the safe handling of WAG, regular air monitoring to detect early leaks and medical surveillance (16). Other methods to reduce the risk of WAG are work practice controls which include a complete machine check, the use of appropriate sized face masks, the correct positioning of airway devices, filling the vaporisers in a well ventilated area, closing the vaporiser when not in use, cleaning the spills of liquid gases, commencing the anaesthetic agent after the airway device is placed, low flow anaesthesia and flushing the anaesthetic agent into the scavenging systems towards the end of a procedure (24).

Anaesthetists may contribute to reducing environmental contamination by WAG by assisting in the operating room design and the anaesthetic agent they use (37). An alternative volatile anaesthetic agent for the future is xenon, which is environmentally friendly, provides analgesia, rapid induction and emergence, neuroprotection and is haemodynamically stable (38). Xenon is “a noble gas” obtained from fractional distillation. It is very expensive, close to the ideal anaesthetic agent and will be used more in the near future once a recycling system is available (26).

1.5.2 Precautionary practices for sharps

Sharps injuries in the operating room can be avoided by making the entire process, from drawing up the drug to injecting it into the patient, hazard free (39). To avoid the use of sharps, plastic ampoules, blunt drawing up needles, needleless intermittent intravenous-access systems and syringes that fits into a plastic ampoule can be used. The only concern with plastic ampoules is that some drugs are not compatible with polyvinyl carbon containers. There are two types of needleless intermittent intravenous-access systems namely, the Clave-type system and the Interlink-type system. The Clave-type system uses a syringe that is introduced directly into a port in the infusion line. In the Interlink-type system there is a rubber port that forms part of the fluid administration set into which a blunt-tipped plastic needle fits (39).

Engineering controls are specifically engineered sharps injury prevention devices (39). Examples include a protected needle intravenous connector, a needle that retracts into a vacuum tube holder or syringe, a hinged or sliding shield, a protective encasement to place the intravenous stylet after the procedure and a retractable finger or heel-stick lancet (40).

Adequate training on the safe disposal of needles, promoting awareness, planning on how to safely dispose a sharp before a procedure and informing authorities on workplace hazards can reduce the risk of needle stick injuries (40).

The Centers for Disease Control and Prevention standard precautions

The main focus of the CDC standard precautions is the work control practices and personal protective equipment. The work control practices include the use of an instrument rather than fingers when handling a contaminated sharp, giving a verbal warning when placing the sharps into a container, avoiding passing the sharps to a colleague, using a pre-set tray for placing sharps after use, visualising and locating the contaminated needle at all times and using a one-handed technique if a needle needs to be recapped (7). Gloves are still included in the standard precautions as personal protective equipment when handling contaminated sharps (7).

1.6 The South African legislation of hazardous healthcare waste

The South African legislation provides a broad overview of the management of hazardous healthcare waste and the associated occupational hazards (41). The South African legislation regulates healthcare waste management to comply with the Constitution of the Republic of South Africa, 1996, which states that “everyone has the constitutional right to have an environment that is not harmful to his or her health and to have an environment protected for the benefit of present and future generations through reasonable legislative and other measures” (42).

The legislation that guides healthcare waste management in South Africa is the National Health Act of 2003 (43), the Occupational Health and Safety Act of 1993 (44), The Hazardous Chemical Substances Regulations of 1995 (14), the National Environmental Management Waste Act of 2008 (38) and the Air Quality Act of 2004 (45). According to the National Health Act of 2003 (43), it is the health establishments’ responsibility to implement occupational health and safety systems to protect HCWs from workplace related hazards (43). The Occupational Health and Safety Act of 1993 (44), defines occupational health and safety, risks and hazards in the South African law (44). The Hazardous Chemical Substances Regulations of 1995 (14) defines hazardous waste and provides the classification and control of hazardous substances (14). The National Environmental Management Waste Act of 2008 (38) emphasises the responsibility of waste producers and provides general duties with respect to the management of waste (38). The Air Quality Act 2004, provides the national norms and standards to monitor, manage and control air quality (22).

According to the National Health Act of 2003 (43), the health establishments must provide a plan each year to manage the risks identified from the risk assessment performed on hazardous healthcare waste. Procedures must be in place for the appropriate collecting, handling, storage and disposal of hazardous healthcare waste. If the HCW fails to dispose of hazardous healthcare waste accordingly, the health establishment can proceed to corrective actions. The safe management and disposal of sharps must be introduced into the healthcare setting to reduce the risk of infection to users and others. The health establishment is responsible for training the HCWs and users on infection prevention and control practices (43).

The Occupational Health and Safety Act of 1993 (44) documented that the health establishment, the employer and the employee are responsible for maintaining a safe and hazard free working environment. Occupational health is defined as “occupational hygiene, occupational medicine and biological monitoring”(44). Biological monitoring is a program that periodically collects, analyses and quantifies hazardous substances. Occupational illness is defined as “a condition that results from exposure in a workplace to a physical, chemical or biological agent to the extent that the normal physiological mechanisms are affected and the health of the worker is impaired”(44). Occupational hygiene programs and medical surveillance should be available in the workplace. The employer must identify and minimise potential hazards and provide information, instructions, supervision and training where necessary. Employees are responsible for their health and safety and should report any unsafe or unhealthy conditions or incidents regarding health and safety to the employer (44).

The Hazardous Chemical Substances Regulations of 1995 (14), applies to any employer and employee who carries out work in a workplace in which they are exposed to hazardous chemical substances (14). Employees who may be exposed to hazardous chemical substances should initially have a consultation with the health and safety committee. The employer must provide adequate information and training on the potential sources of hazardous chemical substances, the associated health risks and the effects it may have on the employees’ reproductive ability (14). Employees should receive training on how to protect themselves, on the correct and safe usage of equipment and engineering controls, as well as the necessity of personal air sampling and medical surveillance. The employee should know the procedures to follow in event of spillages or leakages (14). There should be structured measurement programs the place to quantify airborne concentrations where the inhalation of hazardous chemical substances is a concern**.** The exposure to the hazardous chemical substance should be below the provided control limit. In situations where there is a temporary excursion above the control limit, the employer must install local extraction ventilation systems, equipment and tools for the control of the emission of airborne hazardous chemical substance (14).

The Hazardous Chemical Substances Regulations of 1995 (14) do not provide exposure standards for most anaesthetic gases. It is acceptable practice in South Africa to use international standards and exposure limits (46). The guidelines for the occupational exposure limits for anaesthetic gases are from the Occupational Safety and Health Administration and the American Conference of Governmental Industrial Hygienists. The Occupational Safety and Health Administration was created to ensure that employers provide safe working conditions for employees (47). NIOSH does not provide recommended exposure limits for isoflurane, sevoflurane and desflurane (13). The occupational exposure limits for desflurane and isoflurane as per the American Conference of Governmental Industrial Hygienists is 75 ppm. The occupational exposure limits for sevoflurane as per the National Institutes of Health of 2015 is 2 ppm measured as the time-weighted average for the duration of the procedure (46).

Air pollution from the atmospheric emissions of substances produced by healthcare facilities and waste disposal sites, place an enormous burden on the economy and the environment. The Air Quality Act of 2004 (45) is part of the legislation to protect the environment. Pollution can be minimised by implementing strict control, cleaner technologies and cleaner production practices (22).

1.7 Standards and guidelines

1.7.1 South African Bureau of Standards and South African National Standard

The main objective of the South African Bureau of Standards (SABS) Code of Practice (48) is to prevent injury and the transmission of infections to HCWs due to the mismanagement of healthcare waste (48). According to the standards, each generator of biohazardous waste must have a plan to identify and handle all waste generated within the facility. Training programs should be available for all staff managing hazardous healthcare waste and they must be familiar with the potential hazards (48).

Training must include safety instructions, precautions on the handling of healthcare waste, the correct use of personal protective equipment and quality control. At the point of use, there must be visual illustrations with instructions on

how to identify hazardous healthcare waste and how to segregate the waste into colour-coded containers. An employee must receive training at the beginning of his or her contract to provide information on the nature of the work, associated hazards, disposal procedures and safe handling of hazardous healthcare waste. Regular assessments and reinforcement of the training programs should be done each year (48).

The South African National standard (SANS) (5) provides standards for the effective management of healthcare waste. The document provides information on how to control potential hazards that can harm the HCW and the environment. The healthcare facility is responsible for healthcare waste from generation to final disposal. The chief executive officer has the overall responsibility in the management of healthcare waste. The head of department should manage hazardous healthcare waste through avoiding the production of hazardous healthcare waste, adequate segregation, containerisation, adequate storage, appropriate treatment and disposal in their department. The generator (HCW) is responsible to identify and segregate hazardous healthcare waste at the point of generation. The operating room is part of the waste management team and has the responsibility to establish, implement and maintain a waste management plan, which includes the health and safety policy (48).

Scavenging systems

The SANS for medical gas pipelines systems (49) is not only directed to the people involved in designing or constructing scavenging systems, but also to those involved in the inspecting and operating these systems in the healthcare facilities. Means should be provided to indicate to the operator that the system is functioning and to adjust the pressure and flow. The operator should have access to an operational management document supplied by the manufacturer. The manufacturer must supply instructions that include the recommended periodic checks, maintenance tasks with their frequency and a list of spare parts required. The manufacturer must provide a certificate that indicates that all tests and procedures done on the anaesthetic scavenging system was satisfactory (49).

The SANS provides specific requirements for the design, installation, functioning, performance, documentation and testing of scavenging systems to ensure minimal gas exposure to patients and personnel working in the operating room. The design of the scavenging system should have no backflow or cross connections. Training on the scavenging system and competency of the staff should be recorded. A scavenging system should be tested and certified to function without a leak and at safe flows (49).

Medical pipelines in the scavenging systems must be according to the International Organisation for Standardisation guidelines, which is a worldwide federation of national standard bodies. The connection assemblies or disposable hoses available in a healthcare facility should be type specific for the scavenging system. The pipelines must be marked with ‘AGSS’. The three functional parts of the scavenging system are the transfer system, the receiving system and the disposal system. Specific terminal units are associated with specific transfer, receiving or disposal systems (49).

The disposal systems pipelines and its components must be corrosion resistant and compatible with the anaesthetic gases. There must be a non-return valve in the disposal system to prevent backflow. There are different power devices for disposal systems. The discharge port of the disposal system must be directed to the outside of a building. The exhaust outlet must be distant from air intake for medical air, compressor systems, doors, windows or any openings to the buildings (49).

Control measures should be in place to identify blockages in the pipeline systems and loss or reduction of flow. There must be operational procedures in place during an emergency to ensure continuity of the scavenging system, an alarm system to indicate a loss of compressed air and adequate spare parts for critical components. The vacuum pump generates high temperatures during the compression process and when in combination with anaesthetic gases can cause a fire (49).

Sharps

According to the SANS (5), hazardous healthcare waste must be disposed of into appropriate colour coded containers. Containers are colour coded for identification. A sharps container can be identified by the words “SHARPS”, a symbol or both as demonstrated in Figure 1. It is important that the HCW is familiar with the type of sharps container used in their facility. The sharps container must be rigid, puncture-proof, tamper proof and manufactured from a material that can safely retain the sharps. Handles, a wall bracket and a lock are other useful features. The capacity of the container is 75% (48). A sharps container is a single-use waste container and should not be re-used. The lid of a single-use container must have a tight seal and only an automated process should be able to open the reusable container’s lid. In specific areas, the appropriately sized sharps container should be available. Sharps must be stored at the infectious waste storage area in the healthcare facility with a time limit of 90 days and a temperature of -2 °C. A registered contractor must collect healthcare waste from the storage area (5).

The hazard rating of the untreated waste must be determined before disposal in order to dispose of the waste to the appropriate landfill sites. When incineration or alternative methods are used, the hazard rating is determined by the residue and then disposed of accordingly. The untreated sharps hazard classification is class 6 (5).



Figure 1: Sharps container (50)

1.7.2 South African Society of Anaesthesiologists guidelines

The South African Society of Anaesthesiologists (SASA) (51) provided practice guidelines for the training of the anaesthesiologists in South Africa. SASAs' vision is to lead the science and the practise of safe anaesthesia to the highest standard and to ensure the sustainability of anaesthesiology services (51).

The SASA guidelines provide recommendations for anaesthetic practice in different healthcare settings with the minimum requirements for the conduct of a safe anaesthetic. The breathing circuit, a suitable range of facemasks and different sized endotracheal tubes must be available. A tight-fitting facemask and the circle system will minimise exposure of WAGs to the HCW. Any institution at which anaesthesia is conducted must have an efficient and reliable maintenance and repair service for all anaesthetic equipment. Faulty essential equipment must be able to be replaced immediately (51).

Regarding the operating room ventilation, the systems should be in a working condition to allow for appropriate infection control and WAG disposal. The SASA guidelines recommend that there "should be at least 20 - 25 air changes per hour" in the operating room with a positive pressure difference between the inside of the operating room to the outside passage of 19 mmHg. Air that is filtered through a high-efficiency particulate air filter should be delivered to each operating room from the ceiling downwards and returned via several exhaust outlets near the floor (51).

The SASA (52) guidelines on needle safety are as follows: needles and syringes are intended for single use only and must be considered contaminated following contact with a patient, infusion bag or administration set. It is unacceptable practise to reuse a syringe with medication from a previous patient for a new patient, even if the needle is sterile. Any needle that was used may not be reinserted into a multiple dose vial, solution bag or container. Even if a one-way valve is used in a syringe driver must the syringe not be re-used. At the end of a working day, the needles and syringes used must be discarded in an appropriate manner. Single-dose vials must be disposed of appropriately and not reused (52).

1.8 The scavenging and ventilation system

The physics of the operating room form a significant part of the anaesthesiologists' training curriculum, especially the different types of scavenging and ventilation systems (9).

1.8.1 Scavenging

A scavenging system collects and removes WAG from the operating room (9) and is considered as an integral part of the medical gas system. The central vacuum system in a hospital may be used for waste anaesthetic disposal but with modern anaesthetic machines, a dedicated WAG disposal system is required (53).

The five basic components of a standard scavenging system are depicted in Figure 2. The scavenging system consists of a gas collection assembly tube, transfer tubing, receiving system or the interface, gas disposal assembly tubing and the gas disposal assembly. The gas-collection assembly collects the WAG and directs it to the transfer tubing, which carries gas to the scavenging interface. The gas collection assembly tubes are connected to either the adjustable pressure-limiting valve or the ventilator relief valve (9). The Mapleson A, B, C and D circuits can be used with a collecting system through a shrouded adjustable pressure-limiting valve (54). The Jackson Reece circuit used in paediatric anaesthesia is a low resistance circuit. High resistance will occur in the Jackson Reece circuit if it is connected to a scavenging system (54). To avoid misconnections, the transfer tubing gauge is 19 mm or 30 mm and the breathing tubing gauge is 22 mm. The transfer tubing may be colour-coded. If the transfer tubing is occluded, it can increase the pressure towards the patient and may result in barotrauma (9). The transfer system should be less than 1 m to avoid kinking in the system (54).

The receiving system is the interface between the breathing and disposal system and is one of the most important parts of the scavenging system. The interface protects the ventilator or breathing circuit from excessive positive or negative pressure (9). Scavenger interfaces may be open to the atmosphere or closed, with the gases within the interface only communicating through valves to the atmosphere (55). To be able to remove all the expired gases, the scavenging flow

should be 80 litres per minute (56). An open interface system is safer for the patient and should be used with an active system (55). The open end is a safety feature and may be called an air break (56). Thereafter, the gas disposal assembly tubing carries gas from the scavenging interface to the gas disposal assembly**.** The gas disposal assembly eliminates the gas into the atmosphere (9).

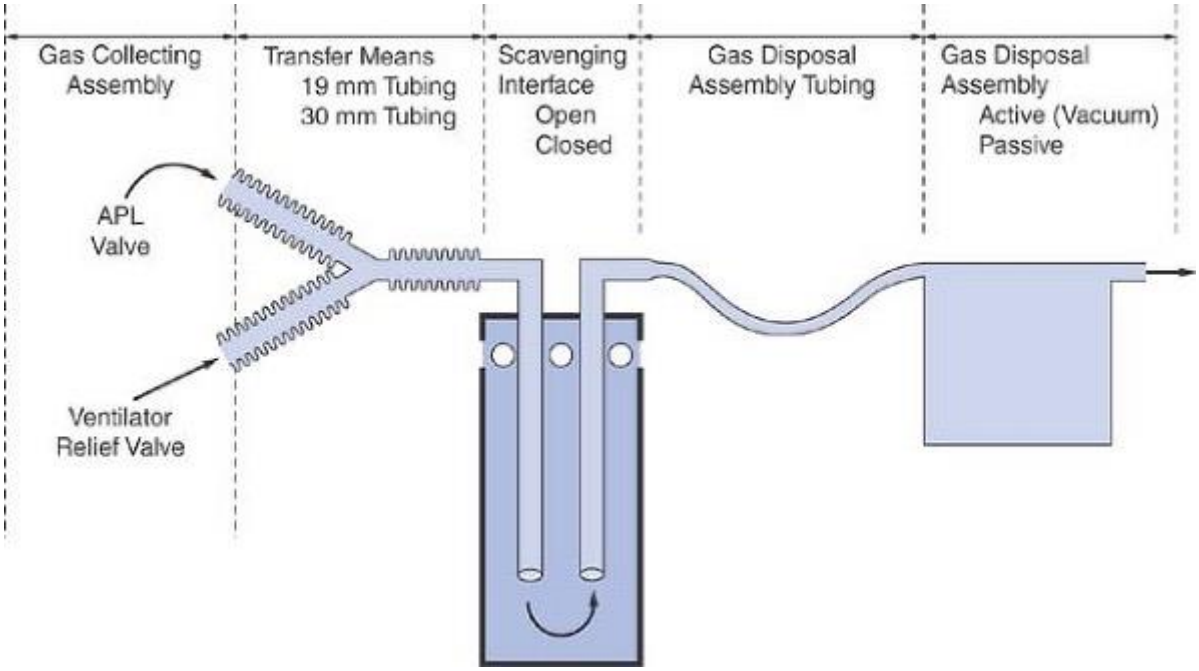

Figure 2: The five components of the scavenging system (9)

The gas disposal assembly consists of an active or passive system. An active system is where the interface is connected to a vacuum or source of negative pressure (53). In an active system, excessive suctioning from the vacuum can result in inadequate patient ventilation and insufficient suctioning can result in an inability to eliminate WAG (53). Active systems are more effective than passive systems in reducing gas exposure, especially in larger hospitals (13). The disadvantage of an active system is that the vacuum system and pipe work is expensive (57). In the passive system, a positive pressure is produced by the patient exhaling the WAG or by manually compressing the reservoir bag (13). A passive system is simple to operate and cheap, although this system may not be practical in all buildings (57).

1.8.2 Pre-anaesthetic inspection of a scavenging system

The HCWs using anaesthesia devices should be familiar with the specific features (58). Lack of understanding anaesthesia equipment will lead to pollution in the operating room. Anaesthetists have the responsibility to check that the scavenging and ventilation systems in the operating room are functioning (9). The six monthly and yearly maintenance of the anaesthesia devices and associated equipment is the responsibility of the anaesthetist together with the anaesthesia technician if available (58). The Anaesthesia Apparatus Checkout Recommendations of 1993 (59) provides guidelines for anaesthetists to check the scavenging system. According the guidelines, the anaesthetist must check that the scavenging system is connected to both the adjustable pressure-limiting valve and the ventilator relief valve. The scavenging vacuum is assessed with a bobbin. The bobbin must be between the minimum and maximum marks (9). Occlude the Y-piece and open the adjustable pressure-limiting valve. The absorber pressure gauge should read zero when the scavenger reservoir is completely collapsed on minimum oxygen flow. Press the oxygen flush to distend the reservoir bag fully. The absorber pressure gauge should then read less than 10 cmH_20. The modern anaesthetic machines have different techniques to check the safety of the scavenging system, therefore the American Society of Anaesthesiologists can't update the 1993 guidelines (9)

1.8.3 Ventilation systems

Ventilation in the operating room is at a high airflow rate to prevent bacterial contamination. The ideal flow for ventilation is when the circulating air can blend with up to 80% of the fresh air. The ventilation system should be structured in a way that flow is unidirectional and turbulence is decreased. Recirculation of air is not suitable for WAG disposal. The ventilation in the recovery room should have at least six air changes to decrease the exposure to WAG (16).

1.8.4 Monitoring of waste anaesthetic gas concentrations in the operating room

There are four different sampling methods for monitoring the trace levels of WAG. Monitoring will aid in detecting early leaks. The four methods are; grab sampling,

time-weighted average sampling, continuous sampling and the measuring of WAG with passive dosimeters.

Grab sampling is a method used to detect any leaks of WAG caused by a high-pressure system. Grab sampling measures steady state levels. The air sample is taken when the operating room is not in use. This method may not be a true reflection of an active operating room and the results may be delayed. Grab sampling is a method whereby an air sample is taken in an inert container, sealed and sent off to a laboratory for analysis (47).

Time-weighted average sampling is the conventional method of monitoring and the results indicate the average exposure over time. The operating room air is continuously sampled over a one- to eight-hour period. The air is collected into a bag by means of a pump and in the end, the content gets analysed in a laboratory (47).

Continuous sampling is the most convenient method. An infrared analyser continuously samples and analyses the WAG in the operating room. The advantage of the infrared analyser is that it can display the time-weighted average, is portable, has good battery power, can be used for grab sampling and detects early leaks in the operating room.

Passive dosimeters are badges to measure exposure to nitrous oxide in the breathing zone of the operating room HCW. The trapped nitrous oxide is later released in a laboratory to provide results in ppm (47).

1.8.5 Alternative methods for waste anaesthetic gas disposal

Charcoal canisters can eliminate anaesthetic agents when incorporated into the outlet of the breathing system. The advantage of this is that it has no set-up cost and is mobile. The disadvantages are that it needs to be replaced after twelve hours of use, is very expensive and if heat is applied to the canister it releases the absorbed inhalational agent (57).

Another alternative is zeolite absorbers that can be placed in the WAG outlet (60). Zeolite has the potential to reduce the impact of WAG on the environment with the ability to absorb up to 86% of desflurane. The absorbed desflurane can then be

recovered and reused if a purification system is available. This makes the zeolite filters more cost effective (60).

1.9 Current views of healthcare waste management

1.9.1 Anaesthetists' knowledge of waste anaesthetic gas exposure

One of the most concerning health hazards in anaesthesia is the chronic exposure to high concentrations of WAG. A study done in Turkey in 2015 assessed anaesthetists' knowledge of, and approach to maintenance, calibration and cleaning of anaesthesia devices. Most of the respondents had less than five-year experience as anaesthesiologists. In the healthcare setting, anaesthetists and anaesthetic technician are both responsible for ensuring that the six monthly and annually maintenance on the anaesthetic machine is done. Of the participants, 62.7%, said that their organisation does six monthly and once a year anaesthetic machine maintenance. Of the participants, 63.7%, did not routinely check their scavenging system and 80.5% did not know the negative flow value required for the scavenging system. The author concluded that anaesthetists needed more training regarding issues of maintenance, calibration and cleaning of anaesthesia devices (58).

In Ghana, at an annual refresher course in 2017, a study was conducted amongst 71 anaesthetic care providers to assess their knowledge on chronic exposure to WAG. The majority, 90.1%, perceived being chronically exposed to WAG, however only 40.8% knew that WAG had a recommended exposure limit for the workplace. The 5% who perceived that they were not exposed to WAG had functioning scavenging systems at their healthcare facility. Poorly functioning scavenging systems and Jackson Reece circuits were amongst the leading causes, 28.2% and 28.2%, respectively, cited by the participants as sources associated with an increased risk to chronic exposure of WAG. The common symptoms related to chronic exposure to WAG by the participants were tiredness, headaches and irritability by 87.3%, 70.4% and 35.2%, respectively. All the respondents applied precautionary practices to minimise their exposure to WAG. The practices provided were a functioning scavenging system (100%), regional anaesthetic techniques (95.8%), total intravenous anaesthesia (83.1%), circle

system (73.2%), functioning ventilation (23.9%), tight fitting facemask and avoiding the Jackson Reece circuit (16.9%) and low fresh gas flow anaesthesia (7%). In conclusion, the anaesthetic providers had adequate knowledge on sources that can lead to an increased risk of WAG exposure, on health effects related to chronic exposure and on the available precautionary practices (61).

1.9.2 Precautionary practises reducing waste anaesthetic gas exposure

Precautionary practices to reduce WAG have been available for years. NIOSH conducted a national survey in 2011 to examine the adherence to precautionary measures and the use of exposure controls amongst anaesthetic care providers, which reflects their knowledge. The surveyed population consisted of 1104 physician anaesthesiologists, 1783 nurse anaesthetists and 100 anaesthesiologist assistants. Most of the respondents, 82%, had training on the safe handling of anaesthetic gases. Half of them, 54%, reported that the employer provided the standard procedures required to minimise exposure to WAG and nearly all the respondents, 97%, used scavenging systems every day. For the remaining 3%, the scavenging systems were not functioning or were unavailable. The precautionary practices discussed were the following: checking the delivery system for leaks, starting the anaesthetic gas flow after the mask was applied and turning off the anaesthetic gas before the carrier gas. Most of the respondents, 95%, checked the delivery system for leaks before use. Only 65% of the paediatric anaesthetists started the anaesthetic agent after they had applied the mask to the paediatric patient and therefore had lower adherence to precautionary practices. The most common fresh gas flow technique was high flow followed by low flow. Almost all, 86%, used key-fillers or closed system techniques to fill the vaporisers and 17% used a funnel. In general, the precautionary practices of the anaesthetic care providers were very good. Unfortunately, only 30% of the respondents reported WAG monitoring in their working environment and even fever monitored personal exposure. The availability of ventilation in the recovery room was unknown (24).

1.9.3 Knowledge of occupational hazards, precautionary practices and associated risks

Sharps injuries are a common health hazard in the operating room with serious complications, therefore Sharma et al (62) assessed the knowledge, attitude and practices amongst HCWs on needle stick and sharps injuries in 2010 at a cardiac hospital in Delhi. The study sample consisted of mostly nursing staff, 52.6%, the others 26.3% were doctors. Most, 91.5%, of the HCWs knew that a needle stick or sharps injury should be reported and 94.7% knew about the standard precautions. A needle attached to a syringe was the most common type of sharps injury. A concerning observation was that 10.6% of the HCWs did not wear gloves during phlebotomy and 34.2% documented that recapping and bending of needles are allowed. Sharma et al (62) concluded that there is a gap in the knowledge on preventative measures and associated risks with needle stick and sharps injuries (62).

Due to the vulnerability of the HCWs to occupational health hazards, a study was conducted in 2016 in Nigeria. The study focused on the HCWs knowledge, attitude and perception of occupational hazards and the associated precautionary practices. The participants included medical doctors and nursing staff. The nursing staff constituted 52.4% of the study and the majority, 89%, had good knowledge on the occupational hazards in their working environment. Safety precautions to prevent occupational hazards were recognised by 99.7% of the participants and 94.5% perceived that a major hazard is needle stick injuries. Recapping used needles is not part of the CDC for disease control and prevention standard precautions and 81.1% of the HCWs agreed. The majority, 98.2%, indicated that sharps should be disposed into a sharps container after use and 95.8% stated that the sharps container should be in close proximity during a procedure. Most of the respondents, 93.5%, reported that they comply with safe precautionary practices when disposing of contaminated sharps. Amongst the participants, 98.3%, believed that the responsibility for occupational hazards in the healthcare setting should be shared between the hospital management and the staff and 99% felt that training and personal protective equipment should be compulsory. Only half, 52.1%, of the participants were compliant with the safety precautions provided

which was due to a lack of safety equipment, time and it being inconvenient. More than half of the participants, 58%, attained knowledge through their professional training, while 6% attained it from pre-employment orientation. The study concluded that knowledge was related to previous education and from the results, the researcher suggested that pre-employment and routine training, together with safety precautionary drills, should be institutionalised for HCWs in order to minimise the risks associated with occupational hazards (63).

In 2017, another Nigerian study conducted at the University of Nigeria Teaching Hospital investigated the knowledge, attitude and practises of hospital waste management among HCWs. The study was done due to the detrimental effects of poor waste management on human health and the environment. Most of the HCWs in the study, 80.9%, had heard of healthcare waste management and 42.6% knew that there is a law that applies to it. Only 57.4% of the participants were aware of the facility's waste management plan and team. The participants knew about the types of treatment and disposal methods available for the management of healthcare waste and the disposal methods were burning pits, incineration, chemical disinfection, burying, recycling, sanitary landfill and composting. The mismanagement of the disposal of healthcare waste can lead to disease transmission and 94.8% of the participants were aware of this. Only 21% of the participants dispose their healthcare waste into specific colour coded containers, despite 54.8% being aware of the different colour coded containers available. Only 22.6% of the participants had training in health waste management. The study concluded that the poor practice was due to inadequate training in healthcare waste management (64).

In Mpumalanga in November 2016, a study showed that a high proportion, 44.9%, of HCWs (doctors, nursing staff, dentists and allied health) did not have adequate knowledge regarding the disposal of healthcare waste. The majority, 61.8%, did, however, dispose of medical waste adequately. The level of knowledge and adequacy of practice related to specific professional categories (although statistically insignificant). The researchers suggested that more regular training should improve the level of knowledge of the HCW and may further increase compliance with the guidelines on disposal of healthcare waste (65).

1.9.4 Knowledge, attitude and practices related to healthcare waste management

In 2014, Adogu et al (66) assess the healthcare waste management knowledge and practices of HCWs in a general hospital in Anambra, Nigeria. The study population consisted of doctors, nurses, pharmacists, laboratory technicians and healthcare attendees. Most of the doctors, 90%, and the nurses, 90%, knew about waste segregation and 80% of the doctors knew it should be segregated at source. Only 35.7% of the doctors knew that sharps must be separated from other waste and 60% knew about the colour coded bags for different waste materials. Furthermore, 80% of doctors knew which waste should go to the landfill site and 85% knew which should be incinerated. With regard to the general practice of waste management, 80% of all participants dispose of their waste in the correct manner. A concerning result was that only 17% of the participants reported to always wearing protective equipment when handling waste, whereas 45% sometimes and 38% rarely wear the necessary personal protective equipment. The study showed a significant difference in the knowledge of healthcare waste management between the different groups of HCWs. Most of the doctors, 80%, and nurses, 60%, attended training on waste management (66).

Mashao (67) assessed the knowledge and practices of HCWs on healthcare waste disposal at George Masebe Hospital in Limpopo, South Africa, in 2016. The overall finding was that only 43% of the participants had adequate knowledge of the disposal of healthcare waste. Of the participants, only 49.6% complied with healthcare waste precautionary practices. Of the participants who had sufficient knowledge, 44.3% complied with precautionary practices in place. The study, however, showed that there was no relationship between the knowledge and practices of the HCWs (67).

In 2018, Olaifa et al (68) did a study to assess the knowledge, attitude and practices of healthcare waste management amongst 241 HCWs, including non-HCWs, at a district hospital in Kwazulu-Natal. The majority of the HCWs, 67.7%, had an overall poor knowledge of healthcare waste management and 61.3% had poor practices. Only 51.7% of the participants reported that they received formal training on healthcare waste management and 53.9% received supervision during

waste handling. Of the HCWs, 54% had a good attitude towards healthcare waste management. The author suggested that healthcare waste management training should be implemented in undergraduate schools and in healthcare settings to ensure adequate knowledge and practices amongst HCWs.

The knowledge and practices of HCWs, specifically doctors and nurses at Johannesburg Hospital, on the management of healthcare waste were assessed by Ramokate (69) in 2008. There was in general, a low level of awareness about the documents regulating healthcare waste, but most, 84%, of the participants had adequate knowledge of the Johannesburg Hospital Waste management policy. Most, 45.35%, of the participants acquired their knowledge of the policy independently, with only 40.32% acquiring it from seminars or courses. Senior personnel had more knowledge than the junior personnel about the policies of healthcare waste management. Of the participants, 91% segregated waste into general and hazardous healthcare waste and 95% reported that they always wear gloves when handling healthcare waste. The availability of different types of containers for healthcare waste was confirmed by 97% of the participants and 96% knew how to distinguish between the different types of bins and used them appropriately. Of the participants, 16.3% did not agree that HIV/AIDS can be transmitted through infectious waste, but 84% strongly agreed that improper management of healthcare waste could lead to infection transmissions (69).

1.9.5 Training on waste management improves knowledge among healthcare workers

In 2017, Perrego (70) did a quality improvement project at a healthcare facility in Dover, Delaware in the USA to assess the knowledge of 66 perioperative HCWs on hazardous healthcare waste before and after compulsory training. The online training was based on the Occupational Safety and Health Administration guidelines and local policies. The results indicated an overall improvement on knowledge of 5%. As part of the study, Perrego assessed the contents of some of the hazardous healthcare waste bags before and after the training. The correct disposal of hazardous healthcare waste improved from 33% to 69% (70).

Training on healthcare waste management improved the knowledge of HCWs in the surgical departments of Al-Mansoura University Hospital in Egypt. A 2007 study by Mostafa et al (71) showed that training on healthcare waste management improved the knowledge of the nursing staff. Nursing staff spend most of their time with patients and therefore, need to be equipped with the latest information, skills and practices on healthcare waste management. The lack of knowledge of the nursing staff in this study, was due to a lack of pre-employment orientation programs, lack of refresher programs and no handouts or guides regarding healthcare waste management. Repetitive periodic training programs on healthcare waste management are of benefit to create awareness, orientate new staff and provide an opportunity for all staff members to improve their existing knowledge. The author suggested that the results can be used to develop and implement a waste management protocol (71).

1.10 Conclusion

The history of WAG and sharps, risks to healthcare workers (HCW) and the environment, precautionary practices, the South African legislation, standards and guidelines, scavenging and ventilation systems, monitoring of WAG, alternative methods and relevant studies were discussed.

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Cite references in numerical order in the text, in superscript format (Format> Font> Click superscript). Please do not use brackets or do not use the foot note function of MS Word.

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The following are sample references:

1. Jun BC, Song SW, Park CS, Lee DH, Cho KJ, Cho JH. The analysis of maxillary sinus aeration according to aging process: volume assessment by 3-

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Draft article

Knowledge and practices of anaesthetists regarding the disposal of waste anaesthetic gases and sharps in a department of anaesthesiology

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Key words: Knowledge, waste anaesthetic gases, sharps

Abstract

Background

The operating room has numerous healthcare hazards that can lead to detrimental health effects. The South African legislation, standards and guidelines governs the management of hazardous healthcare waste. It is the responsibility of the individual healthcare worker (HCW) and the hospital authorities to take the necessary steps to reduce the risks associated with healthcare waste. Anaesthetists are often exposed to waste anaesthetic gases (WAG) and sharps and if managed poorly, can lead to an unsafe working environment.

Methods

A prospective, contextual, descriptive research design was followed. The study population consisted of anaesthetists working in the Department of Anaesthesiology at the University of the Witwatersrand (Wits). The data were collected through a self-administered questionnaire and analysed using Stata version 15 (StataCorp, USA)

Results

The results indicated that the anaesthetists had inadequate knowledge of the legislation of WAG and sharps disposal, WAG disposal and sharps disposal. However, the knowledge of sharps disposal was greater than the knowledge of WAG disposal. The practices of WAG and sharps disposal varied and only few of the anaesthetists attended training on WAG and sharps disposal.

Conclusion

The knowledge of the anaesthetists of WAG and sharps disposal was poor with the knowledge of sharps being better than the knowledge of WAG. There was low attendance of training of WAG and sharps disposal, with no significant difference between the adequacy of knowledge and those who received training. The results were concerning, especially with anaesthetists in this study working in a high risk environment due to few-functioning scavenging systems and the high incidence of human immunodeficiency virus (HIV) in South Africa.

Introduction

Anaesthesia providers are exposed to numerous occupational hazards that are workplace-related or personal. The workplace related hazards are waste anaesthetic gases (WAG), infections transmitted through sharps injuries and bodily fluids, air-borne infections, musculoskeletal injuries, latex allergy, radiation, magnetic resonance imaging, diathermy, laser smoke inhalation and electromagnetic fields. Personal hazards include substance misuse, stress and fatigue (1).

The Constitution of the Republic of South Africa, 1996 (2) states that “everyone has the constitutional right to have an environment that is not harmful to his or her health and to have an environment protected for the benefit of present and future generations through reasonable legislative and other measure”. The legislation that guides healthcare waste management in South Africa is the National Health Act of 2003 (3), the Occupational Health and Safety Act of 1993 (4), the Hazardous Chemical Substance Regulations of 1995 (5), the National Environmental Management Waste Act 2008 (6) and the Air Quality Act 2004 (7). The South African Bureau of Standards and South African National Standard (SANS) provides the minimum standards to ensure the disposal of hazardous healthcare waste is adequate (8, 9).

It is the responsibility of anaesthetists to familiarise themselves with the risks associated with WAG and sharps and to be updated on the latest knowledge, education and training (9). The anaesthetist should routinely check that the equipment in the operating room is safe to use and functioning (10). The anaesthetist plays a vital role in managing sharps disposal from generation to adequate segregation (9).

Poor management of WAG and sharps can lead to detrimental effects on human health and the environment. If the scavenging and ventilation systems in the healthcare facility, especially in the operating room are non-functional, the entire team is at risk of being chronically exposed to high concentrations of WAG (11). Acute exposure to high concentrations of WAG can lead to headaches, irritability, fatigue, nausea, drowsiness and difficulty with judgement and coordination.

Chronic exposure may lead to congenital abnormalities, genetic damage or cancer (12). Chronic exposure to nitrous oxide is associated with significant neurological effects (13). Nitrous oxide is known as a greenhouse gas and together with the other anaesthetic agents have the ability to destroy the ozone layer (14). The improper disposal of sharps can lead to the transmission of blood-borne infections to the anaesthetist, other healthcare workers (HCWs), waste handlers and scavengers at landfill sites (1, 15). The common blood-borne infections related to needle stick injuries are human immunodeficiency virus (HIV), hepatitis B and hepatitis C (1). The prevalence of HIV in South Africa in 2018 was as high as 13.1% (7,52 million people) (16).

Anaesthetists must have adequate knowledge and comply with precautionary practices to reduce the risks associated with WAG and sharps disposal to ensure a safe working environment for all HCWs. Regular training on healthcare waste management amongst HCW has been shown to improve knowledge, awareness and practices (17). There are limited literature regarding anaesthetists knowledge and practice of WAG or sharps disposal. The aim of this study was to describe the knowledge and practices of anaesthetists regarding the disposal of WAG and sharps in the Department of Anaesthesiology at the University of the Witwatersrand (Wits).

Methods

Approval to conduct the study was obtained from the Human Research Ethics Committee (Medical) and other relevant authorities. A prospective, contextual, descriptive research design was followed.

The study population consisted of anaesthetists working in the Department of Anaesthesiology at Wits. The sample size were determined by the response rate. A minimum of 60% (125) of the anaesthetists in the department was considered an acceptable sample size (18). A convenience sampling method was used. Interns and anaesthetists who declined participation were excluded from this study.

The draft questionnaire was developed following a review of the national legislation, standards, guidelines and relevant literature, thereby ensuring content

validity. The draft questionnaire was reviewed by three senior consultants, thus ensuring content and face validity. The reviewers' comments were incorporated into the final questionnaire. Each question had only one correct answer and each correct answer was allocated one mark. Unanswered questions were considered incorrect.

The questionnaire consisted of six sections namely:

- Section 1: demographics
- Section 2: knowledge of the legislation (5 questions)
- Section 3: knowledge of WAG disposal (13 questions)
- Section 4: practice of WAG disposal (5 questions)
- Section 5: knowledge of sharps disposal (16 questions)
- Section 6: practice of sharps disposal (5 questions).

All the anaesthetists in the department were given an opportunity to participate in the study, with the data being collected at several departmental academic meetings. The study was explained to the anaesthetists present at the meetings and those who agreed to participate received an information letter and a questionnaire. The researcher was present during the completion of the questionnaires to assist with any queries and to prevent data contamination. Each participant was asked to fold their questionnaire in half and place it in the sealed box, even if they did not complete it. The modified Angoff method (19) was used to determine adequate knowledge (pass mark) of 60%.

A Microsoft® Excel spreadsheet was used to capture data. Data were analysed in consultation with a biostatistician using Stata version 15 (StataCorp, USA). Categorical variables were described using frequencies and percentages and compared using Fishers exact tests. The overall knowledge score was normally distributed and reported using a mean and standard deviation. Knowledge scores for the sections were not normally distributed and were reported using medians and interquartile ranges and compared between groups using Mann-Whitney U tests. A p value of <0.05 was considered statistically significant.

Results

Of the 133 questionnaires distributed, 127 (95.5%) were completed and returned. This represents 61.1% of anaesthetists in the department. Table I provides a summary of participant characteristics.

Table I Participant characteristics

Characteristics	Number	Percentage
Age (years)		
20 – 30	31	24.4
31 – 40	75	59.1
41 – 50	9	7.1
>50	12	9.5
Sex		
Male	46	36.2
Female	81	63.8
Designation		
Medical officer	19	15
Registrar 1st – 3rd year	50	39.4
Registrar 4th year	20	15.8
Consultant or career medical officer	38	29.9
Training		
Waste anaesthetic gas disposal		
Attended	7	5.5
Not attended	120	94.5
Sharps disposal		
Attended	30	23.6
Not attended	97	76.4
Is your scavenging system functioning?		
Yes	28	22.1
No	54	42.5
I don't know	45	35.4
Are you familiar with the Centres for Disease Control and Prevention		
Yes	40	31.5
No	87	68.5

The overall mean knowledge score (SD) in this study was 53.2% (8.5), this and the knowledge scores for each of the sections are shown in Table II. Overall 31 (24.2%) participants passed the test by achieving a score of ≥ 60**%.** For the questionnaire as a whole, 15 (21.7%) junior and 16 (27.6%) senior anaesthetists passed. This difference was not statistically significant (p=0.5350).

A question description and the number of correct answers is shown in Table II.

Table II Question description and correct answers

Question description	Correct
Questionnaire overall (mean, SD)	**53.2% (8.5)**
Knowledge of legislation	**n (%)**
South African law applying to HCW management	33 (26.0)
Responsible for HCWs' training	94 (74.0)
Training on hazardous chemical substances	21 (16.5)
Responsible for waste segregation	74 (58.3)
Responsible for reporting unsafe or unhealthy practices	122 (96.1)
Score (median, IQR)	**60% (40.0 – 60.0)**
Knowledge of waste anaesthetic gas disposal	**n (%)**
Sevoflurane exposure limit in ppm	17 (13.4)
Time-weighted average	50 (39.4)
Anaesthetic agents with global warming risk	63 (49.6)
Effects associated with nitrous oxide	94 (74.0)
Precautionary practices to reduce WAG in theatre	57 (44.9)
Devices involved in the disposal of WAG	44 (34.7)
Breathing circuit compatibility with scavenging system	121 (95.3)
Transfer tubing gauge size	5 (3.9)
Waste anaesthetic gas pathway, after the disposal system	89 (70.1)
Measurement of waste anaesthetic gas in theatre	7 (5.5)
Effective air exchange in theatre	22 (17.3)
Effective air exchange in post anaesthetic care unit	44 (34.6)
Ventilation dynamics in theatre	48 (37.8)
Score (median, IQR)	**38.5% (30.8 – 46.2)**
Knowledge of sharps disposal	**n (%)**
Hospital sharps disposal protocol	98 (77.2)
Colour of sharps disposal container	125 (98.2)
Symbol indicating sharps disposal container	108 (85.0)
Fill level of sharps disposal container	121 (95.3)
Reusable sharps disposal containers	64 (50.4)
Infections transmitted through improper sharps disposal	119 (93.7)
Sharps associated with highest risk of HIV transmission	103 (81.1)
Transmission risk of HIV through a needle stick injury	50 (39.4)
Standard precaution	106 (83.5)
Unsafe practices for disposing of sharps	77 (60.6)
Reduction of sharps injuries	113 (88.9)
Segregation of sharps	74 (58.3)
Storage of sharps at healthcare facility	5 (3.9)
Temperature for storage of sharps at healthcare facility	11 (8.6)
Disposal of sharps in current facility	99 (77.9)
By-product of incineration	20 (15.7)
Score (median, IQR)	**62.5% (56.3 – 68.8)**

The practice of waste anaesthetic gas and sharps disposal is shown in Table III.

Table III Practice of waste anaesthetic gas and sharps disposal

Question description	Number (%)
Practice of waste anaesthetic gas disposal	
Frequency of facility's monitoring of waste anaesthetic gas concentrations	
Yearly	3 (2.4)
Six monthly	5 (3.9)
Never	23 (18.1)
I do not know	96 (75.6)
Daily checking of scavenging system	
Yes	57 (44.9)
No	70 (55.1)
Continuation of list if scavenging system non-functioning	
Yes	109 (85.8)
No	18 (14.2)
Authorities informed of non-functioning scavenging system	
Yes	39 (30.7)
No	88 (69.3)
Gloves used for cleaning spillage of liquid anaesthetic agent	
Yes	47 (37.0)
No	80 (63.0)
Practice of sharps disposal	
Planning disposal of sharps before procedure	
Yes	67 (52.8)
No	60 (47.2)
Personal protective equipment when performing a procedure involving sharps	
Yes	105 (82.7)
No	22 (17.3)
Reason for answering no to above question	
No time to put on gloves	3 (13.6)
It is inconvenient	12 (54.6)
It is not available	3 (13.6)
Cost saving	4 (18.2)
Use of engineered controlled devices to minimise sharps injuries	
Yes	26 (20.5)
No	101 (79.5)
Replacement of sharps container in your operating room	
Everyday	6 (4.7)
Every week	2 (1.6)
When it is 75% full	74 (58.3)
When it is 100% full	45 (35.4)
Reporting of inadequate sharps disposal to authorities	
Yes	34 (26.8)
No	93 (73.2)

In Table IV a comparison between junior and senior anaesthetists' knowledge and between knowledge and training is shown

Table IV Comparison between junior and senior anaesthetists' knowledge and between knowledge and training

Questionnaire overall	Mean %	Standard deviation %	P-value
Junior	52.2	8.5	0.5350
Senior	54.4	8.4	
Knowledge of legislation	**Median**	**Interquartile range**	**P-value**
Junior	60.0	40.0 – 60.0	0.5324
Senior	60.0	40.0 – 60.0	
Knowledge of waste anaesthetic gas disposal			
Junior	46.2	30.8 – 46.2	0.6479
Senior	38.5	30.8 – 46.2	
Knowledge of sharps disposal			
Junior	62.5	56.3 – 68.8	0.0019
Senior	68.8	62.5 – 75	
Training in waste anaesthetic gas disposal			
Yes	30.8	26.9 – 42.3	0.2674
No	38.5	30.8 – 46.2	
Training in sharps disposal			
Yes	68.8	56.3 – 68.8	0.9367
No	62.5	56.3 – 68.8	

Discussion

The operating room has numerous healthcare hazards that can lead to detrimental health effects. The South African legislation, standards and guidelines governs the management of hazardous healthcare waste. It is the responsibility of the individual HCW and the hospital authorities to take the necessary steps to reduce the risks associated with healthcare waste. Anaesthetists are often exposed to WAG and sharps and if managed poorly, can lead to an unsafe working environment.

The overall knowledge of WAG and sharps disposal of the anaesthetists was poor (53.2%), with only 24.2% achieving a score of more than 60%, indicating adequate knowledge. This is lower than the other South African studies that assessed knowledge of HCWs regarding healthcare waste management. Adequate knowledge was achieved by 55.1%, 43.0% and 32.3% of participants in the studies by Makhura et al (20), Mashao (21) and Olaifa et al (22), respectively.

The median score for knowledge of legislation was 60%. This is higher than the score in Uchechukwu et al (23) study of 42.6%. Ramokate (24) reported that the awareness of legislation of HCWs in a Johannesburg hospital was low. The higher score in our study could not be explained, however knowledge of the legislation does not necessarily impact on an individual's practice.

It has been stated that WAG exposure in the operating room has reduced significantly due to recommended exposure limits, increased awareness, scavenging systems, effective ventilation and regular machine checks (25). However, Mogodi (26) in Wits affiliated hospitals, showed that only 45% of the scavenging systems were functional, which may expose anaesthetists to high concentrations of WAG. Exposure to high concentrations of WAG can cause headaches, fatigue, drowsiness, poor judgement, neurological, liver and renal disease (12).

This study showed that only 44.9% of anaesthetists check the scavenging system daily and 85.8% of anaesthetists still continue their list despite a non-functioning scavenging system, with only 30.7% reporting this to the hospital authorities. This study also found a low level of knowledge of WAG (38.5%) with only 13.4% knowing recommended exposure limits of sevoflurane, 17.3% knowing the effective ventilation in the operating room and 3.9% knowing how frequently WAG concentrations monitoring should be done. Only 5.5% of the anaesthetists had attended training on WAG disposal, which may be the reason for the low level of knowledge, poor precautionary practices and continuing an operating room list despite a non-functional scavenging system. These results differ from Boiano and Steege (12) where 97% of the scavenging systems were functional, had excellent precautionary practices, and 82% attended training on the safe handling of WAG.

In this study, anaesthetists had better knowledge of sharps disposal than WAG disposal with a median of 62.5% and also more anaesthetists, 23.6%, had received training on sharps disposal. The senior anaesthetists' knowledge of sharps disposal was 6.3% more than the junior anaesthetists which may be statistically significant, but not clinically significant. The greater knowledge may be due to more experience and time spent in the operating room.

The type of infections transmitted through improper sharps disposal was not known by 6.3% of the anaesthetists. This is of concern as the risk of HIV transmission after a sharps injury is 0,3%, the risk of seroconversion is 40% for hepatitis B and 2% for hepatitis C (27). In the studies by Sharma et al (28) and Ramokate (24), 20% and 16.3% did not know the types of infection that could be transmitted via sharps injuries, respectively. The actual risk of transmission of HIV through sharps injuries was known by only 39.4% of anaesthetists and this is of concern given the high incidence of HIV in South Africa (16).

Of anaesthetists, 98.2% knew the colour of the sharps bin and 85% knew the symbol indicating sharps. A possible explanation can be that anaesthetists see the sharps container on a daily basis. Most of the anaesthetists in this study knew that recapping was allowed with a one-handed technique, but in a study by Sharma et al (28) only 34% knew that recapping was allowed, although they did not specify if it was one-handed or two-handed technique. Engineered control devices are sharps injury preventing devices that are not always available in the operating rooms of the Wits affiliated hospitals and only 20.5% of anaesthetists in this study used engineered control devices. Of the anaesthetists, only 58.3% knew that the sharps container had to be replaced when it is 75% full, despite 95.3% knowing the fill line. This may be due to practical reasons, for example doctors not required to replace sharps containers or not applying knowledge to practise.

Waste segregation must occur at the point of generation (29), and only 58.3% of the anaesthetists in this study knew this, which was less than the 90% of HCWs of Adugo et al (30). Inappropriate segregation can result in detrimental health effects to other HCWs and waste handlers.

The results of this study must be read against certain limitations. The study was done contextually in the Department of Anaesthesiology at Wits and the results of the study may therefore not be generalisable to all anaesthetists and institutions. The knowledge of anaesthetists does not always reflect their actual practice. Different facility-based practices at the hospitals affiliated to the University of Wits may also impact WAG and sharps disposal practices.

The overall poor knowledge of WAG and sharps disposal amongst anaesthetists can be improved by education and training on the operating room health hazards, the management of hazardous healthcare waste and the appropriate steps to follow to report unsafe practises. Repetitive training is advised to educate new staff members and provide an opportunity for all staff members to improve on their existing knowledge (17). Regular audits should be done to ensure that anaesthetists apply correct precautionary practises (31, 32).

Conclusion

The knowledge of the anaesthetists of WAG and sharps disposal was poor with the knowledge of sharps being better than the knowledge of WAG. There was low attendance of training of WAG and sharps disposal, with no significant difference between the adequacy of knowledge and those who received training. The results were concerning, especially with anaesthetists in this study working in a high risk environment due to few-functioning scavenging systems (26) and the high incidence of HIV in South Africa (16).

Conflict of interest

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

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Section 3: Proposal

Knowledge and practices of anaesthetists regarding the disposal of waste anaesthetic gases and sharps in a department of anaesthesiology

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3.1 Introduction and problem statement

Anaesthesia providers are exposed to numerous occupational hazards that are workplace-related or personal. The workplace related hazards are waste anaesthetic gases (WAG), infections transmitted through sharps injuries and bodily fluids, air-borne infections, musculoskeletal injuries, latex allergy, radiation, magnetic resonance imaging, diathermy, laser smoke inhalation and electromagnetic fields. Personal hazards include substance misuse, stress and fatigue (1).

The Constitution of the Republic of South Africa, 1996 (2) states that “everyone has the constitutional right to have an environment that is not harmful to his or her health and to have an environment protected for the benefit of present and future generations through reasonable legislative and other measure”. The legislation that guides healthcare waste management in South Africa is the National Health Act of 2003, the Occupational Health and Safety Act of 1993, the Hazardous Chemical Substance Regulations of 1995, the National Environmental Management Waste Act 2008 (3) and the Air Quality Act 2004 (4). The South African Bureau of Standards and South African National Standard provides the minimum standards to ensure the disposal of hazardous healthcare waste is adequate (5, 6).

It is the responsibility of anaesthetists to familiarise themselves with the risks associated with WAG and sharps and to be updated on the latest knowledge, education and training (6). The anaesthetist should routinely check that the equipment in the operating room is safe to use and functioning (7). The anaesthetist plays a vital role in managing sharps disposal from generation to adequate segregation (6).

The poor management of WAG and sharps can lead to detrimental effects on human health and the environment. If the scavenging and ventilation systems in the healthcare facility, especially in the operating room are non-functional, the entire team is at risk of being chronically exposed to high concentrations of WAG (8). Acute exposure to high concentrations of WAG can lead to headaches, irritability, fatigue, nausea, drowsiness and difficulty with judgement and

coordination. Chronic exposure may lead to congenital abnormalities, genetic damage or cancer (9). Chronic exposure to nitrous oxide is associated with significant neurological effects (10). Nitrous oxide is known as a greenhouse gas and together with the other anaesthetic agents have the ability to destroy the ozone layer (11). The improper disposal of sharps can lead to the transmission of blood-borne infections to the anaesthetist, other healthcare workers (HCWs), waste handlers and scavengers at landfill sites (1, 12). The common blood-borne infections related to needle stick injuries are human immunodeficiency virus (HIV), hepatitis B and hepatitis C (1). The prevalence of HIV in South Africa in 2018 was as high as 13.1% (7,52 million people) (13).

The National Institute for Occupational Safety and Health (NIOSH) (9) conducted a survey in 2011 to assess the precautionary practices of anaesthetic care providers when administering an anaesthetic agent. Adherence to precautionary practices by the anaesthetic care providers was exceptional. This result was supported by Darkwa et al (14) in 2017. The majority, 97%, of the participants in the NIOSH survey had functional scavenging systems in their healthcare facilities (9). In contrast, Mogodi (15) found only 45% of the available scavenging systems to be functional at the core hospitals of the University of the Witwatersrand (Wits). In the NIOSH survey, 82% of the anaesthetic care providers did receive training on the safe handling of WAG but only 30% reported that monitoring of WAG concentrations were done in their working environment (9).

Aluko et al (16) showed that HCWs were knowledgeable about the occupational hazards in their healthcare setting, however, most of the HCWs did not comply with precautions when managing sharps disposal (16). This finding was confirmed in 2017 by Uchechukwu et al (17). A study by Makhura et al (18), in 2016, showed conflicting results. The authors showed that a high proportion of the HCWs did not have adequate knowledge, but nevertheless still applied safety precautions during sharps and other waste disposal. A gap in the knowledge of the HCW on the preventative measures and associated risks with needle-stick and sharps injuries was confirmed by Sharma et al (19) in 2010. Regular training on healthcare waste management amongst HCW has been shown to improve knowledge, awareness and practices (20).

Anaesthetists must have adequate knowledge and comply with precautionary practices to reduce the risks associated with WAG and sharps disposal to ensure a safe working environment for all HCWs.

There are limited literature regarding anaesthetists knowledge and practice of WAG or sharps disposal. The current knowledge and practices of WAG and sharps disposal of the anaesthetists at Wits are not known.

3.2 Aim and objectives

3.2.1 Aim

The aim of this study is to describe the knowledge and practices of anaesthetists regarding the disposal of WAG and sharps in the Department of Anaesthesiology at Wits.

3.2.2 Objectives

The primary objectives of the study are to describe:

- the knowledge regarding the national legislation regulating WAG and sharps disposal
- the knowledge of WAG disposal
- the knowledge of sharps disposal
- the practices of WAG disposal
- the practices of sharps disposal.

The secondary objectives of this study are to compare:

- the knowledge of WAG and sharps disposal between junior and senior anaesthetists
- level of knowledge to training.

3.3 Research assumptions

The following definitions will be used in this study.

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

Medical officer: is a qualified doctor practicing in the Department of Anaesthesiology under specialist supervision. Medical officers with more than 10 years of anaesthetic experience are career medical officers and are regarded as consultants.

Registrar: is a qualified doctor who is registered with the Health Professions Council of South Africa as a trainee anaesthesiologist.

Anaesthesiologist: is a qualified doctor who is registered with the Health Professions Council of South Africa as a specialist.

Consultant: an anaesthesiologist or career medical officer.

Junior anaesthetist: in this study refers to a medical officer or a registrar with less than four years of training.

Senior anaesthetist: a registrar with four or more years of training or a consultant.

Adequate knowledge: in this study will be determined by using the modified Angoff method (21).

3.4 Demarcation of study field

The study will be conducted in the Department of Anaesthesiology, affiliated to the Faculty of Health Sciences at Wits. The staff complement of the department is 74 consultants, 112 registrars, and 22 medical officers.

The following are the core hospitals on the Department of Anaesthesiology training platform:

- Charlotte Maxeke Johannesburg Academic Hospital, a 1200-bed central hospital
- Chris Hani Baragwanath Academic Hospital, a 2880-bed central hospital
- Helen Joseph Hospital, a 500-bed tertiary hospital
- Rahima Moosa Mother and Child Hospital, a 338-bed regional hospital
- Wits Donald Gordon Medical Centre, a 190-bed public/private hospital.

3.5 Ethical considerations

Approval to conduct the study will be obtained from the Human Research Ethics Committee (Medical), the Graduate Studies Committee at Wits, and the Head of the Department of Anaesthesiology (Appendix 1).

The researcher will attend academic meetings where the study will be explained and anaesthetists will be invited to participate. Those who are interested will receive an information letter (Appendix 2) and a self-administered questionnaire (Appendix 3). Consent will be implied on the return of the questionnaire. Questionnaires will be numbered for data collection purposes and will not contain identifying information thereby ensuring anonymity. The completed questionnaire will be folded in half and placed into a sealed box. Only the researcher and supervisors will have access to the raw data to ensure confidentiality. The data will be stored in a locked cupboard for six years after the completion of the study. The study will be conducted in accordance with the Declaration of Helsinki (22) and The South African Guidelines for Good Clinical Practice (23).

If the study demonstrates that the anaesthetists have inadequate knowledge and practices on WAG and sharps disposal, the researcher will facilitate education and training workshops.

3.6 Research methodology

3.6.1 Research design

A prospective, contextual, descriptive research design will be followed in this study.

Prospective studies identify a sample and follows it over time to determine outcomes (24). Data will be collected during the course of the study.

Contextual studies are conducted in a specific environment (24).
The study will be conducted amongst anaesthetists working in the Department of Anaesthesiology at Wits.

Descriptive studies are “research studies in which a phenomena are described, or the relationship between variables is examined; no attempt is made to determine cause-and-effect relationships” (24). This study describes the knowledge and practices of anaesthetists regarding WAG and sharps disposal.

3.6.2 Study population

The study population consists of anaesthetists working in the Department of Anaesthesiology at Wits.

3.6.3 Study sample

Sample size

The sample size will be determined by the response rate. A minimum of 60% (125) of the anaesthetists in the department will be considered an acceptable sample size (25).

Sampling method

In this study, a convenience sampling method will be used. Convenience sampling, also known as “availability sampling” involves the including of readily available participants (24), which in this study will be the anaesthetists attending the departmental academic meetings.

Inclusion and exclusion criteria

The inclusion criterion in this study is all the anaesthetists present at departmental academic meetings at the time of data collection.

Exclusion criteria include interns and anaesthetists who decline participation.

3.6.4 Questionnaire development

The draft questionnaire was developed following a review of the national legislation, standards, guidelines and relevant literature, thereby ensuring content validity. The draft questionnaire was reviewed by three senior consultants, thereby ensuring content and face validity. The reviewers' comments were incorporated into the final questionnaire (Appendix 3). The questionnaire contains 34 knowledge and 10 practice questions. Each question has only one correct answer and each correct answer will be allocated one mark. Unanswered questions will be considered incorrect.

The questionnaire (Appendix 3) consists of six sections namely:

- part 1: demographics
- part 2: knowledge of the legislation (5 questions)
- part 3: knowledge of WAG disposal (13 questions)
- part 4: practice of WAG disposal (5 questions)
- part 5: knowledge of sharps disposal (16 questions)
- part 6: practice of sharps disposal (5 questions).

3.6.5 Data collection

To give all the anaesthetists in the department an opportunity to participate in the study, the data will be collected at several departmental academic meetings. Before the meeting, the researcher will approach the chairperson for permission to address the anaesthetists. The study will be explained to the anaesthetists present at the meetings and those agreeing to participate will receive an information letter (Appendix 2) and a questionnaire (Appendix 3). The researcher will be present during the completion of the questionnaires to assist with any queries and to prevent data contamination. Each participant will be asked to fold their questionnaire in half and place it in the sealed box, even if they did not complete it.

The modified Angoff method (26) is one of the most frequently used for setting a pass mark (adequate knowledge) for an examination. This method uses a panel of experts to estimate how often a minimally competent person would answer a test item correctly. It allows judges to modify their estimations after seeing the

estimations of their peers which improves inter-rater agreement between judges (26).

A panel of at least five experts is recommended. Having defined the “minimally competent person” the raters score each test item as “percentage correct” (i.e. how many minimally competent persons, out of 100 would answer the question correctly). Each raters estimates are then entered onto a Microsoft® Excel spreadsheet and the mean and standard deviation for each test item is calculated. Any item that has a standard deviation great than 10 is then discussed with the intent of getting better agreement between the raters. Thereafter each individual rater scores these items again. Should any standard deviation again be above 10, a further discussion and evaluation can be considered (26).

3.7 Data analysis

A Microsoft® Excel spreadsheet will be used to capture data. Data will be analysed in consultation with a biostatistician using the statistical program STATA® version 15 (StataCorp, USA). Categorical variables will be described using frequencies and percentages. The distribution of the data will be determined and the normally distributed continuous variables will be described using means and standard deviations and those not normally distributed using medians and interquartile ranges. Depending on the distribution, the comparisons between continuous variables will be made using unpaired t tests or Mann-Whitney tests. Comparisons between categorical variables will be done using Ficher’s exact tests or Chi-squared tests. A p-value of 0.05 or less will be considered statistically significant.

3.8 Significance of the study

If poor outcomes are obtained that may lead to detrimental health effects, visual aids on correct waste management practices and pre-anaesthetic check lists can be provided. Education and training on WAG and sharps disposal can be facilitated to reduce the risks associated with WAG and sharps in the working environment. Regular auditing can be arranged to measure compliance with precautionary practices. This will ensure a safer working environment for HCWs.

3.9 Validity and reliability of the study

Validity “refers to the degree to which a measurement represents a true value” and reliability “represents the consistency of the measure achieved” (27).

The validity and reliability of the study will be ensured by:

- the use of an appropriate study design
- the use of a draft questionnaire developed after an extensive literature review and therefor providing content validity
- three senior anaesthesiologists having reviewed the questionnaire to provide content and face validity
- the researcher being present during completion of the questionnaire to assist with queries and to prevent data contamination
- performing regular quality checks when entering the data
- analysing data in consultation with a biostatistician.

3.10 Potential limitations

This study will be carried out contextually in the Department of Anaesthesiology at Wits and the results may not be generalisable to other anaesthetic departments. The researcher will distribute questionnaires on different occasions to the anaesthetists, which may lead to data contamination. The data will be collected using convenience sampling. This may only reflect the knowledge and practices of the anaesthetists who attended the specific meetings and not the knowledge and practices of the whole department.

3.11 Project outline

3.11.1 Time frame

Activity	Mar 2019	Apr 2019	May 2019	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Nov 2019	Dec 2019
Proposal preparation										
Literature review										
Proposal submission										
Ethics approval										
Postgraduate approval										
Data collection										
Data analysis										
Draft article										
Submission										

3.11.2 Budget

Item	Price per page	Number of pages	Copies	Total
Proposal	R 1	15	10	R 150
Ethics	R 1	10	6	R 144
Postgraduate form	R 1	2	6	R 12
Information letter	R 1	1	208	R 208
Questionnaires	R 1	9	208	R 1872
Complete report	R 1	100	4	R 400
Grand total				**R 2786**

The Wits Department of Anaesthesiology will incur the costs of paper and printing for the postgraduate application, information leaflet and questionnaires.

3.12 References

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3.13 Appendices

Appendix 1 Request to HOD of Anaesthesiology at the University of Witwatersrand

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

WITS UNIVERSITY

Department of Anaesthesia – University of the Witwatersrand

7 York Road, Parktown, 2193 South Africa • Telegrams "Witsmed" • Telephone (011) 488-4344 • Fax (011) 488-4343

Department of Anaesthesia
Area 361
Charlotte Maxeke Johannesburg Academic Hospital

Tel: 011 488-4344

05 April 2019

Subject: **Permission to collect data from Department of Anaesthesia**

To whom it may concern,

This letter stands to affirm that I, Dr PMV Motshabi, grant permission to Dr Edna Muller, HPCSA number MP 0718270, to collect data in Department of Anaesthesiology at University of Witwatersrand for her study "Knowledge and practices of anaesthetists regarding the disposal of waste anaesthetic gases and sharps in a department of anaesthesiology".

The approximate time frame will be, but not limited to, the months of May to September 2019, until her sample size is obtained. The information obtained from the data will be used for Dr Muller research study for her Masters in Medicine only, and will include information and data relevant to her study.

Yours sincerely,

WITS UNIVERSITY
Dr Palesa Motshabi
Academic Head: Department of Anaesthesia
Head of Clinical Unit: Cardiac Anaesthesia
Tel: +27 (0)11 488 4344
Cell: 083 432 1994
Email: palesa.motshabi@wits.ac.za
Website: www.wits.ac.za
WITS SCHOOL OF CLINICAL MEDICINE
FACULTY OF HEALTH SCIENCES
Charlotte Maxeke Johannesburg Academic Hospital, 6th Floor, Area 361/16, Jubilee Road, Parktown, Johannesburg

Appendix 2 Information letter

Dear Colleague

Hello, my name is Edna Muller and I am currently a registrar in the Department of Anaesthesiology, studying for my M Med at the University of the Witwatersrand (Wits). I would like to invite you to participate in my study: Knowledge and practices of anaesthetists regarding the disposal of waste anaesthetic gases and sharps in a department of anaesthesiology.

Should you decide to participate, you will be required to complete a self-administered questionnaire. Participation is voluntary and if you decide not to participate there will be no negative implications. Consent will be implied upon completion. There will be no incentive for completing the questionnaire. To complete the questionnaire will take approximately 15 minutes. Please do not share information with colleagues. All questionnaires, complete or incomplete must be folded in half and placed into the sealed box provided. No identifying questions will be asked to ensure confidentiality and anonymity. The numbering on the questionnaires if for data collection purposes and only my supervisors and I will have access to the raw data. If the study demonstrates poor outcomes, then education and training workshops will be facilitated on WAG and sharps disposal.

This study has been approved by the Human Research Ethics Committee (Medical) and the Graduate Studies Committee of Wits. Should you require more information, or wish to contact me regarding this study, my mobile number is 079 879 2364. You may also contact the chair of the Human Research Ethics Committee (Medical) on 011 717 1234.

Thank you for your time,

Sincerely,

Edna Muller

Appendix 3 Questionnaire

Knowledge and practices of anaesthetists regarding the disposal of waste anaesthetic gases and sharps in a department of anaesthesiology

Part 1: Demographics

Please select the correct box

1.	**Age in years**
	20 – 30
	31 – 40
	41 – 50
	>51

2.	**Sex**
	Male
	Female

3.	**Designation**
	Medical officer
	Registrar 1st – 3rd year
	Registrar 4th year
	Consultant or career medical officer (>10 years anaesthetics experience)

4.	**Have you attended training on the disposal of waste anaesthetic gases?**
	Yes
	No

5.	**Have you attended training on the disposal of sharps?**
	Yes
	No

6.	**Is the scavenging system in your current healthcare facility functional?**
	Yes
	No
	I do not know

7.	**Are you familiar with the Centers for Disease Control and Prevention standard precautions?**
	Yes
	No

Part 2: Knowledge regarding the legislation of waste disposal

Please select the most correct answer (only one)

1.	**Which South African law does NOT apply to healthcare waste management?**
	National Health Act 2003
	Air Quality Act 2004
	Hazardous Chemical Substances Regulation 1995
	Medicines and Related Substances Amendment Act 2002

2.	**Who is responsible for the training of healthcare workers regarding waste anaesthetic gas and sharps disposal?**
	Health Professions Council of South Africa
	Department of Health
	South African Society of Anaesthesiologists
	South African Bureau of Standards

3.	**The training on hazardous chemical substances does NOT include the following:**
	Personal protection against equipment
	Engineering controls involved for protection
	Events to follow in case of spillage or leakage
	Occupational hazards associated with chemical substances

4.	**Who is responsible for the segregation of healthcare waste?**
	Site cleaner
	Waste handler
	Healthcare Worker
	Employer

5.	**Do you as a healthcare worker have a legal responsibility to report any unsafe or unhealthy practices in your working environment?**
	Yes
	No

Part 3: Knowledge of waste anaesthetic gases

Please select the most correct answer (one only)

1.	**What is the recommended exposure limit in parts per million (ppm) for sevoflurane according to the National Institutes of Health, 2015?**
	2 ppm
	25 ppm
	75 ppm
	100 ppm

2.	**What does the time-weighted-average represent in occupational exposure limits for waste anaesthetic agents?**
	Average airborne exposure in any 8-hour shift over a 40-hour work week which shall not be exceeded
	Average airborne exposure of chemical substances over a 12-hour shift which shall not be exceeded
	Average airborne exposure of anaesthetic gases in the atmosphere over an 8-hour period which shall not be exceeded
	Average airborne exposure of anaesthetic gases over a 7-day period which shall not be exceeded

3.	**Please select the correct sequence of agents from the highest to the lowest global warming risk:**
	Nitrous oxide, sevoflurane, desflurane, isoflurane
	Desflurane, nitrous oxide, sevoflurane, isoflurane
	Nitrous oxide, desflurane, isoflurane, sevoflurane
	Sevoflurane, desflurane, isoflurane, nitrous oxide

4.	**Nitrous oxide exposure can be associated with:**
	Inhibition of thymidalate synthase
	Increase homocysteine levels
	Decrease in myelin synthesis
	All of the above

5.	**Which of the following are NOT precautionary practices in reducing waste anaesthetic gases in the operating room?**
	A daily machine check
	Regional anaesthesia
	Medium flow anaesthesia
	Appropriately sized mask

6.	**Which of these device is involved in waste anaesthetic gas disposal?**
	Charcoal canister
	Ventilator system
	Soda lime
	Heat and moisture exchanger filter

7.	**Which breathing circuit is NOT compatible with a scavenging system?**
	Circle system
	Mapleson A
	Mapleson D
	Jackson Rees

8.	**To avoid misconnections, what is the gauge size of the transfer tubing of the scavenging system?**
	19 mm
	20 mm
	22 mm
	25 mm

9.	**Following the disposal system, where do the waste anaesthetics gases go?**
	Into a recycling device
	Into a cylinder
	Into the atmosphere

10.	**How can you measure waste anaesthetic gas concentration levels in theatre?**
	Grab-sampling
	Threshold limit value sampling
	Intermittent sampling
	Occupational exposure limited sampling

11	**The South African Society of Anaesthesiologists' guidelines for effective ventilation in the operating room is an air exchange of:**
	6 – 10 times per hour
	10 – 15 times per hour
	16 – 19 times per hour
	20 – 25 time per hour

12	**The South African Society of Anaesthesiologists' guidelines for effective ventilation in the post anaesthetic care unit is an air exchange of:**
	≥6 times per hour
	3 – 5 times per hour
	2 – 3 times per hour
	1 – 2 times per hour

13	**Which statement is true for ventilation dynamics regarding waste anaesthetic gas disposal in the operating room?**
	Bidirectional flow from the floor to the ceiling and back
	Positive pressure difference between the operating room and the outside
	Exhaust outlets are near the roof
	Diagonal turbulent flow

Part 4: Practices of waste anaesthetic gas disposal

Please select the most correct answer (one only)

1.	**How frequently does your facility monitor the concentrations of waste anaesthetic gases?**
	Yearly
	Six monthly
	Never
	I do not know

2.	**Do you routinely check your scavenging system on a daily basis?**
	Yes
	No

3.	**Do you continue your list if the scavenging system in your working environment is non-functioning?**
	Yes
	No

4.	**Do you inform your head of department or the occupational health and safety officer if your scavenging system is not working?**
	Yes
	No

5.	**Do you wear gloves when cleaning spillage of a liquid anaesthetic agent?**
	Yes
	No

Part 5: Knowledge regarding sharps disposal

Please select the most correct answer (one only)

1.	**Does the hospital you are rotating at have a sharps disposal protocol?**
	Yes
	No
	I do not know

2.	**According to the South African National Standard what colour should a sharps container be?**
	Yellow
	Green
	Orange

3.	**Which of the following symbols indicate a sharps container?**
	
	
	

4.	**At what filling level is a sharps container full?**
	25%
	50%
	75%
	100%

5.	**Are sharps containers in your current working environment reusable?**
	Yes
	No
	I do not know

6.	**Which of the following can be transmitted through improper sharps disposal?**
	Hepatitis C
	Hepatitis A
	Herpes
	Syphilis

7.	**Which one of the following sharps is associated with the highest risk of human immunodeficiency virus transmission?**
	Scalpel
	Hollow-bore needle
	Contaminated infusion set
	Syringe attached to a needle

8.	**What is the transmission risk of human immunodeficiency virus through a needle stick injury?**
	0.2%
	0.3%
	2%
	3%

9.	**Which of the following is a standard precaution?**
	Recapping a needle with a two-handed technique
	Verbal announcement when disconnecting a needle from a syringe
	Using a predetermined tray (eg kidney dish) to dispose sharps
	Passing the sharps to a trusted colleague close to the sharps container

10.	**Which of the following are unsafe practices when disposing of sharps?**
	Recapping a needle with a one-handed technique
	Re-using a single use needle after rinsing in alcohol
	Discarding a used infusion line into a sharps container
	Autoclaving a reusable needle

11.	**Which one of the following does NOT reduce sharps injuries?**
	Clave type system
	Engineered sharps devices
	Training in sharps disposal
	Bending the needle before use

12.	**When should sharps be segregated?**
	At point of generation
	After a workday
	At the storage site
	Before final disposal

13.	**How long can sharps waste be stored at a healthcare facility?**
	1 day
	7 days
	30 days
	90 days

14.	At what temperature should sharps be stored at a healthcare facility?
	-2 °C
	0 °C
	2 °C
	5 °C

15.	How are sharps disposed of in your current healthcare facility?
	Recycling
	Buried in landfill sites
	Incineration
	Chemical disinfection

16.	Which of the following is a by-product of incineration?
	Dioxins
	Carbon dioxide
	Nitrous oxide
	Sulphur monoxide

Part 6: Practice regarding sharps disposal

Please select the most correct answer (one only)

1.	Do you plan the disposal of your sharps before the procedure?
	Yes
	No

2.1	Do you use personal protective equipment when performing a procedure involving sharps, for example gloves?
	Yes
	No

2.2	If you answered no at the above question, what is the reason?
	No time to put on gloves
	It is inconvenient
	It is not available
	Cost saving

3.	Do you use <u>engineered control devices</u> in your institute to minimise sharps injuries?
	Yes
	No

4.	**When do you replace the sharps container in your operating room?**
	Everyday
	Every week
	When it is 75% full
	When it is 100% full

5.	**Do you report inadequate sharps disposal practices to the head of department of the occupational health and safety officer?**
	Yes
	No

Thank you for answering this questionnaire

Section 4: Annexures

4.1 Ethics approval

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr Edna Muller

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M190439

NAME: (Principal Investigator)	Dr Edna Muller
DEPARTMENT:	Anaesthesiology
PROJECT TITLE:	Knowledge and practices of anaesthetists regarding the disposal of waste anaesthetic gases and sharps in a department of anaesthesiology
DATE CONSIDERED:	26/04/2019
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Juan Scribante, Helen Perri & Cara Redelinghuys
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	29/04/2019

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the Third Floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in **April** and will therefore be due in the month of **April** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

4.2 Graduate studies approval

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

24 June 2019
Person No: 1744273
PAG

Dr E Muller
41 Harebell Street
Weltevredenpark
1724
South Africa

Dear Dr Edna Muller

Master of Medicine in Anaesthesia: Approval of Title

We have pleasure in advising that your proposal entitled *Knowledge and practices of anaesthetists regarding the disposal of waste anaesthetic gases and sharps in a department of anaesthesiology* 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

4.3 Turnitin report

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG | FACULTY OF HEALTH SCIENCES

25 November 2019

The Chairperson
Graduate Studies Committee
Faculty of Health Sciences
University of the Witwatersrand

Dear Professor Papathanasopoulos

Re: M Med: **Knowledge and practices of anaesthetists regarding the disposal of waste anaesthetic gases and sharps in a department of anaesthesiology**

Dr Edna Muller, student number: 1744273, has submitted her research report to Turnitin which revealed a similarity index of 12%. These similarities appear not to be plagiarism but mainly the use of common terminology and phrases specific to the topic of the research.

Yours sincerely,

J Scribante

Juan Scribante
Supervisor

1

1744273:turnitin.docx

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