The practice and knowledge of low flow anaesthesia 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.

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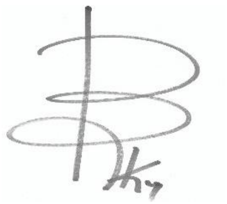
Declaration

I, Dieudonne Bantu Kapajika 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.



27 October 2021

Dedication

A dedication to my late mother and father, Agnes Mbalayi and Vincent Kapajika, whose entire lives were given to their children’s education and success.

Abstract

Background

Low flow anaesthesia has been described and used since the early days of anaesthesia practise. The aim of this study was to describe the practice and knowledge of low flow anaesthesia in an academic department of anaesthesiology.

Methods

A cross-sectional research design was followed using convenience sampling and a self-administered questionnaire. The study population consisted of anaesthetists working in the Department of Anaesthesiology at the University of the Witwatersrand

Results

Of the 142 questionnaires distributed, 140 (98.6%) were returned. The overall mean (SD) knowledge score achieved was 56.3% (13.9%), with juniors achieving 54.3% (14.1%) and seniors 59.9% (12.8%) ($p=0.022$). Of the anaesthetists, 132 (94.3%) routinely practised low flow anaesthesia and 117 (83.6%) used it in paediatric patients. For induction, 125 (89.3%) anaesthetists used a fresh gas flow rate of 6 – 8 l/minute, 130 (92.9%) reduced the flow rate within ≤ 5 minutes after induction and 87 (62.1%) did this in a stepwise fashion. During maintenance, a flow rate of ≤2 l/minute was used by 139 (99.3%) and the same number used air as the carrier gas and 92 (65.7%) reported sevoflurane as the ideal anaesthetic inhalation agent. For emergence, a fresh gas flow rate of 6 – 8 l/minute was used by 115 (82.2%) anaesthetists. The automated system was reported as difficult to use by 107 (76.4%) anaesthetists. The comparisons between the fresh gas flow rate and oxygen concentration used ($p=0.510$), professional designation and use of low flow anaesthesia ($p=0.259$) and professional designation and time to decrease flow rate ($p=0.745$) were not significantly different.

Conclusion

Low flow anaesthesia is routinely practised in the department; however, knowledge was only fair. The practice of low flow anaesthesia was generally in keeping with that suggested in the literature. The majority of the anaesthetists experienced using automated low flow anaesthesia as challenging.

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Lastly, a big thank to Dr Roel Matos Puig and Dr Larissa Cronje for holding my hand during my early steps in practising of anaesthesia.

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Abbreviations

CO_2	Carbon dioxide
CO	Carbon monoxide
FiO_2	Fractional inspired oxygen
MAC	Minimal alveolar concentration
N_2	Nitrogen
N_2O	Nitrous oxide
O_2	Oxygen
VO_2	Oxygen Consumption
Wits	University of the 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 may differ from the author guidelines of the SOUTHERN AFRICAN JOURNAL OF ANAESTHESIA AND ANALGESIA, the journal to which it is intended to be submitted, in order to comply with the University's style guide.

Section 1: Review of the literature

1.1 Introduction

In this section, the background to low flow anaesthesia and its requirements, and the uptake of oxygen (O_2) and inhalational anaesthetic agents during low flow anaesthesia will be described. This will be followed by a discussion of the advantages, disadvantages, and practical conduct of low flow anaesthesia. Lastly, anaesthetists' knowledge, training, and practise of low flow anaesthesia will be presented.

1.2 Background to low flow anaesthesia

In the early days of anaesthetics practise, John Snow, in 1850, noted that inhalational anaesthetic agents are exhaled unchanged in the expired air of anaesthetised patients and concluded that the anaesthetic effect could be markedly prolonged by re-inhaling the unused vapour. In 1924, rebreathing systems equipped with carbon dioxide (CO_2) absorbers were introduced into anaesthetic practise (1).

The era of highly explosive inhalational anaesthetic agents, such as acetylene and cyclopropane, inspired the implementation of the rebreathing technique and the use of CO_2 absorption systems with almost total rebreathing. However, with the development of trichloroethylene, which is incompatible with soda lime, and halothane, in combination with the poor performance of fresh gas flow controls and vaporisers in the low flow range, low flow anaesthesia was largely abandoned (2).

The introduction of circle breathing systems with CO_2 absorption, accurate gas analysers and high-cost inhalational anaesthetic agents has revived the notion of low flow anaesthesia with many advantages put forward (1). There are, however, still safety concerns when used with some inhalational anaesthetic agents, circuits (3) and anaesthetic provider competency.

Herbert and Magee (4) define low flow anaesthesia as "fresh gas flow significantly lower than the patient's minute volume". The authors attributed the first description of modern low flow anaesthesia to Foldes and colleagues (1952), who described it as a fresh gas flow rate of <1 l/minute and minimal flow anaesthesia is attributed to Virtue (1974) who described it as a fresh gas flow of 0.5 l/minute (4).

Baum (1), in a review on low flow anaesthesia, suggests that “the term low flow anaesthesia should be restricted to an anaesthetic technique in which a semi-closed rebreathing system is used, recirculating at least 50% of the exhaled air back to the patient after CO_2 absorption”. Furthermore, Meakin (5) suggested that low flow anaesthesia be defined “as the use of a flow rate less than the patient’s alveolar ventilation”.

Although many classifications exist, the most accepted (3, 6), is the Baker Modified Simionescu classification (7) which classifies fresh gas flow in six categories, namely:

- very high flow >4 l/minute
- high flow 2 – 4 l/minute
- medium flow 1 – 2 l/minute
- low flow 500 – 1 l/minute
- minimal flow 250 – 500 ml/minute
- metabolic flow <250 ml/minute.

1.3 Low flow anaesthesia requirements

In order to practise safe and efficient low flow anaesthesia, certain minimum requirements should be met. Most are equipment related, but importantly an understanding of the basic principles of low flow anaesthesia and pharmacokinetics of inhalation anaesthetics agents by anaesthetists are essential.

One essential prerequisite for the practice of low flow anaesthesia is a leak-proof circle system with a CO_2 absorber and three rules for its efficient use are suggested (4). First, the presence of unidirectional valves between the reservoir bag and the patient on the inspiratory and expiratory side. Secondly, the fresh gas must not enter the system between the patient and the expiratory valve. Finally, the overflow valve must not be placed between the patient and the inspiratory unidirectional valve (4).

Mandatory monitoring of gas concentrations is a requirement for low flow anaesthesia practise as well as a gas flow delivery system with a flowmeter calibrated for flows as low as 50 ml/minute (8). Upadya and Saneesh (9) recommend the following requirements.

- “Flow meters calibrated to flows down to 50 ml/minute.
- A leak-proof circle breathing system and airway devices like cuffed endotracheal tubes (ETT) (LFA [low flow anaesthesia] may be possible with well-fitting supraglottic airway devices also).
- Gas monitoring system providing inspired and end-tidal concentrations of agents. The measurement of expiratory gas concentrations closer to the Y-piece (reflects alveolar gas concentrations) is of crucial importance.
- Vapourisers capable of delivering high concentrations and calibrated to be accurate at low FGF [fresh gas flow].
- The breathing system should have the minimal internal volume to minimise the reserve volume.”

Furthermore, the authors stated that low flow anaesthesia techniques are not suited in the following situations.

- “Anaesthetist not familiar with LFA [low flow anaesthesia].
- Short-term anaesthesia with a face mask.
- Procedures with imperfectly gas-tight airways (i.e., bronchoscopies with a rigid bronchoscope).
- Use of technically unsatisfactory equipment with a high leakage.
- Inadequate monitoring (i.e., malfunction of the gas analyser) or lack of machine/equipment suitable for leak-free closed breathing systems.

- LFA [low flow anaesthesia] techniques combined with a significant overpressure of potent volatile agents should not be applied in situations when other clinical issues like haemodynamic instability require the attention of the anaesthesia provider" (9).

Hönemann and Mierke (10) stated that the modern generation anaesthesia machines meet all requirements to ensure the safe execution of low and minimal flow anaesthesia. The dosage systems and vaporisers operate with a high degree of accuracy, even in the lowest flow range and when breathing systems are tightly sealed. Furthermore, the machines are equipped with a sophisticated monitoring system for both gas flow and composition. This guarantees continuous monitoring of the inspiratory O_2 concentration, the airway pressure, the minute volume and the concentration of the anaesthetic agent (for a flow of <1 l/minute). This technical safety design is a mandatory requirement by national and international standards and regulations (10).

1.4 Oxygen and inhalational anaesthetic agents' uptake during low flow anaesthesia

Hönemann et al. (11) stated that during anaesthesia, patient O_2 uptake corresponds approximately to the basal metabolic rate. The simplified Brody equation allows an estimation of O_2 consumption. Nitrous oxide (N_2O) uptake follows an exponential function and is high during the initial minutes of anaesthesia. With the increasing duration of anaesthesia, tissue compartments become saturated and uptake slows. A rough estimate of N_2O uptake can be calculated by the Severinghaus equation. The uptake of inhalational anaesthetic agents decreases during anaesthesia as a function of tissue saturation. Inhalational anaesthetic agents' uptake is described by the exponential equation derived by Lowe (11)

According to Baum (1) "After the reduction of flow from 4.4 to 0.5 l/minute, an initial increase FiO_2 [fractional inspired oxygen] over the next 30 to 45 minutes can be observed". It will be more noticeable in small or elderly patients with low O_2 uptake than in strong, young, and athletic patients. This initial increase is followed by a slow but continuous decline in the inspired O_2 concentration to lower values, which is more noticeable the higher the O_2 uptake of the patient is (1). During the wash-in and wash-out period in low flow anaesthesia, a high fresh gas flow is used to achieve the desired agent concentration (11).

Bahar et al (12) evaluated the safety of a fixed 1 l/minute fresh gas flow and desflurane anaesthesia in both the wash-in and maintenance periods in patients (including obese patients). The authors demonstrated that low flow anaesthesia without the use of an initial high fresh gas flow during the wash-in period is an effective, safe and economical method that is easy to perform (12).

Leijonhufvud et al. (13) investigated the impact of gas flow on wash-in and wash-out times and inhalational anaesthetic agents (sevoflurane and desflurane) consumption in two anaesthesia machines, the AISYS® (GE, Madison, Wisconsin) and the FLOW-i® (Maquet, Solna, Sweden). Although their study was done with a test lung, the wash-in times were significantly faster with higher flow rates for fresh gas flow from 1, 2 and 4 l/minute. There was, however, a plateau starting at a fresh gas flow of between 4 – 8 l/minute, where increasing the fresh gas flow up to 6 – 8 l/minute did not shorten the time to reach 1 minimal alveolar concentration (MAC) significantly. The Aisys® anaesthetic machine generally had shorter wash-in times for both sevoflurane and desflurane at flow rates of <4 l/minute. Wash-out times were faster at a higher fresh gas flow until a plateau was reached at around a fresh gas flow of 4 – 6 l/minute. Increasing the fresh gas flow further did not lead to faster wash-out times (13).

The consumption of inhalational anaesthetic agents during general anaesthesia, according to Ryu et al (14), mainly depends on the set percentage of the inhalational anaesthetic agent on the vaporiser and the fresh gas flow rate. Throughout surgery, the depth of anaesthesia required is met by increasing and decreasing the percentage of the inhalational anaesthetic agent. Therefore, regulating the percentage of the inhalational anaesthetic is impractical in terms of cost reduction. Nevertheless, using a lower fresh gas flow rate not only has a direct proportional effect on the consumption of the inhalational anaesthetic agent, but has been shown to be safe and effective in several different settings (14).

According to Baum (1), the O_2 concentration in the fresh gas must be increased as the fresh gas flow rate decreases to avoid the delivery of a hypoxic mixture during low flow anaesthesia. There is a marked difference between the fresh gas concentration of the anaesthetic agent and its concentration within the breathing system. This difference increases with decreasing fresh gas flow, but also decreases with decreasing solubility of the inhalational anaesthetic agent. If the concentration of the inhalational anaesthetic agent is changed, the vaporiser must be adjusted to a concentration substantially more than the nominal value intended (1).

1.5 Advantages of low flow anaesthesia

Generally accepted advantages of low flow anaesthesia include cost-saving of anaesthetic agents and other carrier gases, climatisation of inspired gases, reduction of atmospheric pollution, and promotion of a greater understanding of the breathing system and the pharmacokinetics of inhalation anaesthesia (8).

Cost-saving of anaesthetic agents and other carrier gases

Over 90% of an inhalational anaesthetic agent is wasted at high flows of >4 l/minute (15). Using calculations, laboratory models, pharmacy records and measured patient data have shown savings in inhalational anaesthetic agent, and gas usage of 2 – 4 times when using low flow anaesthesia as compared to high flows (15). For example, the reduction of fresh gas flow from 3 l/minute to 1 l/minute results in savings of about 50% of any inhalational anaesthetic agent (6, 16). Ryu et al. (14) concluded that the implementation of a low fresh gas flow rate policy for maintenance of general anaesthesia using sevoflurane reduced the amount of sevoflurane consumed by nearly 40%. Furthermore, the authors suggested that the adoption of similar policies with other inhalational anaesthetic agents and in other institutions may help improve the cost-effectiveness of inhalational anaesthetic agents (14).

Climatisation of inspired gases

Baxter (6) highlighted that inadequate airway humidification and its consequence of damage to bronchial mucosa depend on the duration and intensity of humidity alteration. The cilia and mucosal gland destruction cause flattening of bronchial epithelium, cellular degeneration, increase in desquamation, and keratinisation, which may potentially lead to epithelial ulcerations. The use of low fresh gas flow rates improved mucociliary function in laboratory animals and in patients it provided relative humidity equivalent to in-circuit humidifiers (6). According to Kleemann (17), the temperature of the breathing mixture can get to 30°C after one hour of anaesthesia with a fresh gas flow of 0.6 l/minute, while the breathing mixture temperature is not subject to any variation if fresh gas flow is maintained at ≥1.5 l/minute. The quantity of condensed moisture collected in the respiratory circuit water trap is an obvious sign of humidification provided by low flow anaesthesia (17).

In circumstances where heat and moisture exchangers may not normally be used, the preservation of heat and moisture within the breathing system may be aided using low fresh gas flows (8). With lower gas flows, inspired humidity will be increased, the rate of fall in body temperature reduced, and the subsequent incidence of shivering is lowered (18).

Reduction of atmospheric pollution

All gases delivered from anaesthesia machines are ultimately lost to the atmosphere. Halothane, enflurane, isoflurane all contain chlorine. Although not specifically covered by the Montreal protocol on substances that deplete the ozone layer, these gases are believed to have significant ozone-depleting potential (8). It becomes evident that using low flow anaesthesia lowers the contamination risk because of the reduced total amount of polluting compounds (19).

Upadya and Saneesh (9) strongly believe that anaesthetists should take up environmental stewardship. Because anaesthetists decide on the overall flow rates and composition of the gas delivered, they can impact the overall contribution of anaesthesia gases to environmental pollution. It is being noted that during an average working day, each anaesthetist administering N_2O or desflurane can contribute to the CO_2 equivalent of driving a car for >1 000 km (620 miles) (19, 20).

1.6 Disadvantages of low flow anaesthesia

Disadvantages of low flow anaesthesia include accumulation of unwanted gases in the breathing system (8), and accidental hypoxia and hypercapnia (2).

Accumulation of unwanted gases in the breathing system

Any gases which are not taken up by the patient or absorbed chemically will tend to accumulate and may result in toxicity. These include gases that are exhaled by the patient, contamination of the medical gases or gases resulting from a reaction with the chemical agents used for CO_2 absorption (8).

Substances exhaled by the patient include alcohol, acetone, carbon monoxide (CO) and methane. Therefore, the use of low a fresh gas flow rate is contraindicated in patients who are intoxicated, in uncompensated diabetic states, or who are suffering from CO poisoning (8).

Baxter (6) found that acetone produced by hepatic metabolism is excreted in the expired gas and equilibrates in the anaesthetic circuit during prolonged anaesthesia. Blood acetone concentration may rise, especially in patients with preoperative starvation or when there is increased production (diabetes, cirrhosis). Concentrations >50 ppm may cause nausea, vomiting, and slow emergence (6).

CO produced from the breakdown of haemoglobin or exhaled by smokers may also accumulate in the closed circle system, as do acrylic monomers exhaled when joint prostheses are surgically cemented (18). The recognition of such unwanted accumulation during the period of cementing has led to the recommendations that the breathing system should be vented at this time to prevent rebreathing of these monomers (18).

There will be some accumulation and mixing of gases other than O_2, CO_2, and inhalational anaesthetic agent within the circle breathing system. Nitrogen (N_2) constitutes a major part of ambient air, and it needs to be considered in association with low flow anaesthesia (3). Potential contaminants of medical gas supplies include the lethal gases CO and nitric oxide (NO). While the risks of such contamination are minimal, NO contamination caused a fatality in Bristol in 1965.

More benignly, N_2 and argon may accumulate and cannot be detected by infrared analysers (8).

Peyyety (18), stated that even with initial denitrogenating, N_2 will accumulate in the closed breathing circuit. If O_2 is being supplied by an O_2 concentrator, malfunction of one of the concentrators can cause N_2 to appear in the product gas. Infrared monitors add air to the sample gas after the sample is analysed. If the exhausted gas is returned to the breathing system, N_2 accumulation will be greater than expected (18). This accumulation and mixing may cause a dilution and theoretically lead to a hypoxic gas mixture (3).

Low concentrations of methane (at concentrations of up to 5 ppm versus 1.2 ppm in atmospheric air) may also be found in medical gases and these concentrations could accumulate during prolonged low flow anaesthesia. This may be exacerbated by endogenous methane produced by intestinal organisms and then absorbed (3). Blood methane levels of 2 000 ppm (0.02%) have been found to have no detrimental effect (3). Concentrations of ≥5.4% in O_2 may support combustion. About 14 hours of minimal flow anaesthesia with maximal bowel gas secretion are required to approach combustible concentrations. Methane may also cause an artefactual elevation of infrared measurements of anaesthetic vapour (6). Acetone and hydrogen may accumulate during closed system anaesthesia as well**.** However, dangerous levels are reached only after hours of closed system anaesthesia (18).

It has been recognised that the chemicals used to absorb CO_2 may react with volatile anaesthetic agents. For example, trichloroethylene was known to break down to phosgene which is lethally toxic (8). Halothane reacts with soda lime to produce hydrofluoric acid and bromochlorodifluoroethylene. Desflurane, isoflurane and enflurane react with baralyme to produce CO, but this is less so when soda lime is used (8).

Sevoflurane reaction produces an olefin (alkene) known as compound A which is considered to pose a risk of renal toxicity (8). Nunn (8) highlights that this debate has continued for several years with conflicting evidence and strongly differing views, mainly in the United States of America. It is accepted that prolonged sevoflurane anaesthesia with low fresh gas flows results in proteinuria, glycosuria and enzymuria. However, this has not been shown to be associated with any human clinical manifestations (8).

Nunn (8) stated that most of the laboratory work on renal toxicity was undertaken in rats, where compound A causes acute tubular necrosis at concentrations >250 ppm. It is now known that these studies were invalid due to the marked differences between human and rat renal biochemistry. These concerns led the Federal Drug Administration to recommend that sevoflurane not be used with fresh gas flows of <2 l/minute. This recommendation was only revised in 1997 to suggest that flow rates of 1 l/minute are acceptable but should not exceed 2 MAC (8). However, it has also been suggested that compound A should not be a real clinical concern and that restricting the use of low fresh gas flows with sevoflurane cannot be justified (18).

CO is also produced from the interaction of desiccated absorbent and anaesthetic agent. Low flow anaesthesia preserves the moisture content of the absorbent and consequently may protect against the production of CO. However, if a desiccated CO_2 absorber is present, low flows tend to increase the amount of CO present in the system. CO produced from the breakdown of haemoglobin or exhaled by smokers can also accumulate in the closed circle system (18).

Accidental hypoxia and hypercapnia

Baker (7) concluded that the main barrier to the use of minimal gas flow techniques for general anaesthesia was apprehension and bias by anaesthetists, who learned about their anaesthesia using wasteful gas flows and with “a terror of hypoxic mixtures”. With modern monitoring, “the fear of hypoxic mixtures should decrease, and the excitement and interest in patient physiology and pharmacological responses must replace conservatism and fear of the unknown” (7).

There is, however, a limit to the reduction of the fresh gas flow. To prevent gas volume deficiency, the least gas volume taken up by the patient has to be delivered into the breathing system (1). A fresh gas flow of 500 ml/minute has a larger safety margin than a gas flow of 250 ml/minute (15).

Baum and Aitkenhead (2) point out that during low flow anaesthesia, "there may be a considerable difference between the inspired oxygen concentration and the oxygen concentration in the fresh gas. The lower the fresh gas flow rate and the higher the proportion of rebreathing, the lower the potential inspired oxygen concentration. Therefore, to ensure that the inspired oxygen concentration remains at a safe value, the oxygen concentration in the fresh gas must be increased as the fresh gas flow rate decreases. Compliance with this simple rule is a safe way to avoid the delivery of a hypoxic mixture during low flow anaesthesia" (2).

The use of low flow anaesthesia decreases the efficiency of the CO_2 absorber and increases the risk of hypercapnia. Hypercarbia resulting from an exhausted CO_2 absorber, incompetent unidirectional valves, or the CO_2 absorber being left in the bypass position will be greater when low flows are used (18). CO_2 absorber utilisation time depends predominantly on the degree of rebreathing and the volume of the CO_2 absorber canister. If a fresh gas flow of 4.4 l/minute is used continuously, the utilisation period of a single CO_2 absorber canister filled with one litre of pelleted soda lime ranges between 43 and 62 hours. However, if the flow rate is reduced to 0.5 l/minute, the utilisation period decreases to 10 – 15 hours (2).

Reducing utilisation time of the CO_2 absorber decreases to between one half and one-quarter of the time, which can be gained if a flow of 4.4 l/minute is used. Thus, the performance of minimal flow anaesthesia increases the consumption of soda lime two- to fourfold (21).

1.7 Practical conduct of low flow anaesthesia

There are no formal guidelines on how to conduct low flow anaesthesia but only expert recommendations, which have not been universally adopted. A few of these recommendations will be highlighted.

Welch (15) highlighted that "There are many ways of performing a low-flow anaesthetic, some with highly complex mathematical formulae, but the basic principle is the same. It takes a long time for any change in gas concentration to occur at low-flows. The lower the fresh gas flow the longer this change takes". The author suggested a high fresh gas flow of 6 l/minute for five minutes to hasten the inhalational anaesthetic agent's concentration at the beginning, followed by a decrease to a low flow and then a switch to a high flow at the end for circuit flushing (15). This is consistent with the above-described kinetics of the wash-in and the wash-out periods with a low flow in-between and would constitute a balance between timesaving at induction and emergence versus volatile-saving and gas-saving.

Divekar et al. (22) compared a conventional and computer simulation derived strategy of low flow anaesthesia using isoflurane. The authors suggested a three-step process using a fixed concentration of isoflurane (2.5%) in the initial high flow stage (3 l/minute N_2O plus 1.5 l/minute O_2 for first three minutes), then an intermediate flow stage (1.5 l/minute N_2O plus 1 l/minute O_2 for the next three minutes) and a low flow stage (0.4 l/minute N_2O plus 0.4 l/minute O_2). This dosing is easily memorised, economical and effective. The authors are of the opinion that this may simplify matters for a busy anaesthetist and allow easy adoption and implementation of low flow anaesthesia techniques into routine practise (22).

To enhance O_2 and inhalational anaesthetic agent uptake and the excretion of N_2, a high fresh gas flow is recommended at the start of an anaesthetic (4). When clinically desirable concentrations are reached, the fresh gas flow can be reduced, theoretically to a basal metabolic O_2 consumption rate of approximately 250 ml/minute. This assumes there is no gas leakage and no further uptake by tissues or tubing, although these do occur (4).

Peyyety (18) found that at induction, "by using low fresh gas flows can be accomplished by injecting measured amounts of liquid anaesthetic directly into the expiratory limb of the circuit. Problems associated with this include the following: a) large body stores of nitrogen will be released into the breathing system and will dilute concentrations of other gases. b) If nitrous oxide is being used, it will take a prolonged period of time to establish concentrations high enough to have a clinical effect, and c) rapid uptake of nitrous oxide and volatile agent, as well as high oxygen consumption during this period, mean that the anaesthesia provider will have to make frequent injections and adjustments at a time when he or she is likely to be busy with other tasks". More frequently, induction is achieved by using high flows to allow denitrogenation, establish anaesthetic agent concentrations, and provide O_2 in excess of consumption. During intubation, the vaporiser should be left on and the fresh gas flow turned to a minimum or off until intubation has been completed, and the circuit reattached to the patient. After gas exchange has stabilised, lower fresh gas flows are used (18).

Baum (1) proposed a model of low flow anaesthesia conduct broken down into different phases. The first phase consists of traditional preoxygenation, followed by intravenous induction, paralysis, and airways control. In approximately 85% of cases, the fitted laryngeal mask will allow the fresh gas flow to be reduced to 0.5 l/minute, even if controlled ventilation is performed. For the second phase, the initial high flow phase, the author recommends a duration of 10 – 15 minutes of high fresh gas flow to be used with an O_2 flow of 1.4 l/minute and an N_2O flow of 3.0 l/minute. Vaporiser settings of enflurane 2.5 vol%, isoflurane 1.5 vol%, sevoflurane 2.5 vol%, and desflurane 4.0 – 6.0 vol% are recommended. If these settings are used over the first 10 – 15 minutes, an expired concentration of about 0.7 – 0.8 times the MAC of the respective inhalational anaesthetic agent will be gained in an average adult patient. During the flow reduction phase, the third phase, it was suggested that the flow is reduced to 1 l/minute after 10 minutes to maintain a safe inspired O_2 concentration of about 30%. The O_2 concentration has to be increased to at least 40%, but ideally to 50%, and enflurane increased to 3 vol%, isoflurane to 2 vol%, sevoflurane to 3.0 vol%, and only the desflurane concentration can remain unchanged. In the last phase, when fresh gas flow is reduced to 0.5 ml/minute, in order to maintain a safe, inspired O_2 concentration of at least 30%, the O_2 concentration has to be increased to at least 50%, and the concentration of the enflurane to 3.5 vol%, isoflurane to 2.5 vol%, sevoflurane 3.5 vol%, and the desflurane concentration is raised by 1 vol% (18).

Hönemann and Mierke (10) suggested a practical approach. After preoxygenation with 6 l of 100 % O_2 and intravenous induction, an initial phase with fresh gas flow settings of 1 l/minute of O_2 and 3 l/minute of air resulting in 4 l/minute fresh gas flow and 40% O_2. With vaporiser settings of isoflurane 2.5 vol%, sevoflurane 3.5 vol%, and desflurane 6 vol% the inspiratory O_2 concentration will stabilise between 35 – 40%. Once the target MAC value of 0.8 – 1 has been reached, the fresh gas flow can be reduced, O_2 to 0.3 l/minute and air to 0.2 l/minute, resulting in a 0.5 l/minute fresh gas flow and 68% O_2. The vaporiser settings are then increased, isoflurane to 5 vol%, sevoflurane to 5 vol%, and desflurane to 8 vol%. At the conclusion of the procedure, reducing the vaporiser settings to 0% approximately 10 minutes before the end of the procedure, with a fresh gas flow of 0.5 l/minute allowing for resumption of spontaneous breathing. This allows for a steady decline in the volatile anaesthetic concentration without having to increase fresh gas flows and hence wastage. This is the concept of "coasting". On completion of suturing, prior to extubation, a brief purging of the system with 100% O_2 at 6 l/minute should follow (10).

There are anaesthesia machines with automated low flow anaesthesia capabilities, such as the ZEUS® (Dräger, Lubeck, Germany), the AISYS® the FLOW-i®. These machines use a proprietary algorithm to determine the inhalational anaesthetic agent and carrier gas administration to achieve the targets with the lowest surplus (9). First, the anaesthetist selects a target alveolar concentration of inhalational anaesthetic agent and a target O_2 concentration, either inspired FiO_2 (the ZEUS) or end-tidal O_2 (the AISYS). This automated gas control is a new addition to low flow anaesthesia practice, which helps to reduce anaesthetic waste, cost, and pollution while minimising the ergonomic liability of low flow anaesthesia (9). Due to the inherited savings associated with low flow anaesthesia, its use is likely to become more widespread and may become the new standard of care.

Komesaroff (23) suggested that as low flow anaesthesia techniques are widely used in small animal anaesthesia, that with well-designed, low resistance breathing systems, this technique could replace high flow Ayre's T-piece circuits, even in neonatal anaesthesia.

Welch (15) stated that there is limited information on the use of low flow anaesthesia in paediatrics, with a wide variety of opinions and concerns regarding the leaks with uncuffed endotracheal tubes, dead spaces, and high resistance. Therefore, the author recommends controlled ventilation for low flow anaesthesia in paediatric patients. Meakin (5) concurs with these concerns regarding the use of low flow anaesthesia techniques in paediatric patients, including the problem posed by leaks in the breathing system, questionable economy, predicting inspired anaesthetic and O_2 concentrations, and the possible accumulation of degradation products of sevoflurane. The author concluded that although experience with fresh gas flow rates of <1l/minute is limited in infants and children, studies have shown that such flow rates can be practically and safely used, and airway sealing with both uncuffed endotracheal tubes and laryngeal masks are sufficient to perform low flow anaesthesia in paediatric patients (5).

1.8 Knowledge and training on low flow anaesthesia

Low flow anaesthesia has been extensively investigated and described, however, not much is known regarding the knowledge and training of anaesthetists.

Hanci et al. (24), in 2010 in Turkey, reported a significant reduction in their hospital's use of fresh gas flow during the 3 and 6 months after training of anaesthetic staff and trainees on low flow anaesthesia. Using a practical and theoretical education program, they achieved a 25% reduction in mean fresh gas flow compared with the pre-training period. The mean fresh gas flow decreased from 4 l/minute – 2 l/minute after the training program. In addition, the prevalence of low flow anaesthesia in routine anaesthesia practise increased from 0 – 35% after training. The authors concluded that low flow anaesthesia may be used more frequently if anaesthetists are provided with regular training seminars. The use of low flow anaesthesia applications may be increased further by allocating more time to this technique in anaesthesia training programmes provided at regular intervals (24).

In 2016, Tollinche et al (25) investigated the fresh gas flow rates delivered during general anaesthesia in a New York hospital, which provides both fresh gas flow education and offers ventilators with notification systems to help limit fresh gas flow. The authors concluded that anaesthetists, while receiving education and having the appropriate equipment, failed to follow low flow anaesthesia recommendations. They suggested that anaesthesia departments evaluate and analyse their current practice of gas flow delivery and effect appropriate change as needed to reduce the negative effects of "traditional" anaesthesia gas delivery (25).

Amma et al. (26), in 2014, found that 10.4% of surveyed anaesthetists in India who claimed to use low flows were using flows of >2 l/minute, which does not qualify as low flow anaesthesia.

Baum and Aitkenhead (2) suggested that low flow anaesthesia complications could be avoided if anaesthetists are educated in the use of low flow systems and use monitoring apparatus to determine the appropriate concentrations of gases that are added to the breathing system from the anaesthetic machine.

1.9 Practice of low flow anaesthesia

In London in 1991, Cotter et al. (16) in a departmental survey stated that 96% of the anaesthetists found low flow anaesthesia satisfactory and 68% regarded the low flow circle system as safe and easy to use. Conventional (high flow) anaesthesia was considered easier to use than low flow anaesthesia by 61% of respondents. Most anaesthetists indicated that they would use low flow anaesthesia routinely (16).

Cravero et al. (27), in a 1994 survey of the use of low flow anaesthesia in the United States of America, found that the low flow anaesthesia technique was underutilised, with 12,5% of cases using the technique at university hospital level and 19% in cases at community hospital level. The use was, however, noted to be inhalational anaesthetic agents and surgical procedure dependent (27).

In a survey of 200 anaesthesiologists in India in 2016, Amma et al (26) found that 73% used low flow anaesthesia routinely, with most of them using flows of <1.5 l/minute and 45.1% using O_2 concentrations of 30 – 40%. The majority preferred N_2O as a second gas and sevoflurane as the inhalation agent of choice (26).

Similarly, in a 2017 survey of 250 anaesthesiologists in India, Mahajan and Gupta (28) reported that the vast majority practised low flow anaesthesia despite the lack of adequate monitoring facilities and scavenging systems. Of the anaesthesiologists 12% used fresh flow rate of <0.5 l/minute, 15% used 0.5 l/minute, 32% used 0.5 – 1/minute, 13% used 1 – 1.5 l/minute, 18% used 1.5 – 2 l/minute and 10% used >2 l/minute. The inhalational anaesthetic agents used were halothane, desflurane, isoflurane, and sevoflurane (28).

1.10 Summary

Low flow anaesthesia has gained momentum since the rebreathing circuit was introduced and is currently practised worldwide, although many of its controversial disadvantages remain debated. However, with the era of advanced technology in gas delivery, monitoring, and automated anaesthesia machines, the technique will become more standardised, and the controversies reduced. More work still needs to be done in terms of universally accepted guidelines and training of anaesthetics providers. Advantages of low flow anaesthesia include saving of inhalational anaesthetic agents and carrier gases, climatisation of inspired gases, reduction of atmospheric pollution, promotion of a greater understanding of breathing systems and pharmacokinetics of inhalation anaesthesia. When considering these advantages, it might become the standard of care, and only not be used when a clear contraindication exists.

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Section 2: Author's guidelines

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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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10. All numbers below ten, without percentages or units, must be written in words.
11. Figure numbers: Arabic, table numbers: Roman

Section 3: Draft article

The practice and knowledge of low flow anaesthesia in a department of anaesthesiology

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Keywords: low flow anaesthesia, anaesthetists, knowledge, practise

Abstract

Background

Low flow anaesthesia has been described and used since the early days of anaesthesia practise. The aim of this study was to describe the practice and knowledge of low flow anaesthesia in an academic department of anaesthesiology.

Methods

A cross-sectional research design was followed using convenience sampling and a self-administered questionnaire. The study population consisted of anaesthetists working in the Department of Anaesthesiology at the University of the Witwatersrand.

Results

Of the 142 questionnaires distributed, 140 (98.6%) were returned. The overall mean (SD) knowledge score achieved was 56.3% (13.9%), with juniors achieving 54.3% (14.1%) and seniors 59.9% (12.8%) (p=0.022). Of the anaesthetists, 132 (94.3%) routinely practised low flow anaesthesia and 117 (83.6%) used it in paediatric patients. For induction, 125 (89.3%) anaesthetists used a fresh gas flow rate of 6 – 8 l/minute, 130 (92.9%) reduced the flow rate within ≤ 5 minutes after induction and 87 (62.1%) did this in a stepwise fashion. During maintenance, a flow rate of ≤2 l/minute was used by 139 (99.3%) and the same number used air as the carrier gas and 92 (65.7%) reported sevoflurane as the ideal anaesthetic inhalation agent. For emergence, a fresh gas flow rate of 6 – 8 l/minute was used by 115 (82.2%) anaesthetists. The automated system was reported as difficult to use by 107 (76.4%) anaesthetists. The comparisons between the fresh gas flow rate and oxygen concentration used (p=0.510), professional designation and use of low flow anaesthesia (p=0.259) and professional designation and time to decrease flow rate (p=0.745) were not significantly different

Conclusion

Low flow anaesthesia is routinely practised in the department; however, knowledge was only fair. The practice of low flow anaesthesia was generally in keeping with that suggested in the literature. The majority of the anaesthetists experienced using automated low flow anaesthesia as challenging.

Introduction

Delivery of anaesthesia gases has evolved over the years, from an open to a closed rebreathing circuit and from high fresh gas flow to low fresh flow gas delivery (1). The period 1850 – 1941, called "the pioneer era of anaesthesia" contributed to much of the early work on low flow anaesthesia. This was motivated by cost and safety concerns, as gases were expensive and operating theatres lacked scavenging systems and were polluted with explosive gases, such as cyclopropane and ether, which were popular at this time. A further motivating factor for the use of low flow anaesthesia was heat and humidity conservation (2). A decline in the popularity of the use of low flow anaesthesia occurred between 1945 – 1969, the "era of safety first" after World War II (2). This was due to the development of trichloroethylene which is incompatible with the carbon dioxide absorber (CO_2) soda lime. Another contributing factor was the inaccuracy in halothane delivery due to poor performance of fresh gas flow control rotameters and vaporisers in the low flow range (3). The introduction of novel gas analysers, such as the mass spectrometer (4), high-cost anaesthetic agents and anaesthetic machines with fresh gas control and vaporisers designed for delivery of low fresh flow revived the low flow anaesthesia technique in the 1980s (1).

There is no universally accepted definition of low flow anaesthesia (5). Herbert and Magee (6) define low flow anaesthesia as "fresh gas flow significantly lower than the patient's minute volume". Meakin (7) describes low flow anaesthesia as "the use of a fresh gas flow rate less than the patient's alveolar ventilation". According to Baum and Aitkenhead (3), low flow anaesthesia is "a technique using a rebreathing system which results in at least 50% of the exhaled air being returned to the lungs after CO_2 absorption". Welch (8) is of the opinion that "low flow anaesthesia means that a carrier gas flow of less than two litres per minute is being used to deliver the anaesthetic agent to the patient". Nunn (5) states that low flow anaesthesia implies "a carrier gas flow of less than that attainable with a non-absorber breathing system". Different classifications of fresh gas flow rate have also been proposed, such as the six-category classification by Baker (9) and the four-category classification by Welch (8).

The main advantages of low flow anaesthesia include the cost-saving of inhalation anaesthetic agents and other carriers gases, climatisation of inspired gases and reduction of atmospheric pollution, as well as promoting a greater understanding of breathing systems and the pharmacokinetics of inhalation anaesthesia (5, 10). Accumulation of unwanted gases in the breathing system, substances exhaled by the patient, contaminants of medical gases, products of reactions with absorbents, accidental hypoxia, over-usage of CO_2 absorbers and hypercapnia, are the common disadvantages of low flow anaesthesia (3, 5).

Tollinche et al. (11) stated that “it is of the essence, given the multitude of benefits stemming from a simple change, that anaesthesia departments evaluate and analyse their current practice of gas flow delivery and initiate appropriate change as needed to reduce the negative effects of traditional anaesthesia gas delivery”. The aim of this study was to survey the practice and knowledge of low flow anaesthesia among anaesthetists in the Department of Anaesthesiology at the University of the Witwatersrand (Wits).

Methods

A cross-sectional research design was followed in this study. Approval to conduct the study was obtained from the Wits Human Research Ethics Committee (Medical) M190834 and other relevant authorities.

The population consisted of the anaesthetists working in the Department of Anaesthesiology. The entire accessible population was 208 anaesthetists and a response rate of 60%, which was 125 anaesthetists, was considered acceptable (12). The sample size was realised by the response rate. A convenience sampling method was used. Illegible and blank surveys were excluded. Medical officers and registrars were regarded as junior anaesthetists and anaesthesiologists and career medical officers as senior anaesthetists.

Following a review of the literature the original survey by Amma et al (13) was identified as the most appropriate to use in this study. Permission was requested and granted for use and modification from the corresponding author. The survey was adapted for the Wits context and was then reviewed by three senior anaesthesiologists in the Department of Anaesthesiology and their suggestions were incorporated. Adaptation of the survey was necessary to reflect the anaesthetic gases and equipment used in the Department of Anaesthesiology at Wits. The survey consisted of two sections. Section 1 requested participants' characteristics and Section 2 contained questions on the practice and knowledge of low flow anaesthesia. Low flow anaesthesia in this study was defined as a gas flow rate of less than two litres per minute (8). Welch's (8) four-category classification of fresh gas flow rate in anaesthesia was used, namely:

- high-flow – a fresh gas flow of >4 l/minute
- moderate flow – 2 to 4 l/minute
- low-flow – <2 l/minute
- basal flow – 250 to 500 ml/minute.

Data were collected at departmental academic meetings. The survey took approximately 10 minutes to complete. One author (DBK) was present at the meetings to answer all questions. Completed surveys were folded and put into a sealed box located at the door of the venue.

Data were analysed in consultation with a statistician using STATA version 13.1 (StataCorp, USA). Categorical variables were described using frequencies and percentages. Continuous variables were described using means and standard deviations. Comparison between juniors and seniors and their practice (routine use of low flow anaesthesia and time to reduction of flow rate) and comparison of fresh flow rate with oxygen concentration used were made using chi-square tests. A p-value of ≤ 0.05 was considered statistically significant.

Results

Of the 142 questionnaires distributed, 140 (98.6%) were returned. This represents 67.3% of anaesthetists in the department. The characteristics of the participants are shown in Table I.

Table I Characteristics of participants

Characteristic	Number (%)
Sex	
Male Female	52 (37.1) 88 (62.9)
Professional designation	
Consultant Career medical officer Registrar Medical officer	40 (28.6) 10 (7.1) 65 (46.4) 25 (17.9)
Anaesthetic experience	
<5 years 5 – 10 years 11 – 15 years 16 – 20 years >20 years	58 (41.4) 56 (40.0) 10 7.1) 4 (2.9) 12 (8.6)

The overall mean (SD) knowledge score achieved was 56.3% (13.9%), with juniors achieving a score of 54.3% (14.1%) and seniors a score of 59.9% (12.8%). There was a statistically significant difference between these two scores (p=0.022). The participants' knowledge of low flow anaesthesia, per question, is shown in Table II

Table II Participants' knowledge of low flow anaesthesia

Question	Total score	Score Mean	% Mean	Overall average score (SD)	Overall average percentage (SD)
What fresh gas flow rate is considered high flow?	6	2.4	40.0	15.8 (3.9)	56.3 (13.8)
What fresh gas flow rate is considered low flow?	7	3.8	54.3		
What are the advantages of low flow anaesthesia?	5	3.4	68.0		
What are the disadvantages of low flow anaesthesia?	5	2.1	42.0		
Minimum requirements for low flow anaesthesia?	5	4.2	84.0		

Of the participants, 132 (94.3%) routinely practise low flow anaesthesia. The participants' practice of low flow anaesthesia is shown in Table III. For the question "When would low flow anaesthesia not be used?" the responses are reported per item.

Table III Participants' practice of low flow anaesthesia

Description of question	**Number (%)**
Fresh gas flow rate used for maintenance phase?	
<0.25 l per minute	0 (0)
0.25 – 0.5 l per minute	8 (5.7)
0.6 ml – 1 l per minute	94 (67.1)
1.1 – 1.5 l per minute	35 (25.0)
1.6 – 2 l per minute	2 (1.4)
>2 l per minute	1 (0.7)
Fresh gas flow rate used for induction?	
4 l per minute	10 (7.1)
6 l per minute	78 (55.7)
8 l per minute	47 (33.6)
10 l per minute	5 (3.6)
Fresh gas flow rate used on emergence once volatile discontinued?	
4 l per minute	3 (2.1)
6 l per minute	48 (34.3)
8 l per minute	67 (47.9)
10 l per minute	22 (15)
Decrease to low flow rate after induction after?	
<5 minutes	81 (57.9)
5 minutes	49 (35.0)
10 minutes	8 (5.7)
15 minutes	1 (0.7)
20 minutes	1 (0.7)
>20 minutes	0 (0.0)
Decrease flow rate in stepwise fashion?	
Yes	87 (62.1)
No	53 (37.9)
Concentration of oxygen set for low flow anaesthesia	
30 – 40%	11 (7.9)
41 – 50%	69 (49.3)
51 – 60%	56 (40.0)
>60%	4 (2.9)
Carrier gas of choice?	
Air	139 (99.3)
N_2O	1 (0.73)

Description of question	Number (%)
Use of manual or automated control of end-tidal inhalation anaesthetic?	
Manual	38 (27.1)
Automated	22 (15.7)
Both	78 (55.7)
Never used	2 (1.4)
Find automated mode easy to use?	
Yes	10 (7.1)
No	107 (76.4)
Do not use	23 (16.4)
Which volatile is most ideal for low flow anaesthesia?	
Halothane	0 (0.0)
Isoflurane	12 (8.6)
Desflurane	36 (25.7)
Sevoflurane	92 (65.7)
Which volatile used if ideal agent not available?	
Halothane	0 (0.0)
Isoflurane	57 (40.7)
Desflurane	14 (10.0)
Sevoflurane	69 (49.3)
Low flow anaesthesia used in paediatric patients?	
Yes	117 (86.3)
No	23 (16.4)
When would low flow anaesthesia not be used?	
Unintended leak in system	124 (88.6)
Neonates and infants	41 (29.3)
With laryngeal or face mask use	47 (33.6)
Spontaneous breathing patient	27 (19.3)

The comparisons between the fresh gas flow rate and oxygen concentration used, between professional designation and use of low flow anaesthesia and professional designation and time to decrease flow rate are shown in Table IV. No significant differences were found.

Table IV Comparisons between practice

Flow rate	Oxygen concentration used		p-value
	≤50%	>50%	
	Number		
≤1l/min >1l/min	60 20	42 18	0.510
Professional designation	**Use of low flow anaesthesia**		
	No	Yes	
	Number		
Junior Senior	7 1	83 49	0.259
Professional designation	**Time to decrease flow rate**		
	≤5 minutes	>5 minutes	
	Number		
Junior Senior	84 46	6 4	0.745

Discussion

In this study, 94.3% of anaesthetists routinely use low flow anaesthesia. Mahajan et al (14), in 2017 in a national study in India, similarly found that low flow anaesthesia was routinely used by 90% of surveyed anaesthetists, mainly from private practice. However, Amma et al (13), also in India in 2016, found 73.8% of anaesthetists, mainly from the public sector, routinely use low flow anaesthesia. In this study, the high usage is explained by all the hospitals affiliated to the department being equipped with anaesthetic machines with low flow anaesthesia capabilities. Due to the high usage of low flow anaesthesia, no significant difference in usage was found between seniors and junior anaesthetists.

The knowledge of low flow anaesthesia in this study was low, with a mean score of 56.3%. This was not expected due to the high usage of low flow anaesthesia by anaesthetists in the department. Although a statically significant difference in knowledge was found between seniors and junior anaesthetists, this 5.6% difference is not clinically significant. The lowest score, 40.0%, was obtained for the question regarding the litres of fresh gas flow considered high flow anaesthesia. Amma et al (13) raised a concern that there is a void in concepts regarding true low flow anaesthesia. The authors reported that 10.4% of respondents answered that they used >2 l/minute of fresh gas flow and were under the impression that they were performing low flow anaesthesia. Mahajan et al (14) reported a similar finding.

The majority of anaesthetists in this study, 89.3% used a fresh gas flow rate of 6 – 8 l/minute for induction. Various authors (8, 13, 15) have suggested a fresh gas flow rate of 6 l/minute for induction (wash-in). Leijonhufvud et al (16) determined that a wash-in fresh gas flow rate of 4 – 6 l/minute was ideal and a higher flow rate was of no benefit.

The flow rate after induction was reduced within five minutes or less by 92.9% of anaesthetist and 62.1% do this in a stepwise fashion. There was no significant difference in timing to decrease the fresh gas flow rate between senior and junior anaesthetists. This in keeping with the recommendation by Welch (8) that the fresh gas flow rate be reduced within five minutes. However, this is shorter than the 10 minutes used by participants in the Amma et al (13) study. Leijonhufvud et al (16) stated that the higher the flow rate and anaesthetic agent concentration during wash-in, the shorter the time required to reduction of fresh gas flow rate. This is consistent with our findings.

A fresh gas flow rate of less than 2 l/minute is suggested for the maintenance phase during low flow anaesthesia by various authors (1, 5, 8, 17). In this study, 99.3% of anaesthetists used a flow rate of 2 l/minute or less. This is similar to the findings of Mahajan et al (14) where 90% of respondents used a fresh gas flow rate of 2 l/minute or less during the maintenance phase. A fresh gas flow rate ranging from 0.6 – 1 l/minute was used for maintenance of anaesthesia by 67.1% of anaesthetists in this study. These lower flow rates have been found to be beneficial for heat and moisture conservation (17), but are associated with the use of higher oxygen concentrations (8). In this study, however, no statistically significant difference was found between oxygen concentration and fresh gas flow rate used. This may be explained by lack of knowledge of low flow anaesthesia pharmacokinetics or due to fear of the adverse effects of hyperoxia.

In this study, 99.3% of anaesthetists used air as the carrier gas. This is higher than the 55.8% of anaesthetists that used air as a carrier gas in the Amma et al (13) study. This high use of air as the carrier gas at Wits affiliated hospitals can be explained in that only a few theatres had nitrous oxide available, as nitrous oxide's cost is greater than the benefit. Furthermore, the high altitude in Johannesburg necessitates the use of much higher concentrations of nitrous oxide to achieve the same effect as at sea level (18). However, the nitrous oxide ozone-depleting effect, the risk of a hypoxic mixture and other side effects may also explain its low usage.

On emergence from low flow anaesthesia, coasting, in which anaesthetic administration is stopped toward the end of the operation and the circuit remains closed with enough oxygen flow to maintain a constant end-tidal volume of the ventilator or reservoir bag, is recommended by various authors (1, 15, 19). This contrasts with our findings that show 82.2% of anaesthetists use a fresh gas flow rate of 6 – 8 l/minute for emergence from low flow anaesthesia. This could be explained by the desire to shorten the wash-out time, which is keeping with the suggestion by Welch (8) and the findings by Leijonhufvud et al (16).

Desflurane and sevoflurane have a low blood gas solubility coefficient which is associated with favourable wash-in and wash-out times during low-flow anaesthesia (20). In this study, 65.7% of anaesthetists reported sevoflurane as the ideal anaesthetic inhalation agent for low flow anaesthesia. This is primarily because of its availability and common use at the Wits-affiliated hospitals and is also in keeping with the findings of Amma et al (13) and Mahajan et al (14).

Automated systems of low flow anaesthesia, which allow digital adjustment of fresh gas flow to achieve a target end-tidal concentration, are by their nature more efficient in terms of carrier gas and volatile agent usage and, therefore, result in a cost-saving. In comparison with manual low flow techniques, automated systems require significantly fewer inputs per unit time in gas composition and volatile percentage inputs. This results in a substantial change in the anaesthetist workload in theatre, allowing more attention to be focused on the patient, and less on the anaesthesia machine (21, 22). Furthermore, this results in a decreased risk of hypoxia and over-delivery or under-delivery of the anaesthetic agent (19). In this study, 55,7% of anaesthetists use automated low flow anaesthesia, which is in keeping with the finding of 60% by McGain et al (23) in Australia and New Zealand. In our study, 76,4% of anaesthetists found the automated system difficult to use, which is possibly due to it only recently being introduced at Wits affiliated hospitals. A limitation in paediatric anaesthesia is that most of the current automated low flow anaesthetic machines do not allow for a respiratory rate of more than 30 breaths per minute.

In paediatric anaesthesia, the use of low flow anaesthesia has been limited by concerns such as leaks in the breathing system, high resistance in the circle system, dead space and accumulation of degradation products (7). This study found that 83.6% of anaesthetists use low flow anaesthesia in paediatric patients, which is higher than 37.8% found by Amma et al (13). In our study, 29.3% of anaesthetists reported that low flow anaesthesia should not be used in neonates and infants. Low flow anaesthesia can be used in paediatric anaesthesia, provided the system is leak free and there is good ventilation and minimal dead space. A secondary concern is that the basal oxygen consumption (VO_2) for paediatric patients is approximately 150 – 200 ml/kg/m^2, or 10 ml/min/kg thus, a fresh gas flow rate of 1l/minute with 50% O_2 would represent a significant surplus of oxygen in this cohort, therefore, allaying the fear of the technique being the cause of hypoxemia.

A limitation of this study is that it is contextual and only represents the knowledge and practice of anaesthetists at Wits affiliated hospitals. Furthermore, convenience sampling may have resulted in under or over-representation. A national follow up study is recommended. Furthermore, it is recommended that more formal teaching of low flow anaesthesia is introduced in the Department of Anaesthesiology.

Conclusion

Low flow anaesthesia is routinely practised in the department; however, knowledge was only fair. The practice of low flow anaesthesia was generally in keeping with that suggested in the literature. The majority of the anaesthetists experienced using automated low flow anaesthesia as challenging.

Conflict of interest

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

Acknowledgement

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

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Section 4: Proposal

The practice and knowledge of low flow anaesthesia in a department of anaesthesiology

Dieudonne Bantu Kapajika

Student no: 516295

Supervisor	Juan Scribante Department of Anaesthesiology
Co-supervisor	Helen Perrie Department of Anaesthesiology
Co-supervisor	Oliver Ivan Smith Department of Anaesthesiology

4.1 Introduction and problem statement

Delivery of anaesthesia gases has evolved over the years, from an open to a closed rebreathing circuit and from high fresh gas flow to low fresh flow gas delivery. Baum (1), in 1999 echoed Snow's 1850 statement that "inhalation anaesthetic agents are exhaled unchanged in the expired air of anaesthetised patients and inhalation anaesthetic agents' effect could be markedly prolonged by reinhaling the unused vapor."

The period of 1850 — 1941, called "the pioneer era of anaesthesia" contributed to much early work on low flow anaesthesia, motivated by cost and safety concerns, as gases were expensive and operating theatres lacked scavenging systems and were polluted with explosive gases such as cyclopropane and ether which were popular at this time. Another motivating factor was heat and humidity conservation (2).

A decline in the popularity of the use of low flow anaesthesia occurred between 1945 — 1966, the "era of safety first "after World War II. The development of trichloroethylene which is incompatible with the carbon dioxide (CO_2) absorber soda-lime and the inaccuracy in halothane delivery, due to poor performance of fresh gas flow control rotameters and vaporisers in the low flow range, are other contributing factors to low flow anaesthesia not being used (2, 3). Onishchuk (2) emphasised this by quoting Hamilton stating that "the use of low flow anaesthesia changed when halothane was introduced, because there were some problems associated with the use of 'breathe-through' vaporisers. High flow rates facilitated delivery of a known concentration of anaesthetic agent with 'bubble-through' vaporisers. High flows also facilitated the use of nitrous oxide in a period when oxygen analysers were not widely available".

Variation in gas concentration, volatile and oxygen from the setting in the breathing system to the patient at low flow rates require gas analyser monitoring and adjustment of administered gases. The introduction of novel gas analysers, high cost anaesthetics agents and anaesthetics machines with fresh gas control and vaporisers designed for delivery of low fresh flow revived the low flow anaesthesia technique (1, 4).

There is no universally accepted definition of low-flow anaesthesia (5). Herbert and Magee (6) define low flow anaesthesia as fresh gas flow significantly lower than the patient's minute volume. Meakin (7) defined low flow anaesthesia as the use of a fresh gas flow rate less than the patient's alveolar ventilation. Baum and Aitkenhead (3) define low flow anaesthesia as a technique using a rebreathing system which results in at least 50% of the exhaled air being returned to the lungs after CO_2 absorption. According to Welch (8) low flow anaesthesia means that a carrier gas flow of less than two litters per minute is being used to deliver the anaesthetic agent to the patient. Nunn (5) states that low flow implies a carrier gas flow of less than that attainable with a non-absorber breathing system.

Different classifications of fresh gas flow rate have been proposed, such as

Baker (4) classification in six categories:

- metabolic flow < 250 mL/min
- minimal flow 250 – 500 mL/min
- low flow 500 ml – 1 L/min
- medium flow 1 –2L/min
- high flow 2 – 4L/min
- very high flow > 4L/min.

Welch (8) classification in four categories:

- basal flow 250 – 500 mL/min
- low flow < 2 L/min
- moderate flow 2 – 4 L/min
- high flow > 4L/min.

The main advantages of low flow anaesthesia include the cost saving of inhalation anaesthetic agents and other carriers gases, climatisation of inspired gases and reduction of atmospheric pollution, as well as promoting a greater understanding of breathing systems and the pharmacokinetics of inhalation anaesthesia (5). Accumulation of unwanted gases in the breathing system, substances exhaled by the patient, contaminants of medical gases, products of reactions with absorbents, accidental hypoxia, over usage of carbon dioxide absorbers and hypercapnia, are the common disadvantages of low flow anaesthesia (3, 5).

Tollinche et al (9) in their observational study on analysing volatile anaesthetic consumption by auditing fresh gas flow, concluded that “it is of the essence, given the multitude of benefits stemming from a simple change, that anaesthesia departments evaluate and analyse their current practice of gas flow delivery and initiate appropriate change as needed to reduce the negative effects of traditional anaesthesia gas delivery”. The practice and knowledge of low flow anaesthesia in the Department of Anaesthesiology at the University of the Witwatersrand (Wits) have not been described before.

4.2 Aim and objectives

4.2.1 Aim

The aim of this study is to survey the practice and knowledge of low flow anaesthesia among anaesthetists in the Department of Anaesthesiology at Wits.

4.2.2 Objectives

The primary objective of this study is to describe the practice and knowledge of low flow anaesthesia.

The secondary objectives of this study are:

- compare the fresh gas flow rate with oxygen concentration used.
- compare routine use of low flow anaesthesia between junior and senior anaesthetists.
- compare time after induction to decrease the flow rate between junior and senior anaesthetists.

4.2.3 Research assumptions

The following definitions will be used in this study.

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

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

Registrar: is a qualified doctor registered with the Health Professions Council of South Africa as a trainee anaesthetist, specialising in the field of anaesthesiology in accordance with the regulations put forward by the College of Medicine of South Africa.

Anaesthesiologist: is a qualified doctor registered with the Health Professions Council of South Africa as specialist in the field of anaesthesiology, in accordance with regulation put forward by the College of Medicine of South Africa.

Junior anaesthetist: is a medical officer or registrar.

Senior anaesthetist: is an anaesthesiologist or career medical officer.

Low flow anaesthesia: in this study is a gas flow rate of less than two litres per minute (8).

4.3 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 core hospitals are affiliated to the department's training platform.

- Charlotte Maxeke Johannesburg Academic Hospital, a 1 200-bed central hospital.
- Chris Hani Baragwanath Academic Hospital, a 2 888-bed central hospital.

- Helen Joseph Hospital, a 500-bed regional hospital.
- Rahima Moosa Mother and Child Hospital, a 338-bed regional hospital.
- Wits Donald Gordon Medical Centre, a public private hospital with 190 beds.

4.4 Ethical considerations

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

The self-administered survey (Appendix 2) will be distributed to voluntary participants. The study will be explained at the departmental academic meetings and attendees will be invited to take part. Those who agree will receive an information letter (Appendix 3) and the self-administered survey (Appendix 2). The completion of the survey will imply consent.

Anonymity of the anaesthetist completing the survey will be maintained as no identifying data will be collected. Surveys will be returned by participants into a sealed box located at the door of the venue. Raw data will only be available to the researcher and supervisors to maintain confidentiality. Data will be kept securely for six years after the completion of the study, in a locked cupboard.

The study will be conducted according to the Declaration of Helsinki (10) and the South Africa Guidelines for Good Clinical Practice (11).

4.5 Research methodology

4.5.1 Research design

A cross-sectional research design will be followed in this study.
A cross-sectional study involves obtaining data from a cross-section of the population at a point in time, indicating that data is gathered once from the

specific sample (12). In this study, data will be collected from anaesthetists at departmental academic meetings.

4.5.2 Study population

The population will consist of the anaesthetists working in the Department of Anaesthesiology at Wits.

4.5.3 Study sample

Sample size

The sample size will be realised by the response rate. In this study, the survey will be distributed to the entire accessible population of 208 anaesthetists and a response rate of 60%, which is 125 anaesthetists will be considered acceptable (13).

Sampling method

Most of your studies will use a convenience sampling met A convenience sampling method will be used. According to Brink et al (14) this is a “non-probability sampling procedure that involves the selection of the most readily available people or objects for a study.” Data for this study will be collected by the distribution of surveys at departmental academic meetings.

Inclusion and exclusion criteria

All the anaesthetists working in the department of anaesthesiology will be considered eligible to participate in the study**.**

The exclusion criteria will be:

- interns and community service doctors
- registrars from other medical disciplines
- anaesthetists who refuse to participate in the study.
- illegible or blank surveys.

4.5.4 Data collection

Questionnaire development

A copy of the original survey used in the study by Amma et al (15) was requested and permission granted for modification and use (Appendix 4). The survey was adapted for the Wits context and was then reviewed by three senior anaesthesiologists in the Department of Anaesthesiology and their suggestions were incorporated.

The survey (Appendix 2) consists of two sections. Section 1 requests participants' characteristics data and Section 2 contains data on practice and knowledge of low flow anaesthesia.

Data collection

Data will be collected at departmental academic meetings. The convener of each meeting will be approached to obtain permission to address the attendees. Those present at the meeting will be informed of the study and will be invited to take part. Those who agree to participate will be given an information letter (Appendix 3) and a survey (Appendix 2), which will take approximately 10 minutes to complete. All participants will be reassured about the maintenance of anonymity and confidentiality. The researcher will be present at the meetings to answer all questions.

Completed surveys will be folded and put into a sealed box located at the door of the venue. Blank and illegible surveys will be assigned a study number for response rate calculation but will not be included in the data analysis.

4.5.5 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 13.1 (StataCorp, USA). Categorical variable will be described using frequencies and percentages. Continuous variables will be described using means and standard deviations or medians and inter quartile ranges depending on the distribution. Comparison between juniors and seniors and their practice (routine use of low flow anaesthesia and time to reduction of flow rate) and comparison of fresh flow rate with oxygen concentration used will done using chi-square or Fisher's exact tests. A p-value ≤ 0.05 will be considered statistically significant.

4.6 Significance of the study

Tollinche et al (9) stated that "it is of essence, given the multitude of benefits stemming from a simple change, that anesthesia departments evaluate and analyse their current practice of gas flow delivery and initiate appropriate change as needed to reduce the negative effects of traditional anesthesia gas delivery". This study will describe the current practice and knowledge of low flow anaesthesia in the Department of Anaesthesiology and be the basis for evaluation of the practice. If the results of the study show a shortfall in practice and knowledge, recommendations will be made for re-education.

4.7 Validity and reliability of the study

Validity means the extent to which a measurement represents a true value and validity of conclusion in a study will be justified based on the interpretation and design (12). The reliability of a study is represented by the consistency of achieved measure and it is an indication of the degree to which random error can occur (12).

Maintenance of validity and reliability of this study will be achieved by the following:

- use of an appropriate research design.
- use of a published questionnaire adapted to the study context.
- review of the draft survey by three senior anaesthesiologists
- collection of data anonymously
- presence of researcher at the meetings to answer questions.
- use of appropriate statistical testing in consultation with a biostatistician.

4.8 Potential limitations

This study will be done contextually at Wits, it therefore may not be generalisable to other anaesthesiology departments.

Data are collected only from attendees at the academic meetings therefore this sample may not adequately represent the practice of the entire Wits Department of Anaesthesiology.

4.9 Project outline

4.9.1 Time frame

Activity	2019					2020				
	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Proposal preparation										
Literature review										
Proposal submission										
Ethics approval										
Postgrad approval										
Data collection										
Data analysis										
Draft article										

Submission										

4.9.2 Budget

Item	Number pages	Cost	Copies	Total
Proposal	**20**	**R1/page**	**6**	**R120**
Postgraduate form	**2**	**R1/page**	**6**	**R12**
Complete report	**100**	**R1/page**	**4**	**R400**
Total				**R532**

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

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4.11 Appendices

Appendix 1 Permission from Head of Department of Anaesthesiology to collect data for the study

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

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06 August 2019

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

To whom it may concern,

This letter stands to affirm that I, Dr PMV Motshabi, grant permission to Dr Dieudonne Bantu Kapajika, HPCSA number MP 0645265, to collect data in Department of Anaesthesiology at University of Witwatersrand for his study "The practice of low flow anaesthesia in a department of anaesthesiology".

The approximate period will be, but not limited to, the months of November 2019 to January 2020, until his sample size is obtained. The information obtained from the data will be used for Dr Bantu Kapajika research study for his Masters in Medicine only, and will include information and data relevant to his study.

Yours sincerely,

Dr Palesa Motshabi
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WITS UNIVERSITY | WITS SCHOOL OF CLINICAL MEDICINE | FACULTY OF HEALTH SCIENCES

Charlotte Maxeke Johannesburg Academic Hospital, 6th Floor, Area 300/10, Jubilee Road, Parktown, Johannesburg

.

Appendix 2 Survey

Participant number:

The practice of low flow anaesthesia in a department of anaesthesiology

Please tick the appropriate box

Section 1: Participant characteristics

1.Sex

Male	
Female	

2. Professional designation

Consultant specialist	
Career medical officer	
Registrar	
Medical officer	

3. Years of anaesthetic experience

<5 years	
5 – 10 years	
11 – 15 years	
16 – 20	
>20 years	

Section 2: Survey

Some questions may have more than one correct answer

1. Do you routinely use low flow anaesthesia?

Yes	
No	

2. What do you consider as high flow anaesthesia?

	Fresh gas flow rate of 10 litres per minute
	Fresh gas flow rate of 8 litres per minute
	Fresh gas flow rate of 6 litres per minute
	Fresh gas flow rate of 4 litres per minute
	Fresh gas flow rate of 2 litres per minute
	Fresh gas flow rate of 1 litre per minute

3. What do you consider as low flow anaesthesia?

	Fresh gas flow of less than 6 litres per minute
	Fresh gas flow of less than 4 litres per minutes
	Fresh gas flow of less than 2 litres per minute
	Fresh gas flow of less than 1litres per minute
	Fresh gas flow of less than 500 millilitres per minute
	Fresh gas flow rate of less than patient minute volume
	Rebreathing by patient of more than 50% of fresh gas flow

4. What are the advantages of low flow anaesthesia?

	Cost saving of volatiles anaesthetics agents
	Cost saving of anaesthetics carrier gases
	Minimise operating theatre pollution
	Minimise atmospheric pollution
	Control of patient temperature

5. What are the disadvantages of low flow anaesthesia?

	Accidental hypoxia
	Accumulation of unwanted gases and substances exhaled by the patients in the breathing system
	hypercapnia
	Over usage of carbon dioxide absorbers
	Awareness

6. What fresh gas flow rate do you usually use in maintenance phase?

< 0.250 mL/min	
0.250 — 0.5 mL/min	
0.6 – 1 L/min	
1.1 – 1.5 L/min	
1.6 – 2 L/min	
>2 L/min	

7. Which gas flow rate do you use to induce patient?

4 L/min	
6 L/min	
8 L/min	
10 L /min	

8. Which gas flow do you use on emergence once volatile agents have been discontinued?

4 L/min	
6 L/min	
8 L/min	
10 L/min	

9. Approximately how long after induction do you decrease the flow rate to low flow?

<5 minutes	
5 minutes	
10 minutes	
15 minutes	
20 minutes	
>20 minutes	

10. Do you decrease the flow in a stepwise fashion?

Yes	
No	

11.What concentration of oxygen do you set for low flow anaesthesia?

30 – 40%	
41 – 50%	
51 – 60%	
>60%	

12. What is your carrier gas of choice?

Air	
N_2O	

13. Do you use the manual or Automated control of end-tidal inhalation anaesthetic concentration?

Manual	
Automated	
Both	
Never used	

14. Do you find the automated mode easy to use?

Yes	
No	
Don't know	

15. In your opinion which volatile agent is most ideal for low flow anaesthesia?

Halothane	
Isoflurane	
Desflurane	
Sevoflurane	

16. Which volatile agent would do you mostly use when the ideal agent is not available?

Halothane	
Isoflurane	
Desflurane	
Sevoflurane	

17. Do you use low flow anaesthesia for paediatric patients?

Yes	
No	

18. When would you not use low flow anaesthesia?

	Unintended leak in the system
	Neonate and infant patients
	Laryngeal mask or face mask use
	Spontaneous breathing

19. What are the minimum requirements for low flow anaesthesia?

	Circle system
	Carbon dioxide absorbers
	Gas analysers
	Anaesthesia machines calibrate to low flow range
	Leak free system

Appendix 3: Information Letter

July 2019

Dear colleague

My name is Dieudonne, I am a registrar in the Department of Anaesthesiology doing my M Med titled: **The practice and knowledge of low flow anaesthesia in a department of anaesthesiology**. I would like to invite you to participate in my study

The use of low anaesthesia is becoming more common as it is cost-saving and has benefits for patients. I would like to survey its practice and knowledge in our department. The survey is anonymous, as no identifying data will be asked of you. Confidentiality will be ensured as only my supervisors and I will have access to the raw data.

Completing the survey will imply consent. Participation is voluntary and not taking part will not compromise you in any way. Once the survey is completed, please fold the survey and place it in the sealed data collection box at the door of the meeting room. It will take less than 10 minutes to complete the survey. The result of this study will enable us to describe the practice of low flow anaesthesia in the department.

The Human Research Ethics Committee (Medical) (Ethical Clearance Number xxxxxxxx) and the Graduate Studies Committee of the University of the Witwatersrand have approved the study proposal. If you wish to contact them, Professor Penny (Chairperson) can be contacted on telephone number 0117172301, or by e-mail at Clement.Penny@wits.ac.za.

If you have any questions with regards to the study, please feel free to contact me on 0721476668 or at dieudobantu@yahoo.fr .

Thank you for taking the time and read this letter

Dieudonne

Appendix 4: Permission to use a modified published survey

Dr Dieudonne BANTU KAPAJIKA <dieudobantu@yahoo.fr>

À: rajasreesajan@gmail.com

30 juil. à 14:41

Dear R.O. AMMA

Good day

My name is Dieudonne Bantu Kapajika and I am medical registrar in the Department of Anaesthesiology at the University of Witwatersrand in Johannesburg, Republic of South Africa. I am doing a research project on the current practice of low flow anaesthesia in our department.

I hereby request permission to use and modify your questionnaire used for data collection in your study on the survey on use of low flow anaesthesia and choice of inhalation anaesthetic agents among anaesthesiologists of India.

Thanking you in advance and looking forward to hearing from you.

Regards

Dr. Dieudonne BANTU KAPAJIKA

mobile: 002721476668

email: dieudobantu@yahoo.fr

Rajasree sajan <rajasreesajan@gmail.com>

À: Dr Dieudonne BANTU KAPAJIKA

4 août à 16:17

Hello Dr Kapajika,

Kindly go forward and use the questionnaire for your study.

Please contact me if you need any further clarifications. All the best to you.

Regards,

Dr Rajasree O

Associate Professor,

Department of Anaesthesiology,

Regional Cancer Centre, Thiruvananthapuram.

Section 5: Annexures

5.1 Ethics approval

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

R14/49 Dr Dieudonne Bantu Kapajika

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M190834 MED19-08-049

NAME: **(Principal Investigator)**	Dr Dieudonne Bantu Kapajika
DEPARTMENT:	Anaesthesiology Charlotte Maxeke Johannedburg Academic Hospital
PROJECT TITLE:	The practice and knowledge of low flow anaesthesia in a department of anaesthesiology
DATE CONSIDERED:	30/08/2019
DECISION:	Approved unconditionaly
CONDITIONS:	
SUPERVISOR:	Juan Scribante, Helen Perrie and Oliver Smith
APPROVED BY:	Dr C Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	29/11/2019

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 in Room 301, 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 August and will therefore be due in the month of August each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

2020/02/04
Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

5.2 Graduate studies approval

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

03 January 2020
Person No: 516295
PAG

Dr D Bantu Kapajika
16 Ealing Crecent
Bryanston
2191
South Africa

Dear Dr Dieudonne Bantu Kapajika

Master of Medicine in Anaesthesia: Approval of Title

We have pleasure in advising that your proposal entitled *The practice and knowledge of low flow aneasthesia 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

5.3 Turnitin report

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

4 March 2021

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

Dear Professor Papathanasopoulos

Re: M Med: The practise and knowledge of low flow anaesthesia in a department of anaesthesiology

Dr Dieudonné Bantu Kapajika, student number: 516295, has submitted his research report to Turnitin, which revealed a similarity index of 29%. These similarities appear not to be plagiarism but mainly the use of common terminology and phrases specific to the topic of the research. Due to the technical content of the research report further paraphrasing will not significantly impacted the similarity index. Prof Behrens, Head of Bio-ethics have been consulted in this regard.

Yours sincerely,

J Scribante

Juan Scribante
Supervisor

1

516295:TURNITIN_4.docx

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