PRACTICE OF LOW FLOW ANAESTHESIA AND VOLATILE AGENTS CHOICES AMONG ANAESTHESIA PROVIDERS AT MUHIMBILI NATIONAL HOSPITAL AND MUHIMBILI ORTHOPAEDIC INSTITUTE.

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MMed (Anaesthesiology and Critical Care) Dissertation
Muhimbili University of Health and Allied Sciences
October, 2020.

Muhimbili University of Health and Allied Sciences

School of Medicine

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By

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A Dissertation submitted in (Partial) fulfilment of the requirements for the Degree of Masters of Medicine in Anaesthesiology and Critical Care of the

Muhimbili University of Health and Allied Sciences.
October, 2020.

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Muhimbili University of Health and Allied sciences a Dissertation entitled, **"Practice of low flow anaesthesia and volatile agents choices among anaesthesia providers at Muhimbili national hospital and Muhimbili orthopaedic institute"** in (Partial) fulfilment of one of the requirements for the degree of Masters of Medicine in Anaesthesiology of the Muhimbili University of Health and Allied sciences.

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DECLARATION AND COPYRIGHT

I, **Happiness Joab Mathew,** declare that this **dissertation** is my own original work and that it has not been presented, and will not be presented, to any other university for a similar or any other degree award.

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ACKNOWLEDGEMENTS

Primarily, I would like to thank my almighty God for granting me a precious life and chivalrous health for every step I took from beginning up to the completion of my dissertation work. Without him nothing could be possible.

With all due respect, I would like to thank my supervisor Dr. Respicious Boniface for mentorship and guidance. He devoted his priceless time providing text edits, fact checks, references and advice during the writing of this dissertation. Also, I would like to thank the Head of Department of Anaesthesiology at Muhimbili University of Health and Allied sciences, DR Edwin Lugazia for devoting his precious time to co-supervise and encourage me to complete this work within suggested time.

Likewise, I would like to thank the Executive directors of Muhimbili National Hospital and Muhimbili Orthopaedics Institute (MOI), Prof. Lawrence Mujungu Museru and Dr. Respicious Boniface respectively, for permitting me to conduct and complete my dissertation at their Institutes.

It is not possible to complete a work of this kind without involving one's colleagues. Their critical emphasis and attention to detail was precisely what was needed to make this a better dissertation, and I appreciate for their supports.

To finish, but most outstandingly, I want to thank my Mother (Evelina) and Husband (Dr. Tito Runobo). They never complained and they always revived me with generous words of encouragement when exhaustion had sent my spirits flagging. They deserve as much credit for the completion of this dissertation as I do.

DEDICATION

I dedicate this dissertation to my fellows Anaesthesia providers (research participants) at Muhimbili National Hospital, MNH-Mloganzila campus and Muhimbili Orthopaedics Institute for taking their golden time to respond to questions and make this work completed without difficulty.

I dedicate the dissertation to my husband, Dr. Tito Runobo and my children, Rodrick, Ronica, Ronald and Doreen.

ABSTRACT

Background; Anaesthesia providers worldwide are practicing low flow anaesthesia due to the availability of modern workstations and heightened awareness on the environmental effects of waste anaesthesia gases. The routine practice of low flow Anaesthesia offers several advantages, including preservation of heat and humidity, reduced expenses of inhalational agents and reduction of theatre and environment pollution. Well-equipped Workstation and Stringent monitoring with Capnography, Oxygen and Agent analysers are mandatory for safe conduct of low flow anaesthesia. In most developing countries Low Flow Anaesthesia is still underutilized due to lack of monitoring equipments and sufficient knowledge on Low Flow Anaesthesia. Tanzania appears to have a paucity of studies on the prevailing practice pattern of fresh gas flow and volatile agents choices.

Objective; The study aimed at assessing the practice of low flow anaesthesia and volatile agents choices among anaesthesia providers at Muhimbili national hospital and Muhimbili orthopaedic institute.

Methodology; The study was a hospital based descriptive cross sectional study that was conducted at Muhimbili National Hospital and Muhimbili orthopaedic institute, involving 158 anaesthesia providers working in all operating theatre from July 2019 to February 2020. Approval for the study was granted by Muhimbili University of Health and Allied Sciences ethical committee. A Validated Structured questionnaire and checklist was used to collect information from anaesthesia providers and monitors availability. Data obtained included demographic, practice setting of Low flow anaesthesia, Availability of workstations, scavenging systems, monitoring equipments, breathing systems, Volatile agents routinely used and preferred Agent. Data were analysed using the IBM Statistical package for social science's version 23.0 and Using Pearson's Chi-square test and Fisher's exact test for some of categorical data. P value < 0.05 was considered statically significant.

Results; in this study there were 158 Anaesthesia providers working in different operating room and intensive care according to duty schedule. The Prevailing practice pattern was high flow anaesthesia.

Routine practice of Low flow anaesthesia was 27.2%, however, only 6% used fresh gas flow of 1l/min – 500mls/min complying with the actual meaning of low flow anaesthesia. Anaesthesia providers with > 10 years of experience and from Muhimbili National Hospital had the highest proportion of practice of low flow anaesthesia. There was a paucity of monitoring equipments and some were nonfunctional. All anaesthesia providers had workstations and only 2.3% displayed Minimum Alveolar concentration (MAC) values, 79.1% respondents worked in theatre rooms with functioning scavenging systems, 55.8% used capnography, 6.9% monitored inspiratory Oxygen and none of anaesthesia providers used Bispectral and Agent Analyzers.

Isoflurane was the most routinely used inhalational agents (100%) followed by Sevoflurane (69%), then Halothane (32%). Sevoflurane was the most preferred (55.7%), followed by Isoflurane (42.4%), Halothane (1.9%). Desflurane was not available in these hospitals.

Conclusion; Low flow anaesthesia is seldom practiced despite having strong evidence of attractive advantages in medical practice and ergonomics. Availability of Sophisticated workstation and recommended monitoring equipments for volatile agents and other anaesthesia gas is still a problem within the studied hospitals. Isoflurane is the routinely used volatile anaesthetics; sevoflurane availability is restricted, however a most preferred inhalational Agent. Currently Halothane is occasionally used at Muhimbili hospital and desflurane still not available in all hospitals involved in this study.

Recommendations; Low flow anaesthesia basic principles and technical preconditions should be well taught to all anaesthesia providers. Intensify LFA training during residency and nurse anaesthesia training, Initiate protocols/ codes for LFA and start to implement it in our area. Improve availability of respiratory gas monitors and update our anaesthesia Machines. Further study need to be done on cost analysis of inhalational agent use and knowledge assessment on LFA.

TABLE OF CONTENTS

CERTIFICATION i

DECLARATION AND COPYRIGHT ii

ACKNOWLEDGEMENTS iii

DEDICATION iv

ABSTRACT v

LIST OF FIGURE xi

LIST OF TABLES xii

ABBREVIATIONS xiii

OPERATIONAL DEFINITIONS AND KEY CONCEPTS xiv

CHAPTER ONE 1

1.0 INTRODUCTION 1

1.1 Background Information. 1

1.1.1 Patient's physiology and hemostasis. 3

1.1.2 Reduction of operating room pollution. 3

1.1.3 Reduction of Environment pollution. 4

1.1.4 Economic advantages. 5

1.2 Problem Statement 7

1.3 Rationale....7

1.5 Research Questions....10

1.6 Objective:....10

1.6.1 Broad Objective....10

1.6.2 Specific Objectives;....10

CHAPTER TWO....11

2.0 LITERATURE REVIEW....11

2.1 Practice of Low flow anaesthesia....11

2.2 Recommended and required monitors in conducting LFA....14

2.3 The choices of volatile Anaesthetics....16

CHAPTER THREE....18

3.0 METHODOLOGY....18

3.1 Study approach....18

3.2 Study design....18

3.3 Study area....18

3.4 Study population....19

3.5 Inclusion criteria....19

3.6 Exclusion criteria....19

3.7 Study duration....20

3.8 Sample Size Determination. 20

3.9 Study Variables 21

3. 10 Sampling techniques; 22

3.11 Data collection instruments 22

3.12 Data collection methods 23

3.13 Data Management. 23

3.14 Data analysis. 23

3.15 Ethical clearance and ethical considerations. 24

CHAPTER FOUR 25

4.0 RESULTS 25

4.1 Routine Practice of Low Flow Anaesthesia. 26

4.2 Practice Settings During Conduct of LFA 30

4.3 Availabity of Monitors, Scavenging And Advanced Anaesthesia mchines during practice of LFA. 32

4.4 Volatile agents used routinely 34

4.5 Preffered volatile agents. 35

CHAPTER FIVE 37

5.0 DISSCUSSION 37

5.1 Study limitations. 41

5.2 Mitigations 42

CHAPTER SIX....43
6.0 CONCLUSSION AND RECCORMENDATIONS. 43
6.1 Conclussion....43
6.2 Reccormendations. 43
REFERRENCES. 44
APPENDICES....52
APPENDEX 1....52
STUDY QUESTIONS. 52
APPENDIX 2....57
CHECKLIST OF FLOW RATE, AVAILABLE MONITORS AND VOLATILE AGENTS. 57
APPENDIX 3....58
CONSENT FORM....58
APPENDIX 4....60
Ethical Clearance....60

LIST OF FIGURE

Figure 1; Source conceptual framework of the study (self-developed Mathew et al).....8

Figure 2 Screen displaying values to be monitored during implementation of LFA (34).

Figure 3: Routine practice of low flow Anaesthesia 26

Figure 4; The Association of practicing low flow Anaesthesia among providers with years of Experience 27

Figure 5; The Association of practicing low flow Anaesthesia among providers with the study sites (hospitals). 28

Figure 6: Fresh gas flow rates used during routine use of low flow anaesthesia. 30

Figure 7: Volatile agents routinely used (Some providers opted more than one volatile agent as "routinely used". 34

Figure 8: Volatile agent of preference for daily anaesthesia practice. 35

LIST OF TABLES

Table 1: Fresh gas flow used in daily anaesthesia practice are categorized into (8, 9). 2

Table 2: Demographic characteristics of the study participants 25

Table 3: Association of practice of low flow Anaesthesia in relation to Type of volatile agent used, Subspeciality of practice and professional cadre of Anaesthesia providers. 29

Table 4: Practicing characteristics of low flow anaesthesia among anaesthesia providers. 31

Table 5: Availability of workstations, scavenging systems and minimum monitoring equipments. 33

Table 6:Influence of provider's subspecialty to anaesthetic Agents choices. 36

ABBREVIATIONS

ASA	American society of Anaesthesiologists.
BIS	Bispectral index.
CME	Continuing Medical Education
CO_2	Carbon dioxide.
ECG	Electrocardiogram.
ERAS	Enhanced recovery after surgery.
$ETCO_2$	End-tidal carbon dioxide.
FGF	Fresh Gas Flow.
FiO_2	Fraction of inspired Oxygen.
HFA	High Flow Anaesthesia
LFA	Low Flow Anaesthesia.
MAC	Minimum Alveolar Concentration.
MNH	Muhimbili National Hospital
MOI	Muhimbili Orthopaedic institute.
MOT	Main operating theatre.
N_2O	Nitrous oxide.
NIOSH	National Institute for Occupational Safety and Health.
OSHA	Occupational Safety and Health Administration.
OT	Operating Theatre.
WAGs	Waste Anaesthesia Gases.

OPERATIONAL DEFINITIONS AND KEY CONCEPTS

Low flow Anaesthesia:- can be defined as an inhalational anaesthetic technique which, using a rebreathing system, results in at least 50% of the exhaled air being returned to the lungs after CO_2 absorption.

High flow Anaesthesia: - an inhalational anaesthetic technique in which a rebreathing of exhaled gas is negligible with a fresh gas flow greater than 2 litres per minute.

Volatile Agents/Inhalational anaesthetics:-These are volatile drugs (gases or Vapors) administered through the respiratory route to produce anesthesia, includes diethyl ether, cyclopropane (gas), trichloroethylene, halothane, enflurane, isoflurane, sevoflurane and desflurane.

Fresh gas flow: -mixture of medical gases and volatile anaesthetic agents from the anaesthetic machine to a patient's airway and it is always determined by anaesthesia provider.

Breathing system: - an assembly of components, which delivers gases from the anesthesia machine to the patients' airways (1).

Circle system: - unidirectional flow system in which gases flow in a circular pathway through carbon dioxide absorber with inspiratory and expiratory tubing separate (1).

Minimum Alveolar Concentration (MAC):- is often referred to as the ED_{50} for immobility and is defined as the minimum alveolar concentration of inhaled anesthetic at sea level required to suppress movement to a surgical incision (pain) in 50% of the patients. It compares the strengths, or potency, of anaesthetic vapours.

Respiratory gas analysis: is a standard monitoring technique during anaesthesia comprising of oxygen, carbon dioxide, N_2O and volatile anaesthetic agents analysis.

Workstation: - is an Anaesthesia care station comprising of the gas delivery and scavenging system, vaporizers, Electronic/non electronic flow meters, ventilator and different types of monitors.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information.

A significant amount of volatile anaesthetics, up to 90% is expired unchanged when we use a relatively high fresh gas flows >2L/min and emitted as waste anaesthetic gases(WAGs) into the operating theatre (OT) or to the atmospheric air (2), therefore can be re-used by implementing LFA technique after remove of CO_2.

LFA was introduced by John Snow in 1850 and it was also well described in 1952 by Foldes using nitrous oxide–oxygen anaesthesia with a fresh gas flow of 1 l /min. However didn't last long, was abandoned following the development of halothane and trichloroethylene which was incompatible with soda lime in conjunction with the poor performance of fresh-gas flow controls and vaporizers in the low-flow rates (3,4).

According to survey done in Canada 85-90% of anaesthesia providers were using high fresh gas flow rates of inhalational anaesthesia as a result huge amount of inhaled anaesthetics were wasted (5).Another study results showed that there was ongoing usage of high flow anaesthesia despite effort made by institution on providing Anaesthesiologists with adequate LFA educations and ventilators with notification systems to help limit fresh gas flow (6).

LFA gained popularity worldwide following advancement in anaesthesia workstations and introduction of expensive and low solubility inhalational agents, Sevoflurane and Desflurane. It has been employed in daily clinical practice as a routine anaesthetic technique in many countries. Situation is not the same for third world countries in which even the availability of monitoring equipment to provide safe anaesthesia still a huge problem (7).

The classification of fresh gas flow as described by Brattwall and vecil has been accepted by majority of society of Anaesthesiologist and authors (8,9),According to this a gas flows less than 1 L/min are defined as low-flow anesthesia (LFA).By definition Low flow Anaesthesia is a technique that at least 50% of the expired gases are returned to the lungs after thoroughly carbon dioxide absorption specifically a fresh gas flow (FGF) of 500ml/min to <1000ml/min(10), a widely accepted definition by majority (11–13).

Fresh gas flow (FGF) is defined as mixtures of oxygen, inhalational anaesthetic agents and either medical air or nitrous oxide as carrier gases delivered to the patient's lungs to provide a complete state of anesthesia.

Table 1: Fresh gas flow used in daily anaesthesia practice are categorized into (8, 9).

Anaesthesia technique	Fresh gas flow
Metabolic flow	~ 250 ml/min
Minimal flow	250-500 ml/min
Low flow	500-1000 ml/min
Medium flow	1-2 L/min
High flow	2-4 L/min
Very high flow	> 4 L/min

Routine practice of Low flow anaesthesia has shown promising advantages and it’s a duty for every Anaesthesiologist/Anaesthesia provider to be aware of these valuable advantages from judicious use of low flow rates .Anaesthesia cost containment, Patient safety, theater staff safety and reduction in environmental pollution are the major potential advantages.

1.1.1 Patient's physiology and hemostasis.

Preservation of patient's pre-anaesthetic physiological status is a dream of every Anaesthesiologist. Implementation of LFA during general anaesthesia results in temperature regulation and humidity control hence conserving body temperature and reducing water loss as highlighted by Aldrete (14), improved flow dynamics of inhaled anaesthesia gases, increased muco-ciliary clearance and Reduced accumulation of dried airway secretions as pointed up in different studies (15–17).

Klemann PP et al found that Reducing the fresh gas flow to 1.5l/Imin increased heat and moisture content in the respired gases from 28^0C to 32 ^{0}C and moisture from 20 to 27 mg H2O/l in anesthesia breathing systems (18).Also Respiratory function and mucociliary clearance were better preserved in a low-flow anaesthesia technique than in high-flow anaesthesia as reported by Bilgi et al (19).Concerning Enhanced recovery after Anaesthesia LFA is a better choice to achieve ERAS as was observed in certain studies (20).

1.1.2 Reduction of operating room pollution.

Unscavenged operating rooms show up to 10-70 ppm halothane level and 400-3000 ppm of N_2O, scavenging brings these levels down to 1 and 60 ppm respectively. Studies shows, high ambient air concentrations of anesthetic gases have been linked to the practice of maintaining unnecessarily high FGF during general anesthesia (21).

There is negative effect of trace concentration of inhalational Agents in personnel working in theater. These studies found a significantly increased risk of spontaneous abortion and more risk of having children with congenital abnormalities for female and male working in theater (22). Amrutha et al (23) reported female anaesthesiologists(24.68%) and spouses of male anaesthesiologists had a higher incidence of first trimester spontaneous abortions and birth defect than the general population(11.7%).

Guidelines and recommendations for Work place developed by OSHA and NIOSH recommends maximum allowed concentration of halogenated anaesthetics of 2ppm and nitrous oxide of 25ppm-50ppm, however exposure limits vary among countries (24,25). OSHA recommendations to reduce operating room contamination involve, the reduction of fresh gas flow, usage of closed circuit anaesthesia and avoidance of nitrous oxide as carrier gas (26). Implementation of LFA and Careful attention to leaks can yield levels as low as 0.005 halothane and 1 ppm N2O which is far away below the recommended level by OSHA.

1.1.3 Reduction of Environment pollution.

The earth's Ozone layer is destructed by numerous wastes, among of them being waste anaesthesia gases (WAGs) produced from inhalational anaesthetics in form of Fluorocarbons and nitrous oxide. WAGs accounts to around 6% of the heating effect of greenhouse gases in the atmosphere. N_2O is the most important ozone-depleting substance emission and is expected to remain the largest throughout (27).A study done on Global Warming potential of Inhaled Anesthetics revealed that, Desflurane had a significantly larger global warming impact (which depended on FGF rate) compared with sevoflurane or isoflurane, particularly at higher FGF rates or longer delivery times (28).

Practice of low flow anaesthesia results in production of extremely low WAGs as well as reduction in consumption of gases (28,29). Ekbom, et al. reported that the amount of sevoflurane, consumed, vaporized and released into the atmosphere at 1 MAC decreased from 0.66 (0.07) to 0.48 (0.05) g/min, a 27% reduction by halving fresh gas flow (30). Also study done in US found that exceptionally low anesthetic gas concentrations stipulated by the US NIOSH can be achieved easily only by the use of low-flow techniques, Eisenach et al (31).

1.1.4 Economic advantages.

Anaesthetic drugs account for up to 6% of total pharmacy costs, of which inhalational agents may comprise up to 20% (32).Due to Alarming high cost of anaesthesia services especial for long operations (total knee/Hip, neurosurgery, cardiac surgery) with use of high FGF, several studies has been done to decipher a way to reduce these cost and expenditures from department. Various cost analysis studies have revealed that constant innovation of sophisticated workstations which are equipped with econometers, new automated exhaled gas monitor and modern ventilator is a safe procedure to perform routine LFA for consistent economic benefit and reduction of environment pollution.

Reduction of FGF to less than 2l/min during maintenance stage of Anaesthesia has demonstrated significant savings of up > 75% especially when there is a high proportion of lengthier surgical procedures without an impairment in patient comfort or an increase in adverse events (33,34).A clinical study done in patients having elective knee arthroscopy demonstrated reduction of hourly sevoflurane consumption by 80% , also another study revealed the number of anesthesia hours per bottle of sevoflurane increased from 10.0 hours to 17 hours per bottle after the implementation of the low fresh gas flow policy (35,36). Another cost analysis done in UK comparing between high flow anaesthesia and low flow anaesthesia revealed that there was 2 hours reduction in cost of volatile Agents, Desflurane from 4533 euro to 955 euro, Sevoflurane from 5243 euro to 1564 and Isoflurane from 1132 euro to 309 euro respectively (34)**.**

Low flow Anaesthesia implementation has some prejudice including increased risk of over- or under dosage of inhalation anaesthetics leading to intraoperative awareness, increased risk of hypoxia, increased risk of hypercapnia and increased risk of accumulation of dangerous trace gases. However, the use sophisticated workstation equipped with O2 analysers to measure inspired and expired oxygen, End-tidal carbon dioxide monitoring, volatile agent analyser to measure inspired and expired agent concentration and audible alarm safety feature has eliminated all uncertainties against the use of low-flow techniques (4,37).

Also according to study done by Food and drug authority revealed that less amount of degradation products which are far below threshold values to endanger patient safety are produced when LFA is used, hence no FGF restriction nowadays even with sevoflurane (38,39).

Contraindication/Limitation to low flow Anaesthesia depends on patient comorbidities and type of circuit available. Patient with ketoacidosis, End stage renal diseases, short-term anaesthesia with a face mask and short duration surgery are relatively contraindicated to use of LFA (38). Also LFA techniques cannot be implemented in some situations/ settings, including, Anaesthesiologist not familiar with LFA, procedures with imperfectly gas-tight airways (i.e., bronchoscopies with a rigid bronchoscope) and Use of technically unsatisfactory equipment with a high gas leak.

As Anaesthesia providers we should Always remember that, no matter how 'high we go'/ "low we go" a normothermic adult at rest needs a minimum of 250ml of oxygen per minute therefore implementation of LFA is within safety Window. However, in Developing countries Paucity of Advanced workstations, multi gas monitors, lack of initiatives and policy to promote LFA, scanty knowledge gained during residency/training impedes the implementation of Safe low flow anaesthesia.

1.2 Problem Statement

With the increasing awareness on anaesthesia services cost and environmental pollution of anaesthesia waste gases (WAG), Worldwide anaesthesia providers are utilizing LFA. Researchers have demonstrated up 75% reduction in expenses and ERAS using LFA especially for longer procedures (20,40).

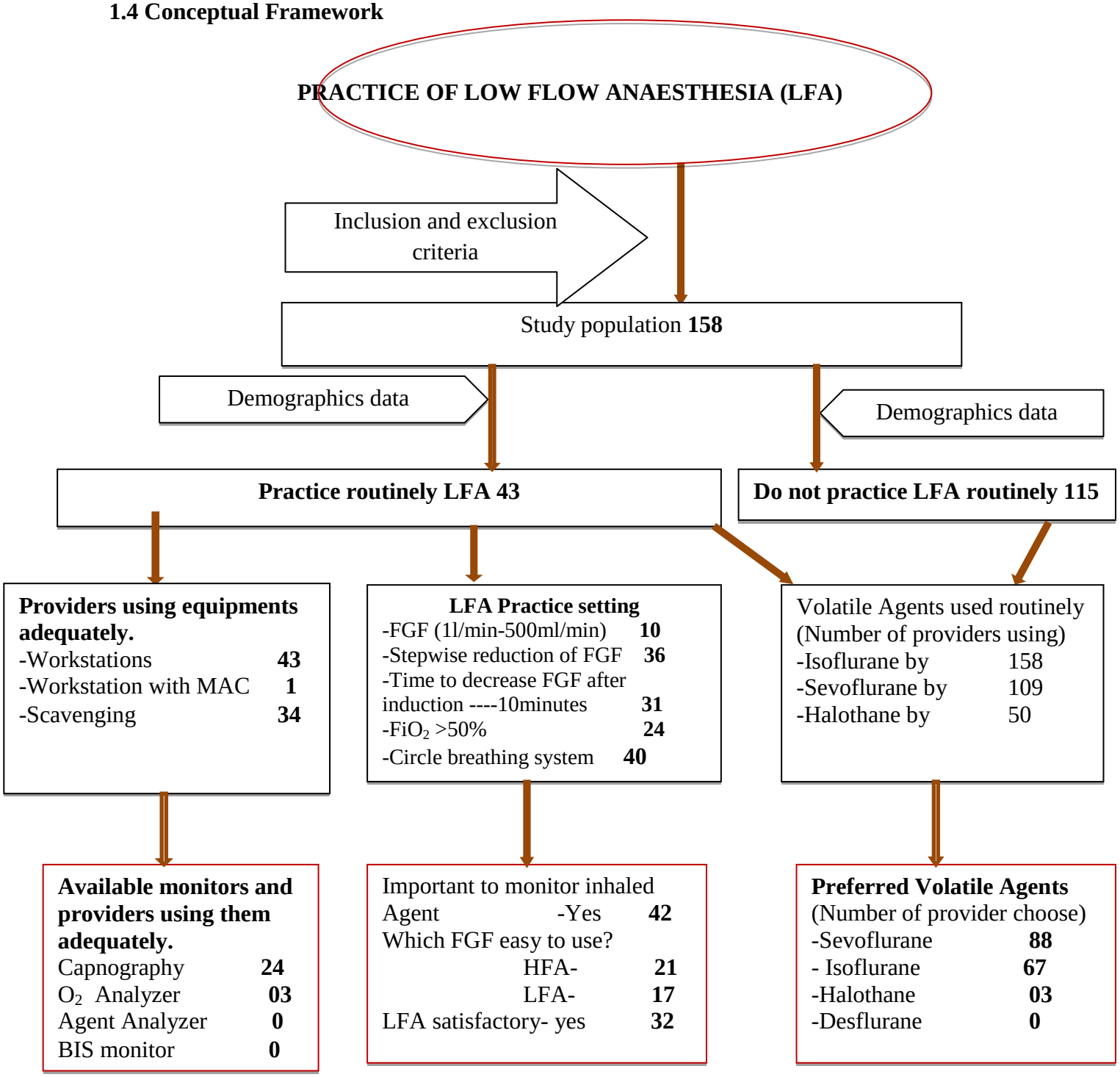
However in our vicinity the prevailing practice pattern of FGF and volatile agent choices is not known. There is paucity of studies that has been done to assess the availability of recommended monitors for safe practice of LFA.

1.3 Rationale

Majority of surgeries in our locality are done General Anaesthesia and maintained with volatile inhalational agents. Limited data on LFA practice in our country necessitate this study. The study is essential as a baseline reference that will help us in setting protocols & standard guidelines on LFA.

It is hoped that materials from this study can be used to improve knowledge and raise awareness on LFA whether through on job training or CME to match with current Anaesthesia practice. This study can be used as a baseline for improvements in monitoring tools availability for safe practice of safe LFA.

1.4 Conceptual Framework



LFA-low flow Anaesthesia, HFA-high flow Anaesthesia, FGF-Fresh gas flow

Figure 1; Source conceptual framework of the study (self-developed Mathew et al).

Figure 1: Demonstrated the conceptual framework of the study. Anaesthesia providers who were providing anaesthesia services in all operating theatres during the study period were screened for inclusion and exclusion criteria and a study population of **158** was obtained. The information on demographic data such as Gender, years of experience in anaesthesia, professional rank, subspecialty of the practice and the workplace of the participant were recorded. Respondents were, 11 Anaesthesiologists, 21 Residents, 6 Anaesthesia registrars and 120 Nurse Anaesthetists who worked tirelessly to provide Anaesthesia services at MNH, MNH Mloganzila and MOI.

There were 43 Anaesthesia providers who routinely practiced LFA, and those who didn't practice LFA were 115.The actual low flow anaesthesia were practiced by only 10 anaesthesia providers, used a fresh gas flow setting of 1l/min-500mls/min, the rest 33 anaesthesia providers used FGF of >1l/min and >2l/min. Stepwise reduction was done by 36 anaesthesia providers, Up to 31 anaesthesia providers reduced FGF 10minutes after induction of anaesthesia, 24 anaesthesia providers used a fraction of inspired Oxygen concentration of >50% and 40 anaesthesia providers used the circle breathing system during the performance of Low flow anaesthesia.

All 43 respondents had anaesthesia Machines, functioning Scavenging system was available daily to 34 respondents and only 1 used adequately workstation displaying MAC values. Appropriate capnography monitoring was done by 24 participants, inspiratory O_2 monitoring by 3 Anaesthesia providers and no one did BIS and inhalational agents monitoring, however, 42 participants said it was important to monitor inhalational agents' concentration. LFA was perceived as a satisfactory technique by 32 anaesthesia provider, though 21 said is still difficult to perform LFA but easier for high FGF.

Isoflurane was routinely used by all 158 anaesthesia providers, Sevoflurane by 109 and Halothane by 50 while none of the anaesthesia providers used Desflurane. The volatile Agents of preference were, Sevoflurane was preferred by 88, Isoflurane by 67, Halothane by 03 anaesthesia provider and none of anaesthesia providers preferred Desflurane.

1.5 Research Questions

1. What is the prevailing practice pattern of low flow anaesthesia at MNH and MOI?
2. Does years of experience and level of knowledge have any impact on the practice of LFA?
3. What is the status on Availability of minimum Monitors required for practice of low flow anaesthesia?
4. Which of volatile agent is preferred by the majority of anaesthesia providers during the practice of LFA?
5. What are the advantages of LFA implementation?

1.6 Objective:

1.6.1 Broad Objective

- To assess practice patterns of low flow anaesthesia and the choice of volatile agents among anaesthesia providers at Muhimbili national hospital (MNH) and Muhimbili orthopaedic institute (MOI) from July 2019 to February 2020.

1.6.2 Specific Objectives;

- To assess prevailing practice patterns of low flow anaesthesia among Anaesthesia providers at Muhimbili national hospital (MNH) and Muhimbili orthopaedic institute (MOI) from July 2019 to February 2020.
- To determine association between years' experience, Education level and area of practice with practice of low flow Anaesthesia from July 2019 to February 2020.
- To assess the availability of minimum recommended monitors for the practice of low flow anaesthesia at Muhimbili national hospital (MNH) and Muhimbili orthopaedic institute (MOI) from July 2019 to February 2020.
- To determine the choice of volatile agents among anaesthesia providers at Muhimbili national hospital (MNH) and Muhimbili orthopaedic institute (MOI) from July 2019 to February 2020.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Practice of Low flow anaesthesia

Low flow anaesthesia has been demonstrated to be a safe and reliable technique that offers a considerable reduction in volatile agent utilization. Its enactment has started since the Era of Ether Anaesthesia and gained popularity all over the world, but not to the due place it deserves. Anaesthesiologists and other anaesthesia providers are obliged to understand its basic principles and suitable monitoring.

LFA has three phases of anaesthesia; induction, maintenance and recovery phase. During the initial phase, high FGF practically equal to the total patient's ventilation (>4l/min) and vaporizer dial setting of the 1.3-2.5MAC/maximum dial is vital for uptake of volatile anaesthetics to reach a steady state and to attain state of surgical anaesthesia. Regarding to uptake and distribution of inhaled anaesthetics, a steady state is reached after 10minutes when using LFA and for minimal flow is reached after 15 to 20minutes.Within these initial time (10-15minutes) high fresh gas flow together with maximum vaporizer dial is advocated to hasten equilibrium state.

There are should be Stepwise reduction in the fresh gas flow rate in preference to the vaporizer setting to maintain end-expiratory value of 0.8-1MAC as measured by agent analyses, that is reducing the flow to 1 L/min after 10 minutes and finally to 0.5 L/min after 15 minutes which is maintenance phase and concrete phase for implementation of LFA (41,42).

Oxygen concentration should be maintained within a range of 33%-40% as displayed by oxygen analyser, this is attained by flowmeter setting of 40- 50% FiO_2.To prevent administration of hypoxic gas mixtures, Hypoxic guard alarm, low pressure O_2 alarm and O_2 failure alarms should be audible and Oxygen analyser should be properly waking to display actual FiO_2 and FeO_2 (43).

At the end of surgery, vaporizer is switch off 15-30min prior to the end of the surgical procedure, maintain a fresh gas flow rate of 0.5 L/min, lead patient to spontaneous breathing by manual ventilation and wash-out anesthetic gases with high flow of pure oxygen (5.0 L/min) in 5-10 min prior to extubation (34).

There is still a low prevalence and low acceptability of LFA technique in most developing and low resources countries. Baxter et al and the study done in Korea (88.5% of Korean Anaesthesiologists) revealed a lot of Anaesthesiologists were using high FGF of more than 4litres/min, reasons being fear of complications associated with LFA (5,44). Also, a study done by Vecil reported in 2008 reported that , the usage of high FGF (3-5l/min) was treasured by most clinician in their routine anaesthesia Practice (9).

The introduction of low solubility but prohibitively expensive inhalational Agents (Sevoflurane and Desflurane) and sophisticated anaesthesia workstations fueled molarity towards LFA technique with current prevalence being >80% in various countries. Numerous Institution and hospitals have tried to come up with solutions to tackle obstacles towards acceptance of low flow anaesthesia. Some of these measures involve, Providing Anaesthesia providers with education on implementation of LFA, Setting standard guidelines and protocols on FGF, establishment of Feedback mechanisms and follow-up on the practice of LFA, Use of automated fresh gas analysers, Procurement of Advanced and updated Anaesthesia machine and ensuring availability of minimum monitoring equipments for judicious practice of LFA (2,45,46).

In south African Initiation of guidelines and 0028 code for low flow anaesthesia along with introduction of Desflurane and sevoflurane in South Africa market revived interest towards LFA according to Welch et al (47). Carter et al documented on the importance of initiation low flow board as a result at the end of study >90% anaesthesia providers were using LFA (48). In USA, Real-time notification system was found to be an effective way to reduce inhalation agent usage through decreasing excess FGFs in a quality assurance study done in four phases (49).

Innumerable studies in India have publicized that, Low flow anaesthesia is being practiced by many anaesthesiologists despite the lack of adequate monitoring facilities and scavenging systems. Amma et al and Vivek et al reported Implementation of LFA in India was 73.8% and 63% respectively and majority of senior providers uses the flow rate of 0.5L/minutes (50,51).

Prevalence of LFA in Paediatrics is a continuing challenge because; use of open circuits or semi closed circuits is also more common in Paediatrics practice necessitating higher flows. Several studies have cleared queries regarding LFA in Paediatrics and it is currently being executed with maximum intraoperative child safety. Use of cuffed endotracheal tubes, automated volatile delivery systems and circle breathing circuits is becoming more common in pediatric practice eliminating many reasons for not lowering FGFs (52).

In Paediatric population and infants' low flow Anaesthesia also offer several advantage same as in the adult population. A study done on pediatrics using sevoflurane showed, Absolute humidity in the inspiratory gas with LFA was 4 times higher than with the HFA group and body temperature during anaesthesia was well preserved on LFA group compared to HFA which had low body temperature (53,54).

The attitude and acceptability towards LFA technique varies according to level of experience, knowledge and differences in the workplace. Vivek et al reported that senior Anaesthesiologists had higher proportion (32.5% out of 63%) on utilization of low FGF of <1l/min compared to most junior Anaesthesiologists who utilized FGF of >1l/min. Komesarrof et al also reported experienced anaesthetists had guts to use low flow rate ('risk takers') without adequate monitoring of Inhaled gases (55).

Those who practice in general surgery had proportion of 48.7% and Paediatric 37.8% (51), still low prevalence in Paediatrics. Also All anaesthesia providers(100%) from private hospitals practiced LFA followed by government teaching hospitals and lastly general government hospital had lowest proportion reason being lack of monitoring equipments (50).

2.2 Recommended and required monitors in conducting LFA.

A well-equipped anaesthesia workstation is a boon for better anaesthesia practice. In the past it was difficult /impossible to perform this technique because most of anaesthetic machines lacked the key features for low flow rate gas delivery and a leak-free circle system. Sophisticated workstations and automated gas monitoring have taken the guesswork out of low-flow techniques. The discovery of automated gas monitoring has even made LFA practice simpler.

Mandatory minimum monitoring equipments whenever a potent inhaled anaesthetic is used particularly to LFA consist of, Oxygen analyser, Volatile agent analysers, End-tidal CO2 monitor and all these monitors should have audible alarms to notify for any catastrophes. Workstations that display MAC values, proper working scavenging systems and carbon dioxide absorber are crucial for performance of LFA.

Bispectral index (BIS) monitors for monitoring depth of anaesthesia is recommended, however multigas monitor can be used instead. Continuous monitoring is crucial for safe performance of low flow anaesthesia, nowadays a lot of problems such as intraoperative awareness, hypoxia and hypercarbia are better avoided if judicious monitoring of inspired and expired inhalation Agent concentration, inspired oxygen concentration and end-tidal carbon dioxide concentrations is performed.

Currently, according to various developed protocol as published by Association of Anaesthetists of Great Britain and Ireland and other Societies, volatile agent monitor for inspired and expired concentration gas monitoring is mandatory and not an optional feature whenever a potent volatile anaesthetics is used (56–58).

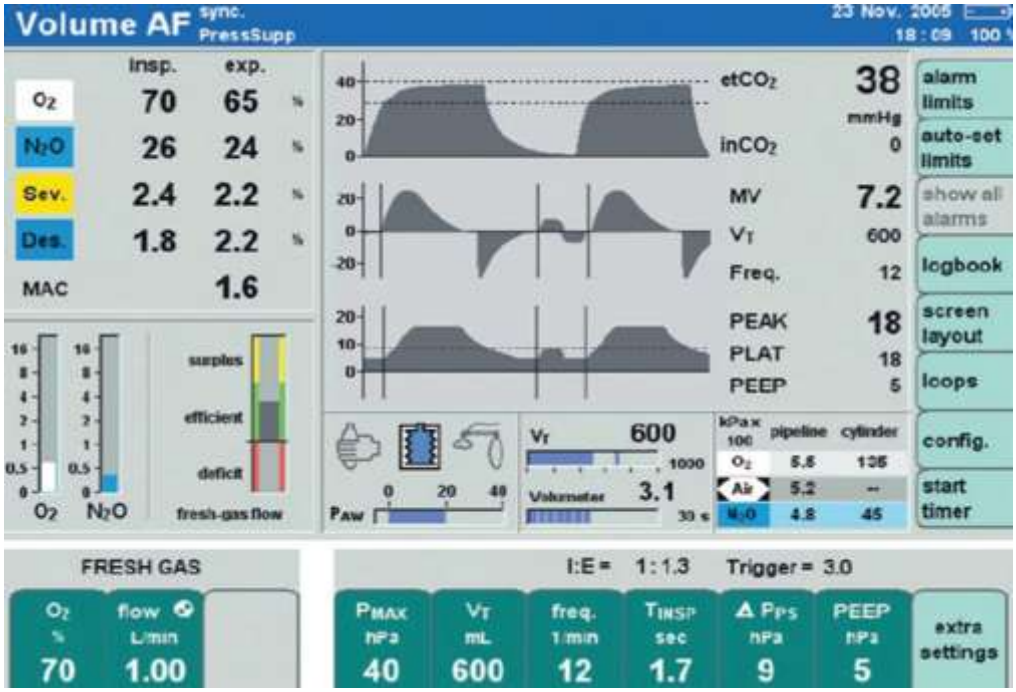


Figure 2 Screen displaying values to be monitored during implementation of LFA (34). ***This is possible when all the above mentioned monitors are incorporated in a workstation*.**

In developing countries, the availability of workstations and these monitors still unending problem. A study done in East Africa 2017, Muhimbili national hospital included, showed that few basic monitors were available however, this equipments were sometimes not functional and was not regularly serviced, was usually only repaired when broken down. Inspired O2 recording and scavenging systems were absent at Muhimbili national hospital (59).Another study done in developing countries ,some of African countries included revealed only 23% of Anaesthetist had access to basic monitors and if damaged expert from abroad had to come for repair (60).

In India, Amma et al reported on the use of different monitors whereby there was 65.9% used capnography, Oxygen analysers were used by 51.6%, agent analysers by 35.4%, BIS monitoring by 11.6%. Workstations were used by 64.6 %, workstations with MAC by 43.9%, Scavenging systems 33.5% (50).Korea, Jang et al reported only 27% of hospitals had pulse oximetry, capnography or multi-gas analyser and a scavenging system (44).

A study done in Ghana reported 18% of anaesthesia provider had no scavenging system, 28% anaesthesia provider had poorly functioning scavenging systems, All (100%)providers had never used inhalational agent analyser, Oxygen analyser and capnography was also a problem (61).

Carbon dioxide absorber is essential element in the entire system while using LFA, allowing a closed loop of gas to be recirculated by eliminating the CO2 being exhaled from the patient's lungs(1).To prevent risk of hypercapnia during LFA, carbon dioxide absorber needs to be changed on time whenever exhausted and the mean time for usage of single canister decrease when LFA is used routinely compared to HFA (62). Anaesthesia machines and breathing systems delivering halogenated anaesthetics and/or nitrous oxide should not be operated unless they are equipped with a functional scavenging system.

2.3 The choices of volatile Anaesthetics.

The customarily choice of volatile anaesthetics is governed by various factors comprising of, Patient disease conditions, type of surgeries (e.g. Neurosurgeries), Patient age groups (adults/Paediatrics), Stock availability of volatile agents, Cost and Expenses of volatile Agents, Need of enhanced emergency and Recovery, Allergies and Anaphylaxis and anaesthesia provider preference.

Most Anaesthesiologists worldwide uses inhalation agents over intravenous/TIVA during maintenance of anaesthesia. Also inhalational agents are used for induction more in paediatric than adult due to difficult venous access. Study done in Australia and New Zealand publicized that, Sevoflurane was preferred by 72%, propofol 16%, desflurane 12% and isoflurane 1% of anaesthetists (63).In America Sevoflurane was chosen most frequently by 66.4%, Desflurane was chosen by 22.3% and Isoflurane was chosen by 10.5% of Anaesthesiologists (64).

In Ghana 2017, a study done on Knowledge of Anaesthesia Providers on exposure to Inhalational Anaesthetic Agents found that Halothane (65%)and isoflurane (67%) were the most frequently used inhalational agents followed by sevoflurane ((49.3%) while desflurane (1.4%) was seldom used in daily practice (61).Findings from online survey done in India 2018 showed that Isoflurane was the commonest (55%) used volatile agents followed by halothane (51.5%), Sevoflurane, lastly Desflurane was used only by 5%. However many senior Anaesthesiologist >10years opted sevoflurane (50%) as a preferred volatile Agents compared to (22.22%) to junior anaesthesiologists (65).

In neuroanaesthesia, different inhalational agents have different effects on brain activities, metabolisms and side effects. A study done on Anaesthetic-Related Neuroprotection of Inhalational Agents found that, the most preferred agent was Isoflurane followed with sevoflurane, however all agents was used depending on stock availability (66).

Low-risk clinical profile of volatile Agents and faster induction/awakening times are among of factors which determine routine inhalational agent preference .At Victorian public hospitals Desflurane and sevoflurane were mostly preferred volatile agent and isoflurane was no longer used in the majority of Victorian public hospitals (67) .Carter et al also reported that Desflurane was the most favored volatile agent in use (36% of cases), followed by isoflurane (31%) and sevoflurane (17%) (48).

Sevoflurane and desflurane has become the agent preferred during maintenance of anaesthesia in many areas regardless of being most costly Agents because, low flow anaesthesia usage has cut down expenditures and hourly consumption of volatile agents. Sevoflurane is mostly used in Paediatrics compared to adult, especially in low resources countries. Diverse articles Shows sevoflurane to be most preferred while halothane is the least in preference. Desflurane is seldom available in most developing countries.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study approach

Hospital based cross sectional study.

3.2 Study design

The study was a hospital based descriptive cross sectional study design involving all Anaesthesia providers working in all MNH, and MOI operating theatres.

3.3 Study area

The study was conducted at Muhimbili National Hospital (MNH), Muhimbili National Hospital (MNH) -Mloganzila Campus and Muhimbili Orthopaedic Institute (MOI), in all operating theatres.

Muhimbili National Hospital is the national referral hospital, research Centre and university teaching hospital located in Dar es Salaam. Currently there are two branches of Muhimbili national hospital to mention, Main Muhimbili national hospital and Mloganzila –Muhimbili national hospital. It is the largest hospital in Tanzania with multiple specialties including medicine, dental, pharmacy, radiology, oncology, public health, nursing etc. with competent teachers in each Specialty. The hospital has 1500 capacity, attending 1,000-1,200 outpatient per day and 1,000-1,200 patients are admitted per week. It provides health services to Dar es Salaam population and also receives referrals from other hospitals all over the country (68).

Anaesthesia department at Muhimbili national hospital together with Mloganzila Campus has **141** Anaesthesia providers **including 11 Anaesthesiologists, 30 Residents, 3 medical officers**, **97 nurse anaesthetists** and nurse anaesthesia student (100) working together to provide anaesthesia services. More than 560 patients per week undergo surgery with more than half (>300 patients) receiving general anaesthesia (GA) under inhalation Agents.

Muhimbili Orthopaedic Institute (MOI) is a tertiary national referral and teaching hospital specialized in providing preventive and curative health services in Neurosurgery, Orthopaedic and Traumatology all over the country and from neighboring countries. The institute has a capacity of more than 380 beds including beds for general and private wards, installed MRI and CT-SCAN and 9 operating theatres with an average of 30 planned and emergency operations performed daily.

Muhimbili Orthopaedic Institute has approximately 40 anaesthesia providers, including a total **of 8 anaesthesiologists** and **28 nurse anaesthetists, 4 anaesthesia medical officers** and variable number of residents who are involved in daily anaesthetic service.

3.4 Study population

The study involved all anaesthesia providers working at MNH, MNH Mloganzila and MOI, anaesthesia residents and Registrars at MNH and MOI who were rotating in anaesthesia department during the study period.

3.5 Inclusion criteria

The study included the following:

- Anaesthesiologists working at MNH and MOI.
- All anaesthetists working at MNH and MOI.
- All medical officers working in the Anaesthesia department at MNH and MOI.
- All Anaesthesia Residents in second (2) and third (3) year of study.

3.6 Exclusion criteria

- All Anaesthesia Residents in first year of study.
- Intern doctors working in Anaesthesia department.
- Student nurse Anaesthetists in one year study program.

3.7 Study duration

The study was conducted for the period of for 8 months from 1st July 2019 to 28th February 2020.

3.8 Sample Size Determination.

The sample size of the quantitative cross sectional study was calculated using the following formula (69).

$$n=Z^2P\ (100-P)/E^2$$

Where

S= sample size of infinite population

Z= Z score, which was equivalent to 1.96 for 95% confidence interval

P= population proportion, taken as 73.2% for practice of low flow anaesthesia 500ml – <2 liters per minute among Anaesthesiologist in India (50).

E= marginal error, will be taken 5%

$S= 1.96^2 \times 73.2(100-73.2)/5^2$

=301

For finite population

SS = S/{1+ (S-1)/POAP}

Where

SS= sample size of finite population

S= sample size of infinite population (=301 from calculation above)

POAP= population anaesthesia providers approximately 160 in each year.

For MNH, POAP was approximately 141.

SS=301/ {1+ (301-1) /141}

=96, Anaesthesia providers were sampled from MNH.

For MOI, POAP was approximately 40.

SS=301/ {1+ (301-1) /40}

=35, Anaesthesia providers were sampled from MOI.

The total sample size was 131 anaesthesia providers sampled from MNH and MOI.

Taking into account non response rate

SS'=SS×100/ (100%-r)

Where

SS'= Actual sample size

r= Non response rate (17%).

Non response rate was 17% in the study done in India on the use of LFA and the choice of inhalational anaesthetic agents. However, the similar study done among Anaesthesiologists in India 2017, the non-response rate was none (51).

SS'= 131×100/ (100%-17%)

= 158 Anaesthesia providers.

Therefore, the minimum sample size taken was 158 Anaesthesia providers.

3.9 Study Variables

The independent variables were Years of experience in anaesthesia, work place, Gender, professional cadre, subspecialty of anaesthesia providers, Fresh gas flow rates setting during practice of low flow anaesthesia, preferred carrier gas, volatile agent used routinely, Types of anaesthesia machine used, Type of breathing system used ,Availability of workstations, scavenging systems, Oxygen analyser, agent analysers and Capnography.

The dependent Variables were practice of low flow anaesthesia technique and the choice of volatile Agents.

3. 10 Sampling techniques;

Anaesthesia providers who were working in all operating theatres at MNH, MNH-Mloganzila and MOI at that particular day were selected by non-probability convenient sampling. Anaesthesia providers were identified by their professional rank including Anaesthesiologist, medical officer, residents and Nurse Anaesthetists.

All 19 Anaesthesiologists, 30 Residents and 7 Anaesthesia Registrars working in all operating theatres in MNH and MOI were selected, The rest 102 study units were selected from Nurse anaesthetists working at MOI and MNH until the desired sample size was acquired. Enrolment was done after proper explanation to the Anaesthesia providers about the study and its rationale, consent for the study was done after fully understanding**.**

3.11 Data collection instruments

Structured questionnaires and checklists were used to collect information, it was a validated questionnaire tool adopted from past similar study with little modification. The questionnaire had a total of 20 questions consisting of demographic data such as Gender, years of experience in anaesthesia, professional rank, subspecialty of the practice and the workplace of participant.

The second part consisted questions specific to the practice of LFA, use of oxygen analysers and agent analysers, routine use of $ETCO_2$ monitors and Bispectral index (BIS) monitors, type of anaesthesia machine being used routinely, preferred carrier gas, the volatile agent of choice as well as the volatile agent in routine use.

Self-structured checklist was used to collect confirmatory information on flow rate setting, the volatile agent used, the specific number of available oxygen analysers and agent analysers, $ETCO_2$ monitors, Bispectral index (BIS) monitors and Workstations.

3.12 Data collection methods

Data were collected by the principle investigator with two research assistants, Research assistants were one Anaesthesia registrar and two Nurse Anaesthetists who were working at Muhimbili National Hospital (MNH). All Anaesthesiogists, Residents and Registrars were enrolled to fill the study questionnaire and more than 91 units were nurse Anaesthetists at the Data collector convenience.

Questions aim at assessing the practice pattern of low flow Anaesthesia, the availability of recommended monitors for the practice of low flow anaesthesia and volatile Agents choices among Anaesthesia providers was provided.

3.13 Data Management.

Data from the dull filled questionnaire were coded and checked for accuracy. A Microsoft excels (office 2010) database was developed with logic data quality check for inconsistence was done on a daily basis to ensure that incomplete and missing data were identified and corrected immediately. The complete database was exported to IBM Statistical package for social science (SPSS) version 23 for cleaning and analysis.

3.14 Data analysis.

Data analysis was done by using statistical software IBM Statistical package for social science (SPSS) version 23 (SPSS version 23). Proportional/ percentages were determined for categorical variables and these percentages were used to summarize categorical variables for Demographic data, practice setting of LFA, Availability of workstations, scavenging systems, minimum monitoring equipment, gas flow rate easier to use, importance of monitoring volatile anaesthetics, volatile agents used routinely and volatile agent of choice**.**

Pearson's Chi-square test and Fisher's exact test were used to determine association of some categorical variables with low flow anaesthesia and at P value < 0.05 the differences were considered statistically significant.

3.15 Ethical clearance and ethical considerations.

Ethical approval was obtained from MUHAS ethical research committee and review board and permission to conduct the study at Muhimbili Orthopaedic institute and Muhimbili National Hospital was granted by Executive Directors before data collection. Anaesthesia providers were informed about the study, given the chance to ask questions and the chance to participate or not to participate in the study without interfering their daily duty. Confidentiality was assured to all participants and they were not paid for being involved in this study.

CHAPTER FOUR

4.0 RESULTS

Total questionnaires of 158 were returned, making a response rate of 100%. Most participants were nurse anaesthetists and residents, Only 11 Anaesthesiologists participated in a study with a response rate of 61%. Demographic characteristics of respondents are summarized in **Table 2.**

Table 2: Demographic characteristics of the study participants

Variable	Categories	Frequency (n)	Percentage (%)
Working experience (years)	≤ 5	93	58.9
	6 – 10	35	22.2
	11 – 15	13	8.2
	16 – 20	6	3.8
	≥ 21	11	7.0
	Total	**158**	**100**
Workplace	MNH	79	50.0
	MOI	59	37.3
	MNH Mloganzila	20	12.7
	Total	**158**	**100**
Gender	Male	117	74.1
	Female	41	25.9
	Total	**158**	**100**
Professional cadre	Anaesthesiologist	11	7.0
	Residents	21	13.3
	Anaesthesia registrar	6	3.8
	Nurse Anaesthests	120	75.9
	Total	**158**	**100**
Subspecialty	Surgical	57	36.1
	Obstetric Anaesthesia	15	9.5
	Paediatric Anaesthesia	11	7.0
	Orthopaedic anaesthesia	60	38.0
	Others (neurosurgery, critical care).	15	9.5
	Total	**158**	**100**

**Subspeciality. Majority from Muhimbili national hospital were practicing in surgical, Obstetric as well as paeditric anaesthesia. * MNH=Muhimbili nation hospital, *MOI=Muhimbili Orthopaedic Institute.*

Table 2 summarizes the demographic characteristics of study participants, Majority of anaesthesia providers had experience of ≤5 years (58.9%) and only 7% had experience more than 20 years. Regarding workplace of practice majority were from Muhimbili national hospital 50%, male participants were 74.1% and the rest were female. Most anaesthesia providers were Nurse Anaesthetists comprising more than half of respondents, 71.5%, while Anaesthesiologists comprised only 7% of anaesthesia providers. Subspeciality of practice, only 38.0% worked solely in orthopaedic anaesthesia but most of anaesthesia providers, 62.0% were rotating according to duty schedule.

4.1 Routine Practice of Low Flow Anaesthesia.

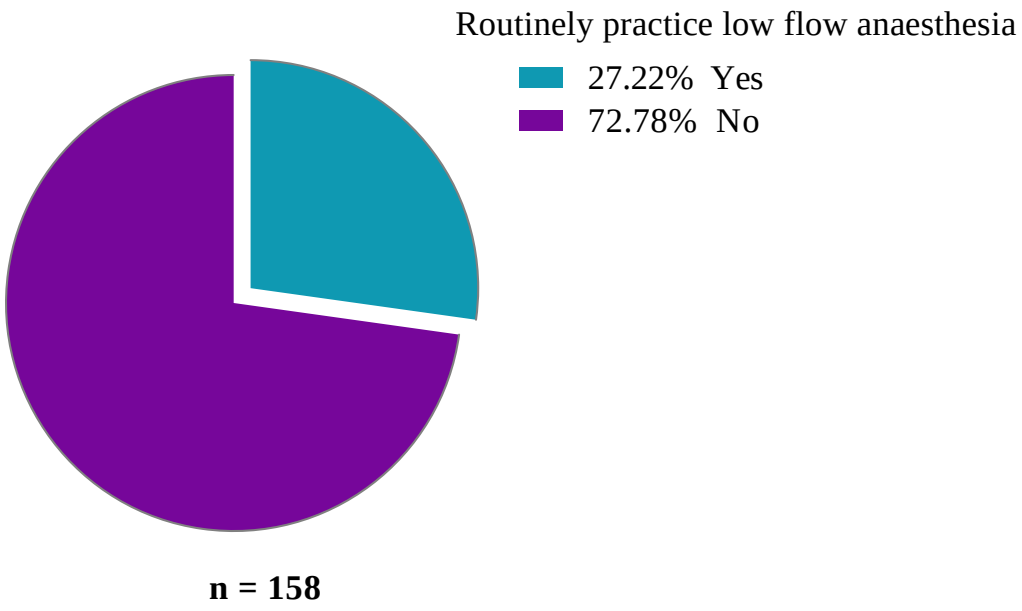


Figure 3: Routine practice of low flow Anaesthesia

Regarding to the routine practice of Low flow anaesthesia, 27.2% of anaesthesia providers routinely practiced low flow anaesthesia **[figure 3].**Experience in anaesthesia services was compared with the practice of LFA.

For those who routinely practice low flow anaesthesia, majority had experience of more than 10years (43.8%), participant with ≤5years of experience in anaesthesia had the lowest proportion (21%) of routine practiced low flow anaesthesia. The difference of practicing low flow Anaesthesia among providers with years of experience was statistically significant with a P value of =0.036 as shown in **[figure 4]**.

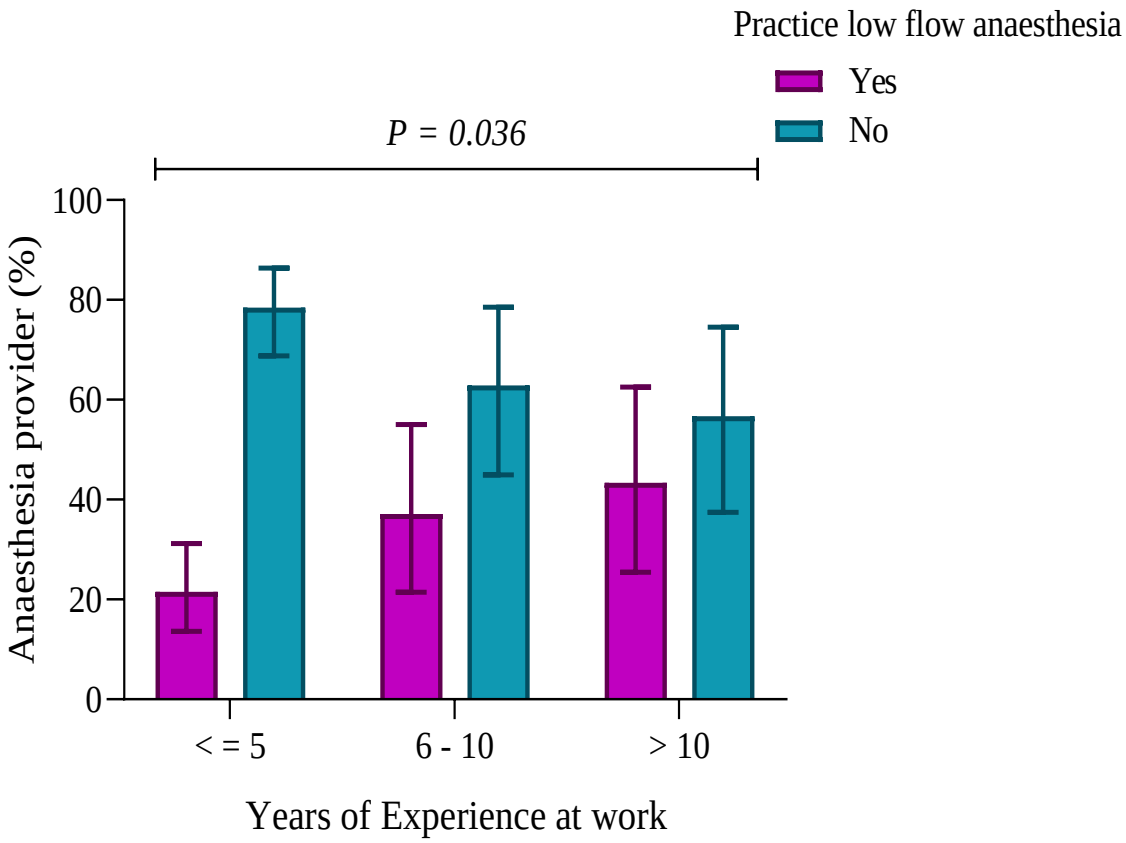


Figure 4; The Association of practicing low flow Anaesthesia among providers with years of Experience

Hospital based practice of low flow Anaesthesia was analyzed, Respondents from Muhimbili national hospital had the highest proportion (41.8%) for routine practice of low flow anaesthesia among study participant compared to MOI and Muhimbili National Hospital Mloganzila branch which had 16.9% and 15.0% proportions of Anaesthesia providers

respectively, as shown in the [**figure 5]**. The difference of practicing low flow Anaesthesia among providers from different work place (study sites) setting was statistically significant with a P value = 0.002 as shown in **[figure 5].**

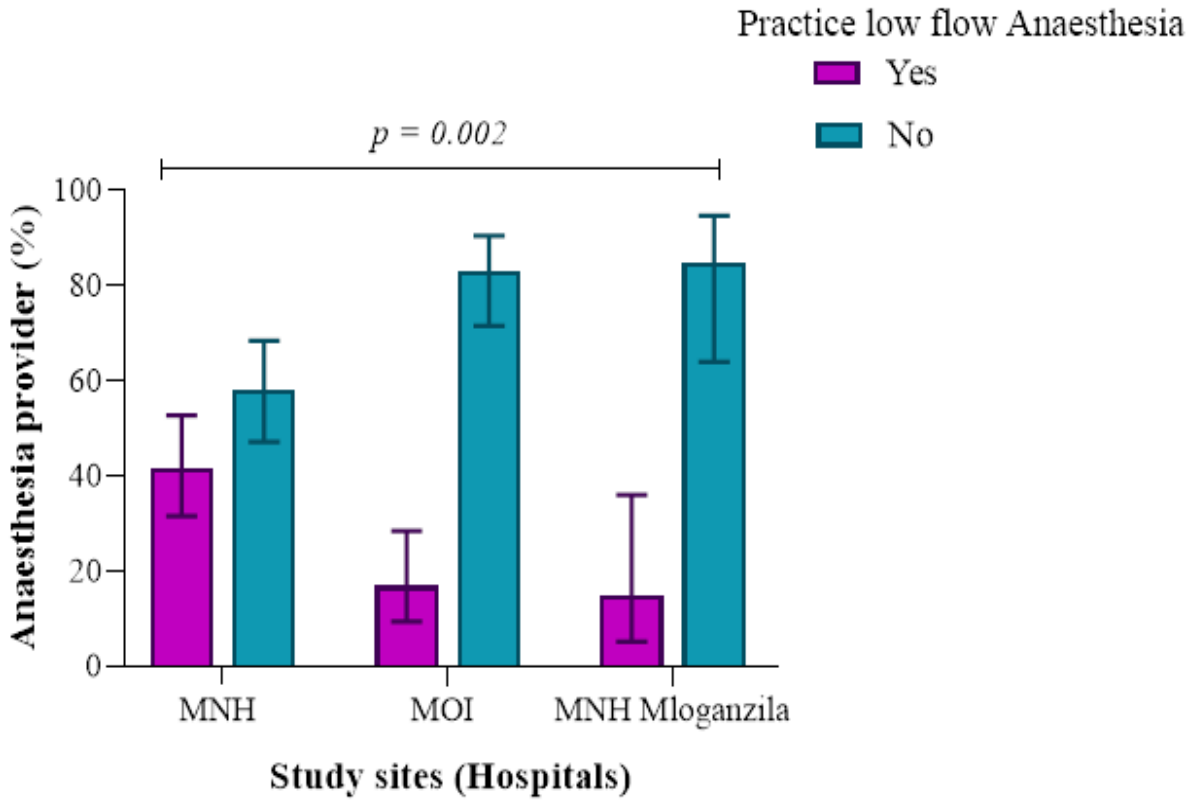


Figure 5; The Association of practicing low flow Anaesthesia among providers with the study sites (hospitals).

Also implementation of Low flow anaesthesia varies depending on the level of Education of anaesthesia providers, more than half of Anaesthesiologists 63.6% practiced LFA in their daily duty. Proportion of implementing LFA anaesthesia reduced as the level of education decreased, Residents had 28.6% proportion followed by 24.8% nurse anaesthetists practicing LFA while none of anaesthesia registrars had ever practiced low flow anaesthesia, The difference was significant with P value of 0.019 as revealed in **Table 3**.

Concerning Subspeciality of practice, Majority of Anaesthesia providers who were in Orthopaedic and obstetric theater didn't practice LFA**.** Anaesthesia providers working in neurosurgery and other Subspeciality had highest proportion 53.3% of daily usage of LFA technique. Anaesthesia provider working in general surgery theaters of 36.8% proportion implemented LFA, while providers from orthopaedic and obstetric theater had lowest percentage of 16.7% and 6.7% respectively in implementing LFA technique on daily bases. The difference was more significant with P value of 0.006.

Type of volatile agents used routinely didn't influence practice habit of LFA technique, the difference was not statistically significant with P value of 0.858 as shown in **Table 3.**

Table 3: Association of practice of low flow Anaesthesia in relation to Type of volatile agent used, Subspeciality of practice and professional cadre of Anaesthesia providers.

Variable	Categories	Practice LFA n (%)	Don't Practice LFA n (%)	Total	P Value
Professional cadre	Anaesthesiologist	7(63.6%)	4(36.4%)	11(100%)	
	Residents	8(28.6%)	20(71.4%)	28(100%)	
	Anaesthesia registrar	0(0.00%)	6(100.0%)	6(100%)	
	Nurse Anaesthests	28(24.8%)	85(75.2%)	113(100%)	**0.019**
Subspecialty	Surgical	21(36.8%)	36(63.2%)	57(100%)	
	Obstetric Anaesthesia	1(6.7%)	14(93.3)	15(100%)	
	Paediatric Anaesthesia	3(27.3%)	8(72.7%)	11(100%)	
	Orthopaedic anaesthesia	10(16.7%)	50(83.3%)	60(100%)	
	Others	8(53.3%)	7(46.7%)	15(100%)	**0.006**
Type of Volatile agents	Isoflurane	35(26.9%)	95(73.1%)	130(100%)	
	Sevoflurane	8(28.6%)	20(71.4%)	28(100%)	**0.858**

4.2 Practice Settings During Conduct of LFA

Concerning FGF rate used during the practice of low flow anaesthesia, Only 23.3% used fresh gas flow rate of 0.5-1l/minutes, Majority Anaesthesia providers (46.5%) who claimed to practice low flow anaesthesia used fresh gas flow rate between 1.6 - ≥ 2l/minutes, which does not tally with an acceptable definition of "low flow anaesthesia" [**Figure 6**].Therefore the actual routine practice of low flow Anaesthesia was **6%**, which is very low.

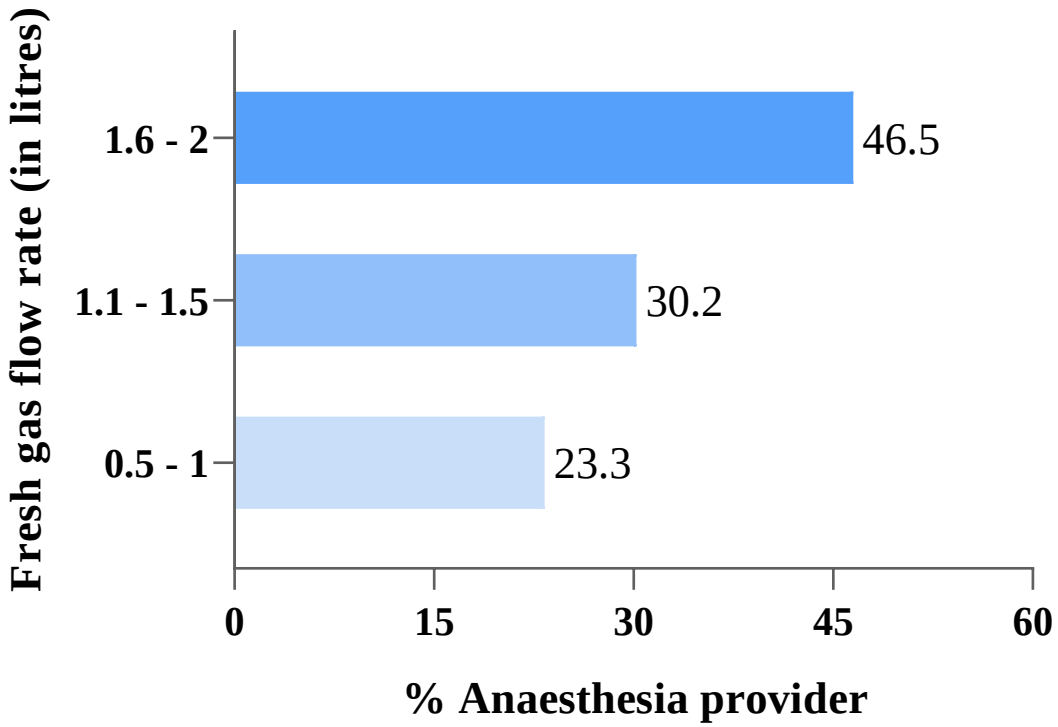


Figure 6: Fresh gas flow rates used during routine use of low flow anaesthesia.

Of those respondents who routinely practiced LFA**,** 83.7% respondents reported to reduce FGF stepwise whereby 72.1% anaesthesia providers reduced FGF 10minutes after induction, 20.9% reduced FGF 15minutes after induction and 7% reduced fresh gas flow >20minutes after induction. Fraction of inspired oxygen (FiO_2) used by respondents when implementing LFA was, FiO_2 of 51%-60% was used by 30.2%, FiO_2 of 30%-40% was used by 30.2%,

followed by FiO_2 of >60%, which was used by 25.6% of respondents and lastly FiO_2 of 41%-50% was used by 16.3% of respondents.

The main carrier gas was mixture of oxygen and air, which was preferred by 90.7% of anaesthesia providers, oxygen as sole carrier gas was preferred by 9.3% of anaesthesia providers and N_2O was not used as a carrier gas at all, **[Table 4].**

Table 4: Practicing characteristics of low flow anaesthesia among anaesthesia providers.

Variables	Categories	Frequency (n)	Percentage (%)
Reduce flow rate stepwise	Yes	36	83.7
Time to decrease flow after induction	10 minutes	31	72.1
	15 minutes	9	20.9
	>20 minutes	3	7.0
Fraction of inspired oxygen	30 – 40%	12	27.9
	41 – 50%	7	16.3
	51 – 60%	13	30.2
	>60%	11	25.6
Carrier gas of preference	Oxygen	4	9.3
	Oxygen and air	39	90.7
	N2O	0	0
LFA satisfactory	Yes	32	74.4
Breathing system which is safe and easy to use	Circle system	40	93.0
	Open system	1	2.3
	Semi open	2	4.7
Important to monitor volatile anaesthetic	Yes	42	97.7
FGF easy to be used	High FGF	21	48.9
	Low FGF	17	39.5
	Minimal FGF	5	11.6

LFA=Low flow anaesthesia, FGF=fresh gas flow

Monitoring concentration of inhaled anaesthetics was considered important by the majority (97.7%) of anaesthesia providers while using low flow anaesthesia. When asked about the breathing system used during practice of LFA 93% reported, a circle system as safe and easy to use while 4.7% and 2.3% reported semi open and open systems as safe and easy to use Respectively **[Table 4].**Regarding fresh gas flow dial on flow meters, majority considered High FGF was simplest flow to be used as revealed by 48.9% of the population, 39.5% considered low FGF to be the simple flow setting as well as 6% considered minimal FGF to be the simple flow setting. On general comment on LFA, 74.4% of respondents still considered this technique to be satisfactory for daily practice while 25.5% reported it is not satisfactory [**Table 4**].

4.3 Availabity of Monitors, Scavenging And Advanced Anaesthesia mchines during practice of LFA.

Table 5: Summarizes the availability of monitoring equipments during the conduct of LFA. There were 37 operating rooms with 37 anaesthesia Machines, all providers (100%) had the opportunity to work in the theatre room with anaesthesia machine however 7 machines were not working properly. Majority of anaesthesia machine were dragger, Mindrey, Datex Ohmeda. There were 10 workstations displaying MAC only 2.3% of anaesthesia providers were using it adequately.

Availability of monitors, which are functioning properly was, Oxygen Analysers (28), Agent analysers (3), Working and non-working Capnography (15 and 12 respectively) and BIS (0). Concerning utilization of these monitors, oxygen Analysers were utilized by 6.9%, Capnography by 55.8% while none of Anaesthesia provider utilized Agent analysers and BIS monitors. Scavenging system (central scavenging and in workstation) was available and 79.1% of anaesthesia had the chance to work in the OT room with properly functioning scavenging system. Anaesthesia machines in Emergency theatre were not functioning **(Table 5].**

Table 5: Availability of workstations, scavenging systems and minimum monitoring equipments.

Type of equipment	MOI hospital	MNH hospital	MNH Mloganzila	Percent of anaesthesia providers using (%).
Workstations (Dragger, Mindrey and others).	9	16	12	100
Workstation with MAC	1	7	2	2.3
Oxygen Analyzer	5	11	12	6.9
Scavenging system	7	14	12	79.1
Capnography	5	8	2	55.8
Agent Analyzer	1	2	0	0
BIS	0	0	0	0

BIS= Bispectral index, MAC=Minimum Alveolar Ventilation.

4.4 Volatile agents used routinely

Isoflurane was volatile Agent routinely used by all anaesthesia providers (100%), Sevoflurane by 69% of anaesthesia providers and Halothane by only 32% of anaesthesia providers. MNH main campus and MNH Mloganzila hospital had abandoned using Halothane and all respondents from all hospitals in the study had never used Desflurane [**Figure 7**].

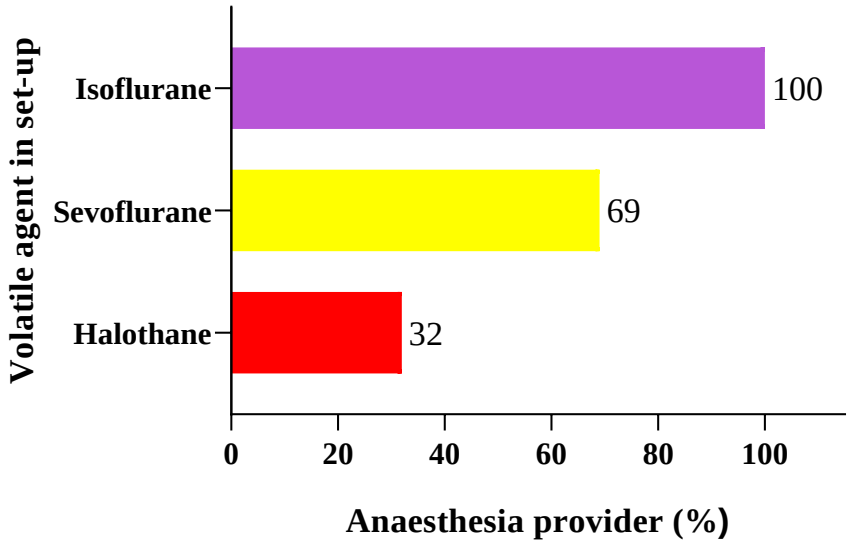


Figure 7: Volatile agents routinely used (Some providers opted more than one volatile agent as "routinely used".

4.5 Preffered volatile agents.

Regarding the volatile agent of preference when given the opportunity to choose, the responses were, Sevoflurane was most preferred by (55.7%) followed by Isoflurane by (42,4%), Halothane by (1.9%) and none preferred Desflurane **[Figure 8**].

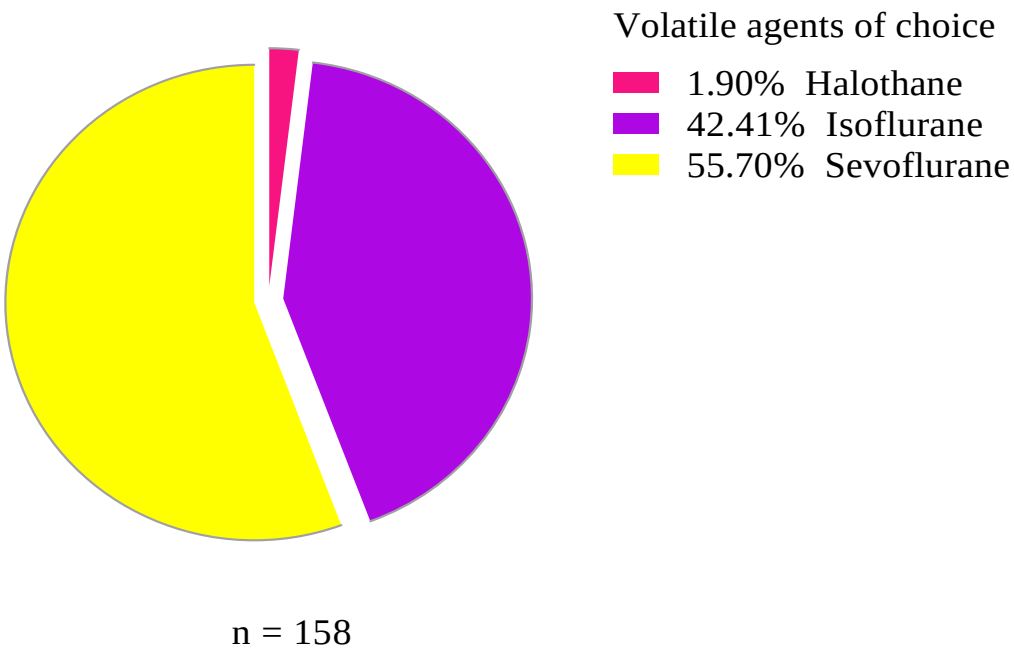


Figure 8: Volatile agent of preference for daily anaesthesia practice.

Table 6:Influence of provider's subspecialty to anaesthetic Agents choices.

Subspeciality of providers had positive influence on the choice of volatile agents, Sevoflurane was mostly used by providers working in paediatric accounting to 38.9%, followed by general surgery (22.2%), and the lowest proportion was from orthopaedic (16.7%) and obstetric (5.6%). Isoflurane was mostly used by providers working in general surgery accounting to 39.2%, followed by orthopaedic 37.6%), and the lowest proportion was from paediatric (2.4%).Halothane was mostly used by providers working in orthopaedic accounting to 66.7% of providers. This difference was statistically significant with P Value of 0.0001.

Volatile agents	Subspecialty n(percentage)						**P VALUE**
	paediatric	general	orthopaedic	obstetric	others	Total	
Sevoflurane	**7(38.9%)**	4(22.2%)	3(16.7%)	1(5.6%)	3(16.7%)	18(100.0%)	
Isoflurane	3(2.4%)	**49(39.2%)**	47(37.6%)	14(11.2%)	12(9.6%)	125(100.0%)	**0.0001**
Halothane	1(6.7%)	4(26.7%)	**10(66.7%)**	0(0.0%)	0(0.0%)	15(100.0%)	
Total	11(7.0%)	57(36.1%)	60(38.0%)	15(9.5%)	15(9.5%)	158(100.0%)	

CHAPTER FIVE

5.0 DISSCUSSION

Low flow anaesthesia deserves a prime place in the clinical anaesthesia practice. With the availability of Protocol and guidelines for executing LFA, advanced anaesthesia machine and mandatory anaesthesia gas monitoring equipments, Anaesthesia provider can accept and willingly practice LFA. Availability of sophisticated workstations along with the introduction of low solubility inhalational agents has made the use of low FGF to become possible even in some of the African and developing countries like in South Africa and India (47,70) .

However in most African countries, prevalence of LFA is still very low. Analysis from my study shows LFA is still underused anaesthesia technique with frequency of 6% as well as in Ghana, results reveled only 7% of anaesthesia providers practiced LFA irrespective of majority (90%) being aware of health and environmental effects of in inhaled anaesthetics.

Working experience in Anaesthesia services and difference in hospitals setup, play an important role in influencing practice of LFA. This study results shows that, those with more than 10years of experience had highest proportion (43.3%, p value 0.036) of routinely LFA practice consistent with study done in India whereby, Anaesthesiologist (32.5% out of 63% who practiced LFA) with many years of experience in anaesthesia loved to use FGF of <500mls resembling with my study findings (55). Also most respondents (41.8%, p value 0.002) who practiced LFA were from Muhimbili national hospital (MNH) consistent with study done in Nigeria which, the use of LFA technique was restricted to only some few tertiary care hospitals according to Okafor et al (71).

Analyses from my study revealed that the use High fresh gas flow is the prevailing practice habits and very common, up to 94% of the population was using high flow rates. Low flow anaesthesia, is seldom used in our vicinity with the true prevalence **6%** although 27.2% of my study participants reported to be practicing LFA, this is because even those who were using FGF of >1L/min and >2l/minutes reported to be implementing LFA. This discrepancy of

analysis between actual Low anaesthesia FGF and reported prevalence from study participants along with low prevalence indicates that there are gaps of knowledge on true concept of LFA.

Several Studies have shown that expanding knowledge of LFA among anaesthesia providers, initiating motivation ways to anaesthesia providers and setting protocol fosters the prevalence of LFA in the country. In south Africa the introduction of 0028 code for LFA reinforced the practice of LFA (47). In Europe and other countries there was escalation in the daily use of LFA as evidenced by 43% increase in application of LFA after training and CMEs (45,72,73). Continuing education and training is mandatory so that Anaesthesia providers can be kept updated with knowledge on individualized medicine to make the correct decision and options when using volatile anaesthetic agents.

Back to the basics of uptake and distribution of inhaled anaesthetics, it takes 5 half-lives to reach state of equilibrium of drugs. The time to reach this steady depends on the flowmeter FGF setting and the vaporizer dial setting, so an initial high-flow phase is needed to establish the desired gas composition within the whole gas-containing space and to establish the desired anaesthetic level . According to Baum and various authors a stead state can be reached after 10minutes if the FGF is kept >4l/min or equal to total patient minute ventilation and vaporizer dial setting of ≥2.5MAC/maximum vaporizer dial setting (5,62).

To practice LFA, high FGF should be reduced 10minutes after induction of anaesthesia and minimal anaesthesia FGF is reduced after 15minutes (12). According to the analysis of my survey, 72.1% of Respondents reduced FGF after 10minutes and 30.1% of respondents used FiO2 of 50%-60% which is in accordance with the practice of LFA. After reduction of FGF, inspiratory Oxygen concentration should be maintained in a range of 33%-40%, of which can be attained by FiO_2 of ≥50% to ≤60% in fresh gas mixture. My survey found that 44.2% of respondent used FiO2 < 50%, which disposes the patients to hypoxic gas mixture in the absence of adequate monitoring tools. The best way to maintain the value of inspiratory oxygen within required level is by use of multigas monitors, Hence rigorous monitoring is mandatory for safe practice of LFA and an advanced workstation is of paramount important.

Respiratory gas analysis has now become a standard monitoring technique in anaesthesia practice in theatres, intensive care unit, and for the transfer of ventilated patients. The AAGBI Recommendations for Standards of Monitoring during Anaesthesia and Recovery 2017 , recommends oxygen analyser with an audible alarms, a carbon dioxide analyser and a vapour analyser as essential components whenever a potent volatile anaesthetic is delivered (56).

Availability of sufficient monitors is still a continuing problem in most developing countries (59,74). According to my survey, there is a shortage of workstations displaying MAC and recommended monitors encompassing of ETCO2, inspiratory oxygen analyser, Agent analyzer and BIS monitors to offer extensive capabilities for ventilation, monitoring and inhaled agent delivery during LFA and closed loop anaesthesia. Several studies has reported incidences of light anaesthesia intraoperatively, therefore MAC need to be monitored correctly together with respiratory gases in order to avoid this incidences of intraoperative awareness (58,75).

Also my study showed that some of the available anaesthesia machines were old-fashioned and some had software for monitoring MAC, respiratory gas and BIS but analyzing equipments/ plug in modules and Gas sampling systems/cables to enable displays were not installed. This study results are consistent with previous study done in East Africa and Tanzania district hospital 2019, which revealed limited monitoring equipments and functioning anesthesia machines and some available tools were non-functioning (59,76).

When using air as a carrier gas during LFA, a mild increase in the concentration of the inhaled anaesthetic agent (0.2–0.25% of MAC value) is to be used (37). BIS monitoring is desirable when air is used as a carrier gas for detection of intraoperative awareness however with the presence of respiratory gas monitors, depth of anaesthesia can be guaranteed. My study revealed none of the respondent used BIS monitor despite 97% of anaesthesia providers using mixture of oxygen and air as carrier gas hence patient are exposed to risk of light anaesthesia crisis intraoperative.

All gases delivered from the anaesthesia machine are released to the atmospheric air and theater environment which adds to the greenhouse effect. There is a lack of scavenging systems in some of the OTs as revealed by my survey consistent with previous survey done at MNH (59). Only 79.1% respondents of my study had opportunity to work in OTs with properly functioning scavenging system. Multiple studies on occupation diseases and control of WAGs have suggested methods to reduce the environmental pollution from anaesthesia wastes by changing practice customs such as **avoiding N_2O use and using low flows** (21,25,28). In our vicinity N_2O is not used but LFA is not implemented, high flow anaesthesia is the predominant practice pattern.

Low flow anaesthesia can be accepted in our vicinity if proper training is given highlighting, how to perform LFA, needed monitors, Advantages of LFA and its limitations for the reason that 74.4% anaesthesia providers reported LFA to be satisfactory and 39.5% said it easier to perform LFA with circle systems consistent with COTTER et al (77). However 48.9% still recommended high FGF as easy to be used regardless of the consequences it carry compared to LFA technique

Routinely used volatile agents were different among study areas, at MNH and MNH Mloganzila routine volatile agents used were isoflurane and sevoflurane, halothane is currently not used while at MOI hospital, anaesthesia providers routinely used Isoflurane, sevoflurane and halothane. Desflurane is not available in all hospitals, Sevoflurane was most used in paediatric department during induction of anaesthesia. This study correlates with studies done in Ghana and Nigeria which isoflurane was routinely used volatile agents by 49.3% and 46.3% of anaesthesia providers respectively while halothane was less chosen (61,65).

However most anaesthesia provider preferred Sevoflurane (55.7%) followed by isoflurane (42.4%) and only 1.9% preferred halothane consistent with various articles which is consisted to this study findings (61,71).

There are several reasons which affected the choice of routinely used Volatile agents, some of these reasons are market cost of inhaled anaesthetics, stock availability of volatile Agents ,age group of patients, safety concern, type of surgery, Environment safety and department bylaws/protocol as shown by study done in USA and other countries (2,64) . My study reveals the same finding, the major reasons being cost, department bylaws and stock availability of volatile Agents in which there was more of isoflurane.

The use of LFA, educational programs, and incentivized or restrictive drugs purchasing can also affects the choice of inhaled anaesthetics. Outcome from study done to determine the effectiveness of an education program on volatile agent choice, revealed increased usage of sevoflurane (26% to 41%) and desflurane (17% to 26%) post education program on LFA (2).

5.1 Study limitations.

- The findings of this study cannot be generalized to other hospitals outside MNH, MNH Mloganzila and MOI, due to the fact that the study is conducted in tertiary national hospitals with huge difference with regional and district hospitals in terms of education and experience of anaesthesia providers , availability of monitors and hospital facilities.
- Knowledge assessment on understanding of theory and how to perform Low flow anaesthesia was not included in my study.
- Cost is very important in medicine practice, but I did not involve part of cost analysis, to reveal the actual loss encountered by these institutions.

5.2 Mitigations

- In future, more informations can be gathered by involving more governments and private hospitals or country based studies using the same questionnaire tools since it was validated from where was adopted.
- Knowledge assessment can be studied as another research to know the precise understanding of theory and technical preconditions of Low flow anaesthesia and how to do it.
- Cost analysis can be studied as another research to know the loss gained by anaesthesia department and hospitals at large, to know cost reduction after implementing LFA and to compare the costs of inhaled anaesthetics in low FGF and high FGF.

CHAPTER SIX

6.0 CONCLUSSION AND RECCORMENDATIONS.

6.1 Conclussion

Low flow anaesthesia is seldom practiced in our locality despite having strong evidence of attractive advantages in medical practice and ergonomics.

Availability of Sophisticated workstation and recommended monitors for volatile agents and other anaesthesia gas is still a problem within the studied hospitals

Isoflurane is the most frequently used volatile anaesthetics, sevoflurane availability is restricted. Desflurane is not available at MNH & MOI tertiary public hospitals .

6.2 Reccormendations.

LFA basic principles and technical preconditions should be well taught to all anaesthesia providers . Intensify LFA training during residency and nurse anaesthesia training.

Initiate protocols/ codes for LFA, start to implement it in our area. Improve availability of respiratory gas monitors and update our anaesthesia Machines.

Further study need to be done on cost analysis of inhalational agent use and knowledge assessment on LFA.

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APPENDICES

APPENDEX 1

STUDY QUESTIONS.

1. General information.

a. Years of experience in anaesthesia: ----------

b. Work place where you practice: ----------

c. Gender:

Male □ Female □

d. Kindly indicate your professional cadre.

Anaesthesiologist□
Residents□
Anaesthesia registrar□
Anaesthests□
Nurse Anaesthests student□

e. Kindly indicate your subspecialty.

General □
Cardiac and Vascular □
Critical Care □
Paediatric Anaesthesia □
Obstetric Anaesthesia□
Other □ (please specify) ----------

2. Do you routinely practice low flow anaesthesia?

   a. Yes □
   b. No □

   ○ If No, kindly return the questionnaire. Thank you for your participation.

3. What is the fresh gas flow rate you use routinely?

   A. <0.5Litre □
   B. 0.5 Litre□
   C. 0.5-1Litre □
   D. 1-1.5Litre □
   E. 1.5-2Litre □
   F.>2Litre□

4. Do you reduce the flow rate of inhalational Anaesthesia stepwise?

   A. Yes □
   B. No □

5. How long after induction do you decrease the flow to low flow?

   A. 10 minutes □
   B. 15 minutes □
   C. 20 minutes □
   D. >20 minutes □

6. What concentration of inspired oxygen (FiO2) do you use when practicing low flow anaesthesia?

   A. 30–40% □
   B. 41–50% □
   C. 51–60% □
   D. >60%

7. Do you use oxygen analyser?

   A. Yes □
   B. No

8. Do you use agent analyser at your work place?

   A. Yes □
   B. No □

9. Do you monitor End -tidal carbon dioxide (ETCO2) routinely in all cases?

   A. Yes □
   B. No □

10. Which is the carrier gas of preference?

   A. N2O □
   B. Air □
   C. O2□
   D. O2 and Air□

11. Do you have workstation (Kindly specify the type of anaesthesia machine).

    A. Dragger □
    B. Conventional Boyles Machine □
    C. Entonox apparatus □
    D. Others (specify……..)

12. Does your workstation display MAC values?

    A. Yes □
    B. No □

13. Do you have scavenging system at your work place?

    A. Yes □
    B. No □

14. Is Bispectral Index (BIS) monitoring routinely used?

    A. Yes □
    B. No □

15. According to your experience is LFA satisfactory?

    A. Yes□
    B. No□

16. Which breathing system is easy and safe to use regarding LFA.

    A. Circle system □
    B. Open system □
    C. Semi open □

17. Which gas flow rate is easier to use for daily practice?
    A. Conventional (high flow) rate □
    B. Low flow rate □
    C. Minimal flow rate □
    D. Metabolic flow (Basal flow) □

18. Is it important to monitor volatile anaesthetic concentrations in the circle system during usage of LFA?
    A. Yes□
    B. No □

19. Which volatile agent do you routinely use at your work place?

    a. Halothane

    b. Isoflurane

    c. Sevoflurane

    d. Desflurane

20. Please specify the agent of your choice while practicing low flow anaesthesia.
    a. Sevoflurane
    b. Isoflurane
    c. Halothane
    d. Desflurane

APPENDIX 2.

CHECKLIST OF FLOW RATE, AVAILABLE MONITORS AND VOLATILE AGENTS.

S/N	Parameter	Total Number
1	Flow rate settings	a. <0.5Litre b. 0.5 Litre c. 0.5-1Litre d. 1-1.5Litre e. 1.5-2Litre f. >2Litre
2	Volatile Agents	a) Halothane b) isoflurane c) sevoflurane d) desflurane
3	Agent analyser	
4	Oxygen analysers	
5	$ETCO_2$ monitors	
6	Bispectral index	
7	Workstations	
8	Workstations with MAC	

APPENDIX 3.

CONSENT FORM

I am Dr. Happiness Joab Mathew, a resident from Muhimbili University of Health and Allied Sciences (MUHAS), I am conducting a study titled "*PRACTICE **OF LOW FLOW ANAESTHESIA AND VOLATILE AGENTS CHOICES AMONG ANAESTHESIA PROVIDERS AT MUHIMBILI NATIONAL HOSPITAL AND MUHIMBILI ORTHOPAEDIC INSTITUTE".***

Participation in the study

You are kindly requested to be part of this study, if you accept to participate your relative particulars/information will be taken and used for the purpose of this study and this involve the Demographic data (Gender, Experience in Anaesthesia, Work place, professional cadre and subspecialty of practice).Your participation is completely voluntary and you may withdraw consent at any time course of interview.

Confidentiality

You are strongly assured of the confidentiality of the information obtained that will only be used for the purpose of this research and anonymity will highly be observed when collecting data and compiling reports. To assure you even your name will not be acquired to appear in the questionnaires and checklist involved.

Risk of Participating

No anticipated or harm that may result from participating in this study. Your participation is absolutely voluntary and there is no penalty for effusing to participate. You are free to ask questions and you may stop to participate in this study at any time.

Contact person

The principal investigator, Dr. Happiness Joab Mathew (0755708666) is a key contact person with regard to any queries about this study.

If you have any question/concern about your rights as a participant you may contact.

Director Research and Publication Muhimbili University Of Health and Allied Sciences (MUHAS) Dr.Bruno Sunguya.

P.O.BOX 65001, Dar es Salaam

+255 222 150 302-6/2152489.

If you agree to participate in this study please sign this consent form.

I (initials) …….Have read and understand the contents of this form and I have been given satisfactory explanation with all my questions answered. I therefore consent to participate in this study

Signature of the proxy…… Date……..

Signature of the interviewer…….Date…….

APPENDIX 4.

Ethical Clearance

MUHIMBILI UNIVERSITY OF HEALTH AND ALLIED SCIENCES
OFFICE OF THE DIRECTOR OF POSTGRADUATE STUDIES

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Ref. No. DA.287/298/01A/

6th August, 2019

Dr. Happiness Joab Mathew
MMed. Anaesthesiology
MUHAS.

RE: APPROVAL OF ETHICAL CLEARANCE FOR A STUDY TITLED: "PRACTICE OF LOW ANAESTHESIA AND VOLATILE AGENT CHOICES AMONG ANAESTHESIA PROVIDERS AT MNH AND MOI"

Reference is made to the above heading.

I am pleased to inform you that, the Chairman has, on behalf of the Senate, approved ethical clearance for the above-mentioned study. Hence you may proceed with the planned study.

The ethical clearance is valid for one year only, from **5th August, 2019 to 4th August 2020.** In case you do not complete data analysis and dissertation report writing by **4th August, 2020,** you will have to apply for renewal of ethical clearance prior to the expiry date.

Dr. Emmanuel Balandya
ACTING: DIRECTOR OF POSTGRADUATE STUDIES

cc: Director of Research and Publications
cc: Dean, School of Medicine, **MUHAS**