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Department of Surgery
Faculty of Health Sciences

Anaesthesia Care Task Sharing, Anaesthesia Care Provided by Anaesthesia Technologists in Central Sudan: A Clinical Audit

A dissertation/thesis submitted in fulfilment of the

MSc Global Surgery Degree

Alaa Mohamed
MSc Anaesthesia and Intensive Care

SUPERVISOR:
Dr. Christella Alphonsus

CO-SUPERVISOR
Professor Sami Mahjoub

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Declaration/Preface

I, Alaa Mohamed declare that this work is my original work (except where acknowledgements indicate otherwise).

Signed by candidate

Date: 4th July 2024

Dedication

This thesis is a testament to the unwavering support of my supervisors, co-supervisors, and fellow countrymen, as well as a tribute to the Almighty Allah, whose boundless Strength, Grace, and Wisdom have been my guiding light throughout this academic journey. It is through His divine Favor that I have been able to navigate the challenges of my scholarly pursuit and emerge triumphant

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Acronyms

AA	Anaesthesiologist Assistant
ASA	American Society of Anaesthesiologists
BSc	Bachelor of Sciences
CPD	Continuous Professional Development
CRNA	Certified Registered Nurse Anaesthetist
D&C	Dilatation and Curettage
DJ	Double J-Stent
ETT	Endotracheal Tube
EUA	Examination under anaesthesia
GP	General Practitioner
GS 2030	Global Surgery Vision for 2030
GU Surgeries	Genitourinary Surgery
HDU	High Dependency Care Unit
HICs	High Income Countries
ICU	Intensive Care Unit
LCoGS	Lancet Commission of Global Surgery
LMA	Laryngeal Mask Airway
LMICs	Low- and Middle-Income Countries
NCEPOD	National Confidential Enquiry into Patient Outcome and Death
NPAPs	Non-Physician Anaesthetists
PAPs	Physician Anaesthesia Practitioners
PCNL	Percutaneous Nephrolithotomy
RCoA	Royal College of Anaesthesiologists
SDGs	Sustainable Development Goals
TIVA	Total Intravenous Anaesthesia

TURBT	Trans-Urethral Resection of Bladder Tumour
TURP	Trans-Urethral Removal of the Prostate
TVP	Trans- Vesical Removal of the Prostate
UHC	Universal Health Coverage
UN	United Nations
VP Shunt	Ventriculoperitoneal Shunt
VTE	Venous Thromboembolism
WFSAs	World Federation of Societies of Anaesthesiologists
WHO	World Health Organization

Keywords

Anaesthesia care

Task sharing

Task shifting

Low Middle-Income Countries.

Universal Health Coverage

Abstract

Introduction.

The bachelor's degree in anaesthesia sciences program was implemented in Sudan in 1998 to alleviate the shortage of anaesthesiologists while minimizing the anaesthesia related complications of anaesthesia technicians' practice

. In the absence of a defined scope of practice and a lack of financial and legal protection, practitioners are leaving their anaesthesia technology careers in Sudan in search of more secure careers, which has resulted in a noticeable gap in anaesthesia practice in Wad Medani, Gezira State. This study was conducted to determine the proportion of anaesthesia care tasks that were carried out by the anaesthesia technologists at four public referral hospitals in Wad Medani, Sudan.

Methods.

The study was a three-month cross-sectional observational clinical audit of anaesthetic services at four Gezira State Ministry of Health tertiary referral hospitals and included a number of 1559 patients. Data was gathered to describe the perioperative anaesthetic care tasks provided to surgical patients undergoing emergency or elective procedures through a questionnaire that was designed based on the definition of the American Society of Anaesthesiologists of the anaesthesia care tasks. The study began on November 3rd, 2022, and lasted three months, ending on February 2nd, 2023.

Results.

The analysed data showed an average of 18 cases per day. Out of the total 1559 surgical anaesthesia cases in Wad Medani, 718 (46%) of cases were carried out by anaesthesia technologists without the presence of supervising anaesthesiologists. A percentage of 65.2 of these cases were spinal anaesthesia while general anaesthesia and sedation comprised 25.6% and 9.2% respectively. In the presence of supervising anaesthesiologist, anaesthesia technologists performed over 80% of the anaesthesia care tasks.

Conclusions:

Anaesthesia technologists make a substantial contribution to Anaesthesia services in Wad Medani. Our results demonstrated that a considerable proportion of Anaesthesia procedures are carried out without any kind of anaesthesiologists supervision. Guidelines and protocols should be developed and implemented to govern anaesthesia practice given

the resource constraints in this setting. Regular training on safe anaesthesia practice should be applied. Further research is needed on to assess the provision of anaesthesia care and the extent of surgical delay in regions of displacement.

Key words: Task sharing, task shifting, anaesthetic technique, intubation, extubation, Low-middle income countries

CHAPTER ONE

SCOPE OF THE STDY AND LITERATRE REVIEW

1.1 Scope of the Study

Achieving universal health coverage and access to quality health care are essential to accomplishing the third of the seventeen United Nations (UN) Sustainable Development Goals (SDGs), which aim to achieve peace and prosperity for people and the planet. It was agreed to achieve these seventeen goals by 2030 [1]. SDG3 is highlighted as “Good health and well-being” by ensuring healthy lives and promoting well-being for all people at all ages [2]. To ensure achieving SDG3, in 2015, the WHO and the Lancet Commission of Global Surgery (LCoGS) released the Road Map to Achieve Vision 2030, in which increasing health financing and the health workforce in developing countries is a key action to implementing SDG3 [3]. Low- and middle-income countries (LMICs) were highlighted in the WHO report as these countries face a variety of constraints that hinder progress toward long-term goals. Many of these conditions can be alleviated with a safe, timely, and cost-effective surgical and anaesthetic treatment [2].

Improving access to health care and fulfilling the right to the highest possible standard of health depends on the availability, accessibility, acceptability, and quality of surgical and anaesthetic providers. A minimum density of 20 specialists (surgeons, anaesthesiologists, and obstetricians) per 100,000 population is considered necessary to manage the burden of surgical diseases and thus achieve UHC and SDG3 by 2030. However, the current density of surgical specialists in LMICs is only 0.7 per 100,000 [2, 3]. Based on the above-mentioned factors, the current situation in LMICs shows a pattern of delay in accessing and receiving surgical and anaesthetic care, which is linked directly to the unavailability or inaccessibility

of surgical, obstetric, and anaesthetic professionals. In anaesthesia, there are a variety of workforce issues in African countries that impact the continent's health metrics and system performance. [3].

In Sudan there has been a long-standing shortage of anaesthesiologists. Our study was conducted before war broke out in Sudan on April 15th of April 2023. At the time of the study in Sudan, more than 95% of anaesthesiologists were practicing primarily in urban areas, particularly in Khartoum State. According to the United Nations Population Fund, Sudan had a population of 48.1 million. According to its 2022 report, the Sudanese Society of Anaesthesiologists has 190 registered anaesthesiologists and 150 doctors with anaesthesia training. [4]. As a result, there are fewer than 0.47 anaesthesiologists available per 100,000 Sudanese, leaving a large proportion of the population without access to safe and timely surgery and anaesthesia [1, 4].

In order to address the serious shortage of anaesthesiologists in Sudan, and to alleviate the complications caused including perioperative patient death; by the practice of anaesthesia assistants (previous title for all NPAPs in Sudan before 2000) the University of Gezira established the Bachelor of Science in Anaesthesia degree program in 1998 which was a four-year, competency-based academic program designed to provide graduates with the scientific and clinical skills necessary to conduct and provide safer anaesthesia practice. The program was originally introduced as a measure to promote community service through the university's mission to serve the people of Gezira State, which is a densely populated agricultural state.

Two major issues undervalued the former practice of anaesthesia technology in Sudan. Firstly, the number of anaesthesia technologists practicing in Sudan is neither reported nor published by the Ministry of Health nor by the Sudan Council for Health and Medical Professions, “which is the regulatory body responsible for the registration, certification, and licensing of non-medical practitioners of all specialties.” Secondly, task sharing and shifting in anaesthesia care is neither regulated nor completely recognized in Sudan, making it a huge concern to both anaesthesiologists, and the Non-Physician Anaesthesia Providers

NPAPs, which undermines the successful application of effective task sharing and shifting in Sudan.

Many factors have been identified to challenge the effective implementation of task sharing and shifting in Sudan between anaesthesiologists and anaesthesia technologists. Firstly, at the time of the study in Sudan, anaesthesia technologists (BSc graduates) were employed by the Ministries of Health. This employment and subsequent practice were without a defined scope of practice or a clear published policy that governs the workload. The assigned tasks and responsibilities while working under or without the supervision of an anaesthesiologist were not defined. There were no policies regarding financial compensation (salaries), medico-legal obligations, or professional development.

Secondly, the unavailability of supervision or attendance by anaesthesiologist and the complaints regarding task creep (working beyond the scope of practice) were major concerns for practicing NPAPs. A third problem was the Ministry of Health's refusal to recognise, accept, or retain master's graduates. This issue highlights the supply-demand mismatch between education products and health provision consumption, a concern raised by the WHO/LCoGS in 2015. A fourth source of worry is the scarcity of published material on the state of anaesthesia in Sudan. Only two studies on the state of anaesthetic care in Sudan have been published. Both studies gathered data primarily in Khartoum, where the majority of anaesthesiologists used to work, and neither study examined the practice of anaesthesia technologists or technicians [7, 14].

A combination of all these challenges has led the BSc graduates to change careers and enrol in full-time medical schools in search of a more secure career. This has, resulted in a noticeable gap in anaesthesia practitioners in Wad Medani and other rural areas of Gezira State, as well as other Sudanese states. This professional shift will have a negative impact on overall anaesthesia care in the near future, with an increasing shortage of anaesthesia providers. Furthermore, this will result in a huge compromise in the provision of anaesthesia care following the current war as a result of voluntary or forced displacement.

The aim of this clinical audit was to collect data on the proportion of anaesthesia care provided by NPAPs in Wad Medani, Central Sudan. This would help develop a better

understanding of the critical role of NPAPs in anaesthesia care through task sharing and/or shifting in resource-limited countries. In addition to obtaining basic information about the quality of care provided and the clinical outcome of using the NPAPs in such settings,

The availability of this data will help the Global Surgery Community increase awareness of the need for these professionals to close the large human resource gap for anaesthesiologists in resource limited settings. It also helps the Sudanese health ministries and regulatory authorities define the scope of practice, create legal and financial frameworks for this profession after the end of the war. The availability of these data will also facilitate the anaesthesia care into primary healthcare settings, facilitating the delivery of surgical and obstetric care at the community level. Ultimately, it will enable the recruitment of NPAP expertise in specialties other than pure surgical anaesthesia, including perioperative care, intensive care, pain management, and patient transfer, which will ensure Sudan's needs are met, particularly after the displacement of healthcare professionals, and support in achieving UHC and thus SDG3. This research serves the second dimension of LCoGS (surgical capacity) by providing an evidence-based estimate of the extent of existing surgical capacity in terms of manpower and infrastructure of the 2030 Global Surgery vision (GS 2030) and the number of surgical procedures performed in the second largest city in Sudan, Wad Medani.

1.1.1 Study Objectives

1.1.1a Primary Objective

Determine the proportion of anaesthesia care provided by anaesthesia technologists in the State Ministry of Health tertiary hospitals in Wad Medani, central Sudan.

1.1.1b Secondary objectives

1. To determine the number and type of surgical procedures carried out per day in each hospital under study.
2. To determine the type of anaesthesia care provided by anaesthesia technologists.

1.1.2 Thesis Outline

Chapter One: Literature Review

A narrative review was conducted to cover the needs for UHC to achieve SDG SDG3 along with giving examples regarding the lack of safe surgical access, especially in Africa and Southeast Asia. Further, the literature review provides an in depth look into the shortage of the surgical and anaesthesia workforce and how it compromises the achievement of UHC and SDG3 and focuses mainly on the variations in the numbers of anaesthesia providers available in LMICs versus HICs.

This chapter discusses the potential solutions for the lack of anaesthesia care workforce through expanding opportunities for medical education and postgraduate training, which is a long-term strategy for recognizing the time and money required for medical education and postgraduate anaesthesiologist training in LMICs. Another strategy which is discussed is the adoption of task shifting and task sharing between anaesthesiologists and non-physician anaesthesia providers, as in the case of anaesthesia technologists in Sudan.

The status of anaesthesia provision in Sudan is discussed later in this chapter. Sudan implemented task shifting in 1966 to recruit anaesthesia assistants, but a two-year in-hospital training program was required for qualification. A 1996 study found that

unsupervised practice led to anaesthesia-related morbidities and mortalities. This led the Sudanese universities to design an academic/clinical four-year bachelor's degree program to address the shortage of anaesthesiologists and minimize the morbidities and mortalities that resulted from anaesthesia assistants.

Effective implementation of task sharing and shifting is discussed further in this chapter to efficiently compare Sudanese practices of task sharing and shifting with regional and international protocols. These strategies include the education and training of NPAPs, the specificity of the scope of practice, and the necessity of implementing legal and regulatory complaints.

Finally, the literature review covers the routinely performed anaesthesia tasks, the international recommendations of the personnel required to perform these tasks and whether these tasks could be shared, shifted or should be provided solely by the anaesthesiologists. These recommendations are cited mainly from the American Society of Anaesthesiologists and the Royal College of Anaesthetists.

Chapter Two: Methodology

This chapter outlines the methods adopted to conduct this clinical audit through the selection of the study centres and the description of data collection and analysis methods. The data was categorized into four main sections to optimally support the objectives of the study: data regarding the study centres, data related to patients' demographics, data assessing the secondary objectives of the study, and data directly assessing the objective of the study.

Chapter Three: Results

The data is presented in tables and figures showing an average of 18 cases per day. The analysed data shows that 46% of surgical anaesthesia cases in Wad Medani, is carried out by anaesthesia technologists without the presence of supervising anaesthesiologists. 58.2% of these cases were general anaesthesia while spinal anaesthesia and sedation comprised 40%

and 56.5%, respectively. In the presence of a supervising anaesthesiologist, anaesthesia technologists performed over 80% of the anaesthesia care tasks.

Chapter Four: Discussion and Recommendations

In this chapter, we summarize all the findings of the previous chapters, review the strengths and limitations of the studies, and provide recommendations and a way forward for future research arising from the findings in this study, as well as any implications for public health.

1.2 Literature review

1.2.1 Universal health coverage and Sustainable development goals

Universal Health Coverage (UHC) is a comprehensive and ambitious health goal designed to ensure that all individuals and communities have access to vital health services without financial hardship. The UHC is an integral part of the United Nations Sustainable Development Goals (SDGs), particularly SDG 3, which focuses on ensuring the health and well-being of all [1,2]. According to the WHO, UHC is a basic human right with the capacity to improve health outcomes, alleviate poverty, and contribute to economic development. Achieving UHC requires the development of strong and resilient health systems capable of delivering essential services efficiently and effectively. This includes sufficient health personnel, health infrastructure, and access to medicines [15,16].

Furthermore, the WHO points out that, currently, five billion people lack access to safe and affordable surgical and anaesthetic care. In the reported 313 million surgical procedures performed worldwide each year, only 6% of this number occurs in LMICs, home to more than a third of the world's population. This significant unmet need is reported to be greatest in Africa and South Asia, which is likely an underestimate of the overall shortage [2]. To achieve the SDG3 goal of saving lives and preventing disability, an additional 143 million surgical procedures should be performed each year. Improving access to timely, affordable, and high-quality surgical and anaesthetic care is critical to reducing these underestimated numbers and achieving SDG [3].

1.2.2 The Shortage of Surgical workforce in LMICs

In Africa, surgical care faces many barriers that negatively impact the delivery of timely and effective surgical care. Addressing these obstacles is critical for improving healthcare access, minimising mortality, and promoting general well-being. Access to surgical care is limited in many African countries, primarily due to factors such as inadequate healthcare infrastructure, a shortage of skilled surgical providers, and financial barriers for patients, among other reasons [1].

The World Federation of Societies of Anaesthesiologists (WFSA) reports that in 2022, the anaesthesiologist-patient ratio is estimated to be 0.17 per 100,000 in Ivory Coast, 0.47 per 100,000 in Sudan, and 0.33 per 100,000 in the Democratic Republic of the Congo, all of

which are low-income African countries. [4]. This ratio is significantly lower than in higher-income countries (HICs), such as the United States, where around 25 anaesthesiologists are allocated to every 100,000 patients, or the United Kingdom, where roughly 20 anaesthesiologists are assigned to every 100,000 patients. Furthermore, when comparing HICs with African countries, there are significant inequalities in training, employment, and retention of anaesthesiologists, as well as differences in population demands and poor working conditions at many levels of the healthcare system [5,6]. This inadequate distribution of anaesthesiologists between HICs and LMICs exacerbates the healthcare workforce crisis. The occurrence of shortages and discrepancies within LMICs, where experienced anaesthesiologists practice mostly in urban areas, reflects the same concern. This makes it more difficult for residents of rural areas to access timely, high-quality healthcare, exacerbating delays and thereby increasing the number of illnesses, injuries, and disabilities that are already threatening these countries' health indicators [1,6].

The surgical workforce deficits are often found to be representative of broader challenges in the public sector, particularly healthcare and education, including infrastructure deficits and financial constraints. Cost and financial barriers, including the cost of surgical care and associated expenses, are other major constraints on the application of surgical care that can be significant hurdles for patients in LMICs [16]. The lack of evidence-based policies and protocols for practice based on data collection of surgical care outcomes and research on surgical challenges has a negative impact on the successful implementation of surgical care in these countries [17]. The surgical disease burden in Africa underlies all these challenges, including injuries, infections, complications associated with childbirth, and communicable and noncommunicable diseases that necessitate access to surgical care. Another factor that constrains the achievement of effective implementation of surgical care targets is a lack of community awareness of the importance of surgical care.

1.2.3 Potential Solutions for LMICs:

Based on the global shortage of healthcare providers and other workforce-related conditions, two key strategies to expand the surgical workforce, including anaesthesia providers, have been proposed [1,2]. The first recommendation is to expand opportunities

for medical education and postgraduate training. This is a well agreed-upon long-term strategy to increase the surgical workforce in LMICs and should be guided by the continuous assessment and re-assessment of the surgical system, workforce allocation, and planning adjustments based on country-specific needs. However, in addition to already existing healthcare burdens, this strategy may be neither operationally nor financially feasible. Recognising the time and money required for medical education and postgraduate anaesthesiologist training in LMICs, as well as a worldwide deficit in training, imposes a limitation in scaling up the anaesthesiology work force [1,5].

The second suggested method for increasing the surgical and anaesthetic workforce is task sharing and/or shifting. To maximise the available health workforce, the WHO defines task shifting as "the rational redistribution of tasks among health workforce teams, from trained and qualified health providers to other health workers with shorter training durations (like associate clinicians or non-specialist physicians) [1]. In task shifting, tasks are delegated or transferred, whereas in task sharing, tasks are delivered collaboratively by different staff categories. [4]. In both cases, both the anaesthesiologists and the non-anaesthesiologist provider with less training take responsibility for the high-quality outcome of the task. In countries where task sharing and shifting are implemented in anaesthesia practice; measures like the scope and outcomes of practice, task breakdown, safety and quality of anaesthesia care provision, responsibilities, and barriers to effective implementation of this approach require assessment and additional research. [1,6,8]

1.2.4 The necessity of task sharing as a measure to enhance anaesthesia workforce:

Task sharing in any medical specialty refers to the participation of non-specialist physicians or non-physician clinicians in performing patient care tasks. This delegation or sharing is exhibited through the reasonable redistribution of tasks among the specialty workforce team, from highly trained professionals who are specialist physicians to health workers with less training and qualifications, such as non-specialist physicians or assistants.

Many healthcare systems around the world have used task shifting and/or task sharing to increase access to care and manage workforce shortages, including anaesthesia (e.g., assistants), primary care (e.g., community health workers), obstetrics (e.g., midwives), and general medical practice (e.g., physicians' assistants) [3]. Across countries of all income

levels, approximately 30 nations utilise surgical task shifting, compared to 108 countries that rely on anaesthetic task sharing, emphasising the global shortage of and the need for anaesthesia providers [3,6].

In anaesthesia, this temporary strategy has the potential to close the large human resource gap in the surgical and anaesthesia workforce, particularly in LMICs, while emphasising the need for these countries to increase the workforce of anaesthesiologists and surgeons as a long-term solution [7,18]. Both the specialised provider and the less-trained provider share the obligation to provide a high-quality outcome for the task [2]. Task sharing is found to be crucial for the future of anaesthesiology and surgery in LMIC, but it must be balanced with high-quality patient care [12].

The WHO-WFSA defines the anaesthesia provider as “any healthcare practitioner who provides anaesthetic care, regardless of their educational and professional background or level of training." Anaesthesia practitioners are either physician anaesthesia practitioners (PAPs) with various degrees of specialist training, or non-physician anaesthesia providers (NPAPs) [1,2,5,6]. A PAP, or anaesthesiologist, has a unified definition internationally, which is a graduate of medical school who has completed a nationally or internationally recognised specialised anaesthesia training program, and is licensed to practice independently and supervise other anaesthesia providers [9]. NPAPs definitions, descriptions, and backgrounds vary among countries. This includes nurse anaesthetists as in the United States, anaesthesia officers and anaesthesia assistants as adopted in Kenya and Uganda, and anaesthesia associates as in the United Kingdom, anaesthesia technicians, and anaesthesia technologists among other descriptions [10-13]. Anaesthesia technician or technologist as in Sudan and the Middle East, are other titles for health care practitioners who have completed academic or clinical anaesthesia training programs, including a bachelor, masters, or diploma degree in anaesthesia technology [9,10].

Despite the long-standing use of this strategy, evidence on task sharing and shifting is few and found to be mostly focused on task shifting. Concerns about task sharing and shifting in anaesthesia care, such as safety, effectiveness, and professional responsibility, have been identified as areas of further research [6,8-10]. These issues have divided the medical community for decades, particularly in LMICs where the practice of NPAPs is not accepted among the medical communities. There is insufficient evidence comparing the clinical

outcomes of PAPs to NPAPs when providing the same anaesthetic procedure. There is also a lack of data on the division of tasks in anaesthesia care when NPAPs work under a supervising anaesthesiologist. Another concern is "task creep," which is working beyond the scope of practice due to the unavailability of anaesthesiologists to perform the task as described by the LCoGS [1,2]. Unavailability here may be due to either not being physically or virtually present, as well as the absence of a certified anaesthesiologists.

Many African countries have adopted the use of NPAPs for providing anaesthesia for several years. Some of the countries had recognised institutions for training and/or regulations, while in other countries, the NPAPs practiced without regulation. In 2017, Ashengo and colleagues evaluated the prevalence of the use of NPAPs in providing anaesthesia and reported that Kenya, Tanzania, Malawi, Mozambique, Ethiopia, Zambia, and Central Africa regulated the NPAPs practice through their ministries of health, universities, or other authorities. Meanwhile, countries like Cameroon, Laos, Djibouti, Chad, and West Africa among other African countries, all adopted an unregulated NPAPs practice [15-17].
Adopting task sharing allows anaesthesia services to be integrated into primary healthcare settings, facilitating the delivery of surgical and obstetric care at the community level. This would improve overall healthcare access while reducing the need for long-distance travel to specialised facilities and the potential delay in receiving care. Task sharing can also improve emergency surgical capacity in hospitals [2,16-19].

The safety of NPAP practice was discussed by Chidambaran and colleagues, who evaluated the use of NPAPs providing propofol sedation for non-operating room procedures and found that there were no significantly increased risks compared to anaesthesiologist practice [7]. This study, which used a large database of sedations and procedural sedation by critical care physicians, provides confidence in the safety of NPAPs in administering propofol sedation. Furthermore, another study focused on paediatric procedural sedations and found that qualified non-anaesthesia physicians and NPAPs can perform these procedures safely and efficiently outside of the operating room, provided that best practices in medication administration and monitoring are followed [18,19].

1.2.5 Sudan the Country Under Study

Historically, Sudan implemented task shifting in 1966 through the recruitment of anaesthesia assistants. The completion of a two-year in-hospital training program was required in order to qualify to work as anaesthesia assistant. Due to the significant shortage of anaesthesiologists in Sudan at that time, the majority of anaesthesia assistants worked without supervision, particularly in remote and rural areas of the country. Thirty years later, in 1996, a cross-sectional observational study was conducted in Khartoum State to assess the practice of supervised versus unsupervised anaesthesia assistants [14]. This study concluded that despite the two-year training program, unsupervised anaesthesia assistant practice resulted in anaesthesia related morbidities and mortalities that had been frequently recorded across several hospitals under study [7,14].

The Ministry of Higher Education and Research accredited the bachelor's degree as a higher educational program, which was later adopted by three other universities, with approximately 110 graduates from the four universities each year. By 2021, a total of 1215 bachelor's degree graduates were reported at the four institutes. A significant proportion of bachelor's and diploma graduates are currently employed in hospitals overseas, particularly in the Middle East, a phenomenon also observed among anaesthesiologists.

Subsequently, the University of Gezira and the University of Al-Zaeem Al-Azhari developed master's degrees in anaesthesia, which enabled training in critically scarce anaesthesia skills, including intensive care and obstetric anaesthesia. There are now 29 MSc graduates, of whom 17 are currently employed full-time at the four universities that provide the Bachelor of Anaesthesia Sciences degree. The remaining 12 MSc graduates were employed as head departments in hospitals or as full-time faculties in similar educational programs in the Middle Eastern countries. A few of the MSc graduates have even earned doctoral degrees from international organisations. Till the time of data collection, no MSc graduates were employed in Sudanese hospitals as there were no positions for postgraduate degrees in anaesthesia technology. Therefore, none of the graduates are currently providing a clinical service in Sudan.

When comparing Sudan with other countries in the region like Uganda and Ethiopia where NPAPs include MSc and BSc anaesthesia technologists and anaesthesia technicians; there are a clear set of practice guidelines that define and govern the clinical practice of all

anaesthesia providers in Uganda and Ethiopia with respect to the educational and clinical training backgrounds. Furthermore, both Ethiopia and Uganda have adopted clearly planned and well-publicised strategic roadmaps for NPAPs that were developed and implemented by each country to achieve the 2030 anaesthesia care workforce vision, thereby achieving UHC while meeting SDG3 [10 - 12]. These roadmaps cover not only anaesthesia care, but extend to the provision of perioperative care, pain management, intensive care, resuscitation, emergency medicine and patient transfers.

In Sudan, a study of obstetric anaesthesia care in Khartoum that was conducted in more than seventeen public hospitals with a median rate of more than 8,000 deliveries per year confirmed that the majority of obstetric anaesthesia care was carried out by NPAPs, with only eight anaesthesia physicians present [14].

1.2.6 Effective Implementation of Task Sharing:

There is a need for informed policy to guide the effective implementation of task sharing. Many low-income countries, such as Lagos, lack formal policies on task sharing, despite its widespread implementation in the healthcare system [3]. Policies, guidelines, and standard operating procedures should be locally derived and consistent with nationally and internationally accepted standards [20,21]. A recently adopted pragmatic approach in HICs, is a flexible, team-based strategy that optimises care depending on patient risk factors, team resources, competence, and other local needs rather than advocating for complete independence or mandated supervision of NPAPs [9,21].

The team approach combines anaesthesiologists with NPAPs, some of whom may practice without direct or on-site anaesthesiologist supervision. The NPAPs component of the team may be made up of different practitioners, each with a different scope of practice based on their level of training. In this scenario, anaesthesia providers working in teams can handle multiple procedures simultaneously, improving the healthcare system's ability to respond to emergencies [21].

When task sharing is well planned and executed, it can maintain high standards of patient safety and quality of care. Anaesthesiologists will be able to oversee and supervise NPAPs, ensuring that care remains of a high standard while an efficient use of Anaesthesiologists' expertise takes place[22].

In order to promote effective implementation of task sharing in anaesthesia practice, resource utilisation was found to play a crucial role. This can be done by scheduling patients and procedures by grouping similar cases together while establishing staffing ratios based on disease acuity and facility size as a measure to reduce setup and turnover times in the operating room. This allowed anaesthesia providers to deliver care to more patients in each time frame [22,23].

Ashengo and colleagues recommend that, in order to ensure the effective application of task sharing; a robust implementation of quality assurance and monitoring programs to track outcomes and identify areas for improvement should be applied. This should be simultaneously performed while investing in ongoing training, continuing education, and professional development for all anaesthesia care teams. This approach was found to help refine resource allocation strategies over time and ensure that each provider remains competent and capable of handling their assigned tasks, making the best use of their skills and knowledge [5,24].

Improving communication and collaboration among anaesthesia care team members and other healthcare professionals involved in patient care was also found to be exceptionally important, as it could aid in the prevention of misunderstandings and the efficient use of resources during procedures [26].Addressing physician resistance to the practice of NPAPs and encouraging anaesthesiologists should take the lead in encouraging harmonisation and fruitful discussion among diverse teams of anaesthesia practitioners worldwide [17].

Effective application of task sharing is challenged by the fact that anaesthesia is a complicated specialty that demands substantial training and knowledge. The lack of direct anaesthesiologist supervision leads to a lesser standard of care and jeopardizes patient life, which may limit access to care [15,19]. Concerns have been raised about the lack of standardisation in training and practice standards across various health systems [3].

According to the literature reviewed, one of the major challenges against effective implementation of task sharing in anaesthesia is anaesthesiologists' opposition to significant engagement in NPAP practice. This was found to be motivated by three major issues: perceived erosion of safety and quality of care, changes in power dynamics, and ethical concerns. While specialists agreed that NPAPs might be successfully educated to do

anaesthesia to attain a comparable degree of clinical skill, they considered that NPAPs lacked the clinical knowledge and understanding required to match the skills. They contended that this inhibits NPAPs ability to make informed decisions about when or whether to undertake a certain task, as well as their ability to respond properly to quickly changing clinical conditions [23,24].

Specialists also confirmed that the extension of the non-specialist's role to do anaesthesia tasks poses a challenge to their status as the clinical team's head. A qualitative study conducted in Mozambique discovered that experts regarded non-specialists as inferior and saw their improved skills as a threat to their control. An ethical standpoint provided additional grounds for specialist opposition. In this case, experts claim that the establishment or growth of a less-skilled workforce aimed at providing services to disadvantaged and predominantly poorer areas. This would eventually produce a tier of second-rate clinical services because the necessity to expand coverage exceeds the quality and safety of care [24].

In conclusion, to promote the provision of surgical care, an effective implementation of anaesthesia care task sharing is recommended. The ultimate goal would be to increase the workforce of anaesthesiologists as a permanent solution. When task sharing is implemented, proper training, supervision, and quality assurance mechanisms can be a valuable strategy to advance UHC. This will contribute to increasing access to essential surgical and anaesthesia services, particularly in underserved areas, while optimising the healthcare workforce and resources. Additionally, it is important that task sharing is regulated and monitored to maintain high standards of care and patient safety.

1.2.7 Education and training

Defining the surgical workforce as a dynamic system that is influenced by the balance of entry and exit is another important consideration in the matching of education production and health care consumption. In the absence of national policies and strong coordination between central government and local government, significant mismatches in workforce supply and demand occur in LMICs, which causes resource constraints, incentives, or push-pull factors to leave the specialty. Anaesthesia education and training should be conducted

collaboratively rather than in educational silos, as is currently the case, which will emphasise team integration and communication [1,2,25].

In order to ensure high-quality anaesthesia care regardless of educational or training backgrounds, the WFSA has proposed an Anaesthesia Training Framework (ATF) encompassing minimal levels of training, competency-based training, and a shared-care model tailored to local needs. This is to aid in scaling up the workforce while ensuring safety and the quality of services provided (2). NPAPs and general practitioners who perform anaesthesia should be trained to high and clearly defined standards using competency-based curricula from authorised schools. However, resources should not be diverted away from anaesthesiologists training to train NPAPs and general practitioners [2,26].

Licensing, relicensing, or maintaining certification, as well as Continuous Professional Development (CPD), should be compulsory for all associate clinicians and General Practitioners GPs. Training programmes should be initiated locally with ongoing local supervision after the completion of formal training to ensure the maintenance of skills and competencies[26,27].. To prevent associate clinicians and GPs from feeling pressured to work outside their scope of practice, adequate referral mechanisms and transportation systems for advanced-level cases are needed. Associate clinicians and GPs need satisfactory supervision, career opportunities, and remuneration, to avoid attrition from the specialty, like that of their specialist counterparts [2,9,16,26-28]. A clear career progression path for associate clinicians and GPs should exist to maintain interest and to increase retention [29].

1.2.8 Scope of practice

Some NPAPs may lack the essential abilities or knowledge to handle complicated cases or emergencies; thus, the presence of an anaesthesiologist will provide broad medical knowledge as well as specialty training (such as pain management and critical care), which will help offer the entire range of pre- and postoperative care, as well as critical care and pain treatments [2,11]. The absolute unsupervised NPAPs practice was found to keep many NPAPs isolated, with little opportunities for clinical assistance, professional advancement, and ongoing medical education [16]. This dispute was further justified by the fact that task sharing might result in a higher workload for non-specialists, which is not always

compensated appropriately. This may result in job dissatisfaction and burnout, a major concern that keeps rising in many LMICs which motivates many NPAPs to leave their careers [14,16,28].

Due to the significant worldwide anaesthesia workforce deficit, a universal paradigm based on service supply by a single anaesthesiologist is globally found to be unfeasible [11,12]. Despite the ongoing debate, the current models of anaesthesia care delivery worldwide include anaesthesiologists who work alone, anaesthesiologists who supervise NPAPs (care teams), NPAPs who work independently, and surgical providers who conduct surgery while also giving some type of anaesthesia [4,5]. This has led to the necessity of tailoring policies, guidelines, and standard operating procedures regarding anaesthesiologist presence, distance supervision, or unsupervised NPAP practice [11].

In the United States, some states still require some sort of physician oversight, and a few allow entirely independent NPAPs practice in obstetric anaesthesia, pain management and general anaesthesia [1,28,29,30]. In Canada, NPAPs assist anaesthesiologists in providing perioperative and pain management care. As per the regulations, assistance extends from providing help in a task to completely performing under minimal to no supervision. Another study that was conducted in Japan in 2020 examined the clinical engineer anaesthesia assistants, in one centre for a period of one month. The study confirmed that, there was indeed a clear scope of practice of NPAPs (anaesthesia preparation, monitoring, operation, and maintenance of life support equipment under the supervision of a physician) but due to the shortage of practicing anaesthesiologists at the centre, clinical engineers' anaesthesia assistants had performed certain tasks that were directly related to anaesthesia care practice. These tasks (such as sole anaesthesia monitoring, documentation, reporting, and monitoring of anaesthesia patients) were essentially described as being beyond the scope of practice [31].

A meta-analysis on task sharing/shifting in Asia and Africa found that in African countries including Kenya, Cameroon, Lagos and Tanzania among other African countries; NPAPs were found to be the predominant providers of both general and spinal anaesthesia at the district level regardless of their clinical or educational background. In all countries under study, there was no reported scope of practises [32].

1.2.9 Implementing legal and regulatory compliance.

This refers to the proactive tasks performed within healthcare entities to prevent misconduct, waste, and abuse. The effective implementation of legal and regulatory compliance results in increased protection, job security, and satisfaction for NPAPs through a variety of means, including but not limited to developing specific regulations related to anaesthesia care, such as task sharing and shifting in terms of scope of practice and governing policies [33]..

Patients should be informed about the credentials and roles of the anaesthetic providers who will be caring for them by ensuring that patients receive accurate information and provide informed consent. Legal and regulatory compliance requires thorough and accurate documentation. Keeping track of anaesthetic care, patient assessments, medications given, and provider certifications is crucial in the case of an audit or a legal issue [33,34].

Another responsibility that should be clearly outlined is the development and maintenance of emergency protocols for anaesthesia-related problems. Anaesthesia providers should be prepared for emergencies, and facilities should have adequate resources and equipment. Legal compliance is well implemented through patient safety reporting by creating a patient safety culture that includes reporting and investigating adverse events or near misses. Compliance with reporting standards is critical for identifying and addressing safety hazards promptly [33].

Billing for anaesthetic services must adhere to healthcare standards and reimbursement policies, as well as the scope of practice. Accurate coding and billing methods are critical for avoiding legal difficulties linked to misconduct or illegal billing, as well as ensuring that all tasks are properly paid for. Another substantial function that assures successful adherence to legal and regulatory compliance is peer review and quality assurance, which monitor and assess anaesthesia providers' performance. It will enable the rapid resolution of any problems or difficulties in order to maintain high-quality care and regulatory compliance [34,35].

Legal Liability Insurance is a final venture that ensures the optimal implementation of regulatory compliance and, thus, the protection of NPAPs practices. All anaesthesia

providers should carry appropriate professional liability insurance to protect themselves in the event of legal claims related to their practice [33]

1.2.10 Anaesthesia tasks:

1.2.10.1 Preoperative visit.

Both the American Society of Anaesthesiologists ASA and the Royal College of Anaesthesiologists RCoA agreed that the practicing anaesthesiologist must visit the patient before surgery. Although no precise time has been determined for this visit, it is agreed that adequate time should be allocated for the visit to provide for a thorough examination of each unique patient as a means of personalising and preparing the specific anaesthesia plan. The primary goals of preoperative evaluation and preparation have been identified to include documentation of the condition(s) for which surgery is needed along with an assessment of the patient's overall health status [33]. Uncovering hidden problems that could cause problems both during and after surgery. Perioperative risk determination is another goal for scheduling preoperative visits. This may lead to optimisation of the patient's medical condition in order to reduce the patient's surgical and anaesthetic perioperative morbidity or mortality. The major objective of the preoperative visit is the development of an appropriate perioperative care plan while educating the patient about surgery, anaesthesia, intraoperative care, and postoperative pain treatments in the hope of reducing anxiety and facilitating recovery. The preoperative visit is considered a main factor in reducing costs, shortening hospital stays, reducing cancellations, and increasing patient satisfaction [33,34].

1.2.10.2 Selection of anaesthesia plan

Both the ASA and RCoA have stated that "the physician anaesthesiologist should prescribe an anaesthesia plan designed for the greatest safety and highest quality of care for each patient." This statement is applied to anaesthesia teams that are led by anaesthesiologists [32]. Developing the initial plan has many components, including pre-anaesthetic patient assessment, which typically starts with a patient history [34]. A pre-anaesthetic patient assessment will allow the anaesthetist to determine the patient's physical status and reveal what the anaesthetist will have to work with [35,36]. Physical status has a very strong

influence on the outcome of anaesthesia [33]. Planning needs to include anticipated anaesthesia and procedural problems, along with contingency planning, Proper planning for post-operative care is essential to ensuring a smooth recovery [33,34].

1.2.10.3 Type of anaesthetic technique

General anaesthesia is the pharmacological induction of complete loss of consciousness through the administration of inhalation or intravenous drugs, muscle relaxation, and alleviation of pain through opioids medications all supported by intubation and mechanical ventilation [337,38]. Spinal anaesthesia or subarachnoid anaesthesia is the placement of local anaesthetic agents into the subarachnoid space. Procedural sedation is intended to induce anxiolysis and sedation. The ASA has developed guidelines for sedation and analgesia by NPAPs to assist in the process of selecting the type of anaesthesia technique [38]. These guidelines provide recommendations that are supported by analysis of the current literature and a synthesis of expert opinion, open forum commentary, and clinical feasibility data [39].

General anaesthesia can be administered by NPAPs, such as Certified Registered Nurse Anaesthetists (CRNAs) and Anaesthesia Assistants (AAs), under the direction of a physician [38]. These non-physician anaesthetists specialise in the provision of anaesthesia care and participate in the administration of anaesthesia in a variety of surgical cases. They are frequently supervised by an anaesthesiologist but may also work under the supervision of other physicians. It's important to note that the administration of general anaesthesia is a complex process that requires specific expertise in pharmacology, physiology, and clinical management. Therefore, non-specialists who are involved in this process should have appropriate training and supervision to ensure patient safety. While non-specialist anaesthesiologists can provide regional anaesthesia, it's essential that they have appropriate training and are closely supervised to ensure patient safety and the highest quality of care. Regional anaesthesia can be provided by NPAPs, such as Certified Registered Nurse Anaesthetists (CRNAs) and Anaesthesia Assistants (AAs), under the direction of a physician [35]. The American Society of Anaesthesiologists refers to this mode of anaesthesia delivery as the Anaesthesia Care Team, which involves the delegation of monitoring and appropriate tasks by the physician to non-physicians.

1.2.10.4 Preoperative check

Failure to check anaesthesia equipment prior to use can lead to patient injury or "near misses," and checking equipment has also been associated with a decreased risk of severe postoperative morbidity and mortality. The publications of the WFA and the ASA indicate that all anaesthesia task forces are entitled to thoroughly check the anaesthesia machine, equipment and ensure the preoperative preparation and infection control measures are all in place [38,41]. Most of the publications agreed that this procedure was not broadly applied by the anaesthesia providers.

1.2.10.5 Line Insertion

Line insertion, a crucial component of providing anaesthesia, has long been debatable as to who should be responsible for it. Current literature supports the approach that the insertion of a peripheral, central intravenous, or arterial line could be delegated from the anaesthesiologist to a skilled team member under close supervision [37]

1.2.10.6 Airway placement

Both the ASA and the RCoA recommend that ETT placement be conducted by an anaesthesiologist, and that supervision be present in cases of placing the ETT by NPAPs. Intubation and airway management by non-specialist anaesthesia providers is a practice that can occur in certain settings, particularly in emergency situations or in areas where there is a shortage of specialist anaesthesiologists. The ASA has developed practice guidelines for the management of difficult airways, which can be applied to non-specialist providers [33]. These guidelines focus specifically on the management of the difficult airway encountered with mask ventilation, tracheal intubation, or supraglottic airway placement during procedures requiring general anaesthesia, deep sedation, moderate sedation, or regional anaesthesia or elective airway management without a procedure. Non-specialists who are involved in this process should have appropriate training and supervision to ensure patient safety. In remote settings outside of the operating room, new developments in patient monitoring, oxygen delivery, and airway adjuncts have provided solutions to the many challenges involved in management of the airway. These devices and techniques may have had their origins in the operating room but are uniquely applicable to outside locations [33,38].

1.2.10.7 Documentation of anaesthesia sheet

The documentation of an anaesthesia sheet is a critical part of the anaesthesia process. It serves as a record of the anaesthesia care provided, including the pre-anaesthetic evaluation, intraoperative management, and postoperative care [1,5]. The pre-anaesthesia evaluation includes a review of the patient's medical history, including anaesthesia, drug, and allergy history [1-5, 35,36]1–5, 45–46). It also includes an interview and examination of the patient (46). The anaesthesia risk is noted according to established standards of practice (e.g., the ASA classification of risk). Potential anaesthesia problems are identified, particularly those that may suggest potential complications or contraindications to the planned procedure (e.g., difficult airway, ongoing infection, limited intravascular access [36,37]. Intraoperative management includes the type of anaesthesia used, the medications administered for induction, maintenance, and postoperative care [37]. It also includes the patient's physiological responses and any complications or events that occurred during the procedure [12]. Postoperative care includes the patient's condition after the procedure, the management of any complications, and the plan for postoperative pain management [12,38]. The anaesthesia sheet is typically completed by the anaesthesiologist or other anaesthesia provider and becomes a part of the patient's medical record [1-5]. It's important to note that the specific format and content of the anaesthesia sheet can vary depending on the institution and the specific requirements of the jurisdiction [1-5, 39].

1.2.7.8 Postoperative care

Postoperative care in low-income countries is a critical issue. The absence of available postoperative care facilities was associated with 7–10 more deaths per 100 major complications in low- and middle-income countries [40]. The Enhanced Recovery After Surgery (ERAS) Society has developed guidelines for perioperative care in elective abdominal and pelvic surgery at primary and secondary hospitals in LMICs [41]. These guidelines include interventions such as the Surgical Safety Checklist (SSC), preoperative routine Human Immunodeficiency Virus (HIV) testing in countries with a high prevalence of HIV/AIDS, delirium screening and prevention, COVID-19 screening, Venous Thromboembolism VTE prophylaxis, immuno-nutrition, pre-habitation, minimally invasive

surgery (MIS), and a standardised postoperative monitoring guideline [42]. However, efforts to improve access to surgical care in LMICs should be accompanied by investment in improving the quality and safety of care.

1.2.7.9 Critical incidents reporting during anaesthesia.

Incidents during anaesthesia are critical events that can have a significant impact on patient safety and outcomes. These incidents can be related to equipment malfunctions, medication errors, and rare complications. A study conducted at the clinical departments of Bogomolets National Medical University found that the incidence of critical incidents was 9.35 cases per 1000 anesthetic procedures. The most common incidents were related to the respiratory system: difficult airway (26.8%), reintubation (6.4%), oxygen desaturation (13.8%), and cardiovascular system: hypotension (14.9%), tachycardia (6.4%), bradycardia (11.7%), hypertension (5.3%), collapse (3.2%), and massive haemorrhage (17%) [43].

Factors associated with critical incidents were elective surgery, age from 45 to 75 years, and ASA II, III, or IV compared to ASA I. Regional anaesthesia or general anaesthesia and regional anaesthesia combined decreased the risk of incidents compared to general anaesthesia alone [44]. Procedural sedation was associated with an increased risk of a critical incident, compared to general anaesthesia [44,45]. The incidents occurred most during the maintenance phase or the induction phases of anaesthesia [44]. The most frequent failings contributing to the incident's occurrence were: insufficient preoperative assessment, incorrect interpretation of the patient's state, faulty manipulation technique, miscommunication with a surgical team, and delay in emergency care [44,45].

The Anaesthesia Incident Reporting System (AIRS) was created specifically to detect rare and novel adverse events that occur in national health care systems during the perioperative period. The record of the clinical event should include objective details of the event, including date, time, and place; the patient’s condition immediately before the event; action taken during and after the event, the patient’s response and their subsequent condition; and all other healthcare members notified of the event.

2. Methodology:

2.1 Target Outcome

The primary objective of this MSc study was to determine the proportion of anaesthesia care provided by anaesthesia technologists in the State Ministry of Health tertiary hospitals in Wad Medani, central Sudan. The secondary objectives were to determine the number and type of surgical procedures conducted per day in each hospital under study and the type of anaesthesia care provided by anaesthesia technologists.

2.2 Study design

The research was a three-month cross-sectional observational clinical audit of anaesthetic services at four Gezira State Ministry of Health tertiary referral hospitals. Data was gathered to describe the perioperative anaesthetic care provided to surgical patients undergoing emergency or elective procedures.

2.3 Study settings

2.3.1 Research Site

The purpose of this clinical audit was to establish the percentage of anaesthetic care provided by anaesthesia technologists in tertiary institutions run by the State Ministry of Health in Wad Medani, Central Sudan. Wad Medani is the capital of Gezira State, which is located in east central Sudan. Wad Madani is located on the western bank of the Blue Nile (186 kilometers southeast of Khartoum, Sudan's capital). Wad Medani is an agricultural city that serves as the centre of a cotton-growing region as well as the headquarters of Sudan's irrigation department. Gezira State, Sudan's second largest state, has an estimated population of 5.8 million people (Statistics Reference 2022). Since Wad Medani is Sudan's second largest city after Khartoum, the researchers chose it for data collection because it would reflect the state of anaesthesia practice in other major urban areas outside of Khartoum; the previous articles on the state of anaesthesia in Sudan were written in Khartoum [7,13].. Wad Medani is home to a number of specialties teaching hospitals, including the National Cancer Institute and the Medani Trauma Center. Although Wad Medani is a huge town in comparison to other Sudanese districts, surgical treatments are mostly performed in government facilities, with a very limited number of private

medical/surgical facilities. The research was carried out in four governmental health institutions, including Wad Medani Teaching Hospital, Wad Medani Maternity Hospital, Gezira Centre for Renal Diseases and Surgeries, and the National Centre for Paediatric Surgeries.

2.3.2 Study Duration

The study began on November 3rd, 2022, and lasted three months, ending on February 2nd, 2023. The cross-sectional approach was chosen to ensure that all the information needed to fully meet the study's objectives was acquired.

2.4 Population

The study population was composed of all elective and emergency surgical cases in need of general, neuraxial, or sedation anaesthesia performed at the study's selected referral hospitals during the study period who satisfied the inclusion criteria of the study..

2.5 Sampling procedures

2.5.1 Inclusion criteria

Surgical procedures in need for general, sedation or regional anaesthesia care services.

2.5.2 Exclusion criteria

Surgical procedures performed under local anaesthesia were excluded from the study. Local anaesthesia was mainly administered by the practicing surgeons under very minimal (pulse oximetry) to no monitoring without the need for the presence of anaesthesia provider. Patients presenting from the ICU or other states.

2.6 Sample Size

Raosoft sample calculator was used to estimate the sample size required to satisfy the study objectives. After meeting the study's inclusion and exclusion criteria, data from 1,559 surgical elective and urgent procedures performed between November 3rd, 2022, and February 2nd, 2023, were collected.

2.7 Data collection and collation

To achieve the objectives of the study, a structured data collection form was developed. Data were collected during the preoperative, intraoperative, and postoperative periods until discharge from the operating room by two independent data collectors in each centre under study. Patient charts or the medical records in the four centres were available in paper form only. They were examined to capture patient specifics along the anaesthesia and surgical records where data regarding anaesthesia and surgical procedures were acquired. Observations from the data collection team were also included to fill information gaps that served the objectives of the study but were not documented in the patient records. The data collection form was designed with a drop-down list of options to standardise information and limit potential errors. To ensure comprehensive data collection, the data collectors were trained by the investigator to complete the form. The data collected was entered into a password-protected electronic database using Google Forms and secured with a cloud system for data storage and transmission.

2.7 Ethics approval and informed consent

Ethical approval from the Ministry of Health and the University of Gezira Ethics Committees was granted before the start of data collection. Ethics approval was also provided by the Human Research Ethics Committee of the Faculty of Health Sciences of the University of Cape Town (ref. no. 542/2022). Informed consent for each patient under study was obtained before the start of the surgical procedure, either signed by the patient himself or herself or by a patient representative. Two anaesthesia technologists from each centre under study were allocated and trained by the researchers on extracting the requested data from patients' files, completing the data capture form, and submitting the collected data into a Google Form.

2.8 Statistical analysis

Collected responses from the capture forms were entered into a password protected Excel spreadsheet available only to the authors. Basic descriptive analyses was performed serving the objectives of the study.

2.9 Data management

Access to the Google Drive and Cloud electronic data entry systems was protected by username and password. Data entry and integrity verification were done by independent investigators.

2.10 Study conduct

2.10.1 Organization of collected data.

To address the objectives of this study, the data was categorised into five sections; each section serves certain indicators. Taking the anaesthesia specialty as a multi-task specialty, all indicators under study were utilised to achieve the objectives.

2.10.1.1 Data related to research centre:

These data were obtained directly from the medical directors of the study centres. The data collected mostly comprised a description of the research centres as well as the number of anaesthesia practitioners and their educational/clinical backgrounds.

A. The research centres

The study featured four pre-selected centres that met both the study's purpose and the mission of Global Surgery and which represent the four models of anaesthesia teams practicing in Sudan., This study included a wide range of surgical populations. Patients were referred to these centres in a variety of ways. Some patients were sent directly for surgery from the surgeons' private clinics. The majority of patients were referred via hospital clinics. These patients were initially referred to hospitals' clinics by medical centres, rural hospitals, or hospitals located in states other than Gezira State.

Wad Medani Teaching Hospital is a state governed public medical facility with different specialties, including internal medicine and general surgery, in addition to the Ear, Nose, and Throat Centre. The general surgery complex comprises five operating rooms. Two rooms are for minor or lower limb procedures performed under regional anaesthesia or sedation, two major rooms for major or prolonged procedures under general anaesthesia with intubation, and one specialised room for laparoscopic surgery beside the holding and recovery areas. The hospital has a medical/surgical high dependency care unit and a medical/surgical intensive care unit.

The surgical complex of Wad Medani Maternity Hospital which is a state run facility has five operating rooms, with only three rooms equipped for intubation, general anaesthesia, and mechanical ventilation. It has a holding area but no specific recovery room. The surgical complex has an integrated intensive care unit. The maternity hospital has a separate specialised centre for emergency procedures, allocated only for dilatation and curettage procedures.

Gezira Hospital for Renal Diseases and Surgeries is a federal run referral facility has three operating rooms all-ready for highly specialised surgeries under spinal, epidural, or general anaesthesia along with advanced anaesthesia monitoring. A holding area, a recovery room, and an intensive care unit are all attached to the complex.

The National Centre for Paediatric Surgeries has four operating rooms. Two rooms are equipped for general anaesthesia with intubation, one for sedation, and one for laparoscopic surgery. At the time of data collection, the National Centre for Paediatric Surgeries was undergoing a maintenance process that affected elective surgery and allowed only emergency procedures.

In the three centres, including general surgery, renal, and maternity hospitals, the anaesthesia staff had a routine of morning shifts (8 hours) for elective procedures, a long afternoon-night shift (16 hours) for emergency cases during the weekdays from Sunday to Thursday, and 24-hour shifts on Fridays and Saturdays. Since the paediatric centre was handling only emergency cases, the anaesthesia staff were working 24-hour shifts.

Except for the renal hospital, which has Drager Fabius Plus anaesthesia machines and uses isoflurane and sevoflurane, all facilities were equipped with Drager Fabius GS premium anaesthesia machines and used isoflurane and halothane. Only cylinders were used to supply oxygen and nitrous oxide. The centres had intravenous anaesthetics such as propofol and ketamine, as well as suxamethonium, atracurium, and pancuronium for muscular relaxation. Endotracheal tubes were used only once, as compared to anaesthetic masks, Laryngeal Mask Airways (LMA), and other airway devices, which were cleaned and disinfected for multiple uses. The four centres used the same breathing circuits throughout the duration of the study. Initially following the war, the number of cases presented to

these hospitals increased because of the displacement of more than 3 million people to Gezira State. Later and after the fire, the region expanded to include Wad Medani; all health facilities in Wad Medani were attacked and destroyed by the armed forces.

B. The number of anaesthesia providers and educational/clinical backgrounds.

Standardised definitions based on the WHO-WFSA were provided for each category of anaesthesia providers. The study observed three types of anaesthetic providers. 1) Anaesthesiologists, who are qualified medical professionals who specialise in anaesthesia and intensive care, are licensed by the Sudanese Council of Anaesthesia and Intensive Care, and work in accordance with its standards. Non-physician anaesthesia providers (NPAPs) observed were: 2) anaesthesia technologists with bachelor's degrees in anaesthetic sciences, as defined by the Ministry of Health, and 3) anaesthesia technicians with diplomas. Because there were no non-specialist physicians undergoing anaesthesia training or practice (registrars of anaesthesia or general practitioners) or nurse anaesthetists at the time of data collection, this information was not included in the data collection tool.

Initially, following the war and the displacement of more than 3 million people to Gezira state from Khartoum, the number of both anaesthesiologists and NPAPs was multiplied. Also, the number of cases presented to these hospitals was maximized. The types and number of surgical procedures were also affected. More varied and more complex procedures took place at the same centres because of the availability of more specialized surgical and anaesthesia staff. Eight months later, after the start of the war, the fire region expanded to include Wad Medani. Healthcare staff working in the centres under study, along with the displaced coming staff, were all forced to leave the state while the facilities were destroyed largely by the fire exchange.

2.10.1.2 Data related to patients' demographics:

These data include the patient's age, gender and residence which was obtained from the patients' files.

A. Age

Age was divided into six groups with a 15-year age difference to fulfil the study's objectives. Group 1 represented children aged 0 to 15 years, and Group 6 was for people aged 75 and

up. This method was chosen for the purpose of including the paediatrics population. The two previous studies on the state of anaesthetic care in Sudan primarily addressed adult patients. [7,12]. (7,12). Aside from being an important aspect of anaesthesia training, specialisation, and practice, dealing with paediatric patients, along with other age groups, was included in this study for the purpose of analysing the diversity of anaesthesia care provided by the workforce in each centre, which will have a direct impact on the techniques used, the workload on the providers, and adverse events encountered across all age groups.

B. **Gender**

A female/ male categorisation was adopted for the study to show the gender gaps in access to healthcare and therefore obtain data that will eventually help in achieving the Sustainable Development Goals. No other gender categorisation is recognised in the Sudan.

C. Residence

The hospitals under study serve as referral centres for several sections of Sudan, and in exceptional cases, patients from outside Sudan are admitted for surgery. The patients' residences were collected to determine the geographical distribution of patients during the study period, which would represent the load of service placed upon the anaesthesia staff along with feedback regarding the surgical services of the other states where these patients came from. This category was classified as 1) Gezira state patients, 2) other Sudanese state patients, and 3) patients from outside Sudan.

2.10.3 Data related to the surgical procedure assessing the secondary objective:

These data were obtained directly from the surgical instructions and operative sheet on the patients' records. It includes the planned surgical procedure, the urgency and complexity of the procedure, the status of obtaining consent, and the type of anaesthesia technique used for the procedure.

To fulfil the study's objectives, this variable was tailored for each individual centre under examination based on the procedures conducted daily. This approach differs from the majority of publications on the topic of task sharing/shifting, where the terms "surgeries and surgical procedures" are used without defining the procedure or its complexity, or whether unsupervised NPAPs or anaesthesia physicians are required based on international

guidelines. Previous publications focused only on the listed surgical procedures according to the provision of related Bellwether Procedures which are obstetrics, general surgery, and Orthopaedic surgery (2).

A. Planned surgical procedure.

Surgical procedures in this study were categorized for each research centre individually to indicate the most common procedures presenting for surgery. The most common procedures reported in Wad Medani Teaching Hospital are Excision of lipoma, Laparotomy, Thyroidectomy (Total or Subtotal), Hernia Repair, Anal fissure or haemorrhoid, Removal of Mycetoma, Fistula repair (anorectal or vesicovaginal), Mastectomy, Splenectomy and Examination under anaesthesia (EUA). Surgical procedures of regular provision in Wad Medani Maternity Hospital include Caesarean Sections, Evacuation and Dilatation and Curettage D&C, Vaginal Tear Repair, laparotomy including (removal of ovarian cysts, abdominal hysterectomy, ectopic pregnancy) Vaginal Hysterectomy, EUA and Inclusion cyst. Gezira Centre for Renal diseases and Surgeries surgical procedures include Prostatic Surgeries (TURP, TVP, TURBT), Testicular surgeries (tumour, varicocele, scrotal exploration), Urethroplasty, Pyeloplasty, pyelolithotomy, Percutaneous nephrolithotomy (PCNL), Nephrectomy (open, radical), renal exploration, other Genitourinary GU surgery Double J DJ removal, visual internal urethrotomy, ureteric reimplant). Emergency procedures reported in The National Centre for Paediatric Surgeries include laparotomy, EUA, Pyloric stenosis, Refusing colostomy, Appendectomy, Circumcision & re-circumcision, Paraphimosis and ventriculoperitoneal (VP) shunt.

B. Type of surgery based on the urgency of the procedure.

To categorize this parameter, the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) explanation of interventions into elective and emergency procedures is used. 1) Any surgical, therapeutic, or diagnostic procedure that is scheduled or booked in advance of usual hospital admission is considered elective surgery. On weekdays, almost all cases are done during the day. Adhering to the same classification, 2) emergency procedures are any immediate, lifesaving, or limb-saving procedures, or any development or deterioration of a medical condition that necessitates surgical intervention within minutes or hours of the decision to operate. Emergency procedures can be performed at any time without prior notice. Each centre has 2 to 3 surgical units performing elective procedures

and one unit responsible for emergency admissions each day, except for the paediatric centre, which at the time of study was undergoing maintenance.

C. Type of anaesthetic technique.

One of the secondary goals of this clinical audit was to assess the anaesthetic techniques provided by anaesthesia technologists to those provided by other anaesthesia practitioners. This metric was classified into the three types of anaesthesia 1) General anaesthesia, 2) neuraxial anaesthesia and 3) Procedural Sedation

2.10.4 Data related to anaesthesia care tasks that directly evaluating the primary objective:

Eight tasks that were directly related to provider or patient care were identified to be provided in the four centres and representing the primary objective of the study. These tasks were the selection of an anaesthesia plan, intravenous line insertion, provision of anaesthesia induction, provision of anaesthesia assistance, placement of the advanced airway, intraoperative monitoring of the patient and management of adverse events, extubating the patient and discharging from the operating room, and finally the provision of postoperative care. Because there was a lack of insufficient availability of these data in the medical records, as stated below, this strategy of observation with or without interviewing was adopted.

This metric was included to address how the various teams working in each study centre select the anaesthetic plan. This parameter specifies the staff responsible for selecting the anaesthesia plan in the presence or absence of the anaesthesiologist's physical or remote supervision, or to whom the plan selection will be assigned. To assess this parameter, it was categorised into the three anaesthesia practitioners who routinely practice in Sudan: 1) Anaesthesiologist; 2) Anaesthesia Technologist; and 3) Anaesthesia Technician in relation to the frequency of modifying the initial anaesthesia plan among each category.

A. Line Insertion

As a primary task in anaesthesia care, this parameter was included in this study to assess the variations among the four anaesthesia teams in delegating the responsibility of placing the

intravenous line. The three anaesthetic practitioners in the team 1) anaesthesiologists, 2) technologists, and 3) technicians—at the study centres were classified to achieve the aim of this parameter.

B. The anaesthesia provider.

Who provides anaesthesia, selects the agents for administration, and calculates the doses of the drugs have long been the main points of contention in the anaesthesia community when discussing task sharing and shifting. The purpose of using this criterion in this clinical audit is to compare the proportion of anaesthesia provided by each category of provider to the number of cases presenting for surgery in the four t centres. Ascertaining the percentage of anaesthetic care delivered by anaesthesia technologists is one of the goals of this clinical audit. To assess this parameter the three categorisations of anaesthesia providers were used 1) Anaesthesiologist, 2) Technologist or 3) Technician.

C. The Provision of Anaesthesia Assistance.

This parameter was considered in this audit to investigate the degree of assistance provision in comparison to the surgical procedures, the classification, and the type of surgery. To obtain this parameter, it was categorised into three choices in the drop-down list. If the anaesthesia assistance was provided by 1) anaesthesia technologist, 2) anaesthesia technician, or 3) whether the assistance didn’t take place (and anaesthesia care was solely by the physician).

D. Advance airway placement

Protecting the patient's airway using an artificial airway, oropharyngeal airway or endotracheal tube (ETT) is required under general anaesthesia with muscular relaxation to maintain respiratory ventilation and oxygenation. This parameter is used in this audit to identify who is responsible for placing the ETT and managing the airway during procedures, which will aid directly in determining the proportion of care and breaking down the tasks between the practitioners. When inserting an advanced airway, this parameter is categorised as 1) anaesthesiologist, 2) technologist, and 3) technician, or not necessary if no advanced airway is required.

E. Monitoring, maintenance of anaesthesia and management of adverse events

This parameter was included to assess the different approaches taken by the four centres in delegation of the responsibility of monitoring the patient intraoperatively and who managed the adverse events when they emerged: 1) Anaesthesiologist, 2) Technologist, or 3) Technician.

F. Extubation and discharge.

This parameter was included to assess the approach in the four centres in handling the responsibility of extubation and discharge from the operating room. 1) Anaesthesiologist, 2) Technologist or 3) Technician. This criterion will further be compared in relation to the provision of supervision and the development of adverse events.

2.10.5 Data representing the indicators of safe anaesthesia practice by anaesthesia technologists:

These data were gathered to examine the safety of practice in the cases provided by anaesthesia technologists.

A. Pre-operative visit.

Taken as a basic standard of care for the operative patient and as a prerequisite for developing the anaesthesia plan, the preoperative visit parameter was included in this study to show the different approaches of the anaesthesia technologists four practicing anaesthesia teams in the centres under study. To achieve this objective; this parameter was categorised into three variables which include 1) meeting the patient the night before surgery or in the morning of surgery in the holding area and 2) meeting the patient at the surgical table before induction of anaesthesia or no preoperative visit.

B. Modification of the Anaesthesia Plan

The modification of the initial anaesthesia technique that was planned in the preoperative period or that took place during the induction phase. The incidence of modifying the anaesthesia plan in relation to the NPAPs was not discussed in the previous literature that assessed task sharing. To assess this parameter, “yes’ or “no” choices were listed in the drop list to indicate the incidence of anaesthesia technique modification.

C. The development of intraoperative adverse events:

In agreement with previous publications this criterion was included in this audit to measure the occurrence of adverse events during anaesthetic care in the perioperative period in accordance with the literature that dealt with quality indicators in NPAP practice. The incidence of unfavourable events was pre-identified as “yes” in cases of occurrence or “no” in cases of not happening. If "yes" was selected, indicating the development of an adverse event, a drop list of options could be selected: 1) drug or technique error or difficulty in obtaining a certain technique, including difficulty in cannulation or obtaining an intravenous line, or failure to place a spinal anaesthetic. 2) unplanned intubation or reintubation in cases of unstable patients, surgical indications, accidental removal of the endotracheal tube, and residual neuromuscular block. 3) difficult intubation in the event that the endotracheal tube insertion difficulty of ventilation difficulty. was inserted inadvertently into the oesophagus or a difficult airway management cascade developed. 4) In cases of the development of any form of cardiovascular event, including but not limited to bradycardia, tachycardia, hypotension, and hypertension. 5) If respiratory compromise was encountered (hypoxia, hypercapnia, apnoea, etc.) or an event of unplanned mechanical ventilation, 6) Significant haemorrhage and need for transfusion 7) Delayed recovery, which resulted from the residual effects of anaesthesia drugs. 8) in cases of unplanned ICU admission resulting from a surgical or anaesthetic complication, including delayed recovery or respiratory failure 9) Anaesthesia-related cardiac arrest due to severe hypotension or respiratory failure resulting from any anaesthesia cause. 10) In the event of the development of any other adverse events that developed during the perioperative period that were not included in the drop list, they would be checked as “other”. 11) If the anaesthesia care during the perioperative period until discharge proceeded without the development of adverse events, a “no” option would be checked. This parameter will further be compared in relation to the presence of supervision, reporting of adverse events and the documentation.

D. Consultation requesting.

It is evident that obtaining the consultation of a more skilled practitioner in cases of difficulty in performing an anaesthesia -related task or the development of adverse events is a quality indicator of practice (7). This parameter will assess the frequency of requesting a senior/ anaesthesiologist consultation among anaesthesia technologists in order to determine the most common form of adverse occurrence that necessitates consultation. If

consultation was requested, it would be reported as 1) Yes and 2) No if no consultation was requested.

E. Reporting of peri-operative adverse events.

Professional and legal accountability requires reporting of adverse events during anaesthesia, including, how they were managed, by whom, and the eventual outcomes of these events. This parameter was used to determine whether adverse events were reported 1) Yes or 2) No if they were not reported.

F. Documentation of anaesthetic sheet.

This parameter will evaluate the extent of implementation of documenting the anaesthesia sheet among the technologists, whether it is governed by institution policy or left for the practice of the practitioner. If the anaesthesia sheet was documented, it would be recorded as 1) Yes or 2) No if it was not reported.

G. Provision of post-operative care.

Anaesthesia personnel are involved in care outside of surgery. This criterion was included to examine the extent to of providing postoperative care by technologists if 1) Yes provided or 2) No if no postoperative care was provided by the technologist.

3. Results:

After obtaining the ethical approval from both the University of Cape Town and the University of Gezira, data collection for this study commenced at all four centres in November 2022 and ended February 2023. The results obtained were as follows.

3.1 Research centres:

Table 3.1 The number of anaesthesia providers per study centre and their educational/ clinical backgrounds.

Centre Name	**Anaesthesiologists – Specialist MD**	**Technologist - BSc**	**Technicians - Diploma**	**Total**
Wad Medani Teaching Hospital	1 (4%)	22 (88%)	3 (12%)	25
Wad Medani Maternity Hospital	5 (12.5%)	25 (62.5%)	10 (25%)	40
Gezira Centre for Renal Diseases Surgeries	1 (6%)	15 (94%)	0 (%)	16
National Centre for Paediatric Surgeries	0 (%)	16 (89%)	2 (11%)	18
Total	7 (7%)	78 (78%)	15 (15%)	99

Wad Medani Maternity hospital reported having the highest number of anaesthesia practitioners across the three categories in the study centres.

3.2 Patient demographics

3.2.1 Age of the patients

Table 3.2: Distribution of patients among age groups

Age Group (years	Research Center				
	Wad Medani Maternity Hospital	Wad Medani Teaching Hospital	Gezira Centre for Renal Diseases and Surgeries	National Centre for Paediatric Surgeries	Grand Total
0 - 15	41 (26%)	18 (11%)	14 (9%)	85 (54%)	158
16 – 30	491 (82%)	67 (11%)	41 (7%)	-	599
31 - 45	302 (59%)	124 (25%)	79 (16%)	-	505
46 - 60	31 (19%)	86 (51%)	50 (30%)	-	167
61 - 75	32 (30%)	17 (16%)	57 (54%)	-	106
Above 75	-	6 (26%)	17 (74%)	-	23
Grand Total	**897 (58%)**	**319 (20%)**	**258 (17%)**	**85 (5%)**	**1559**

More than two thirds of the sample size aged between 16 and 45 years and predominantly admitted for obstetrics or gynaecological procedures. Despite the presence of a specialised centre for paediatric surgery, the paediatric population was treated in all centres while almost 60% of the geriatric population were admitted for urological procedures.

3.2.2 Residency and Gender of the patients

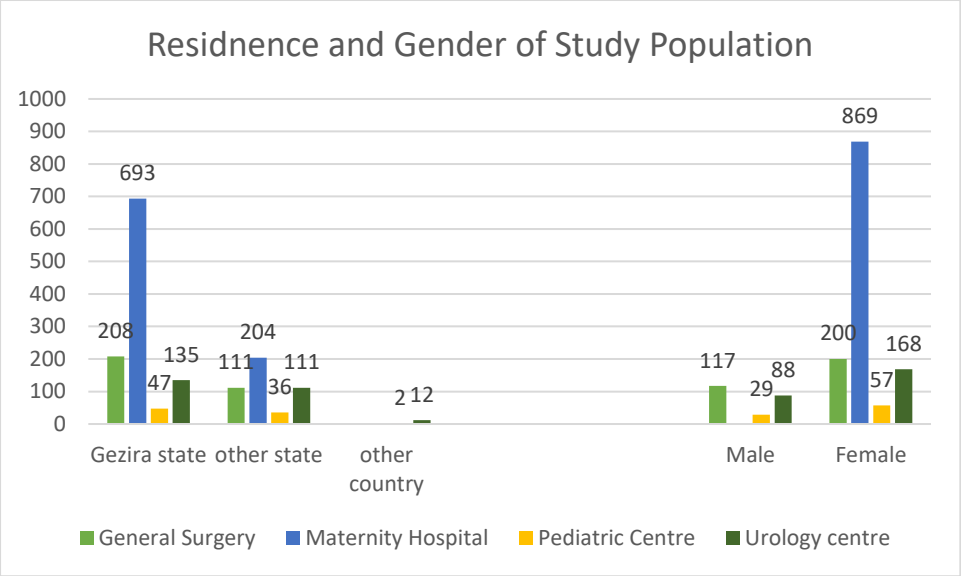

Figure 3.1 Distribution of patients' genders and residency among study population.

Cases admitted during the study period were predominantly from Gezira State (1083) n contrast to 462 cases presented from other states. The National Centre for Paediatrics Surgery and the Gezira Centre for Renal Diseases and Urological Surgeries both had 14 patients from outside Sudan.

A proportion of 80% of the total patients participating in the study were females.

3.3 The primary objective / Anaesthesia Tasks.

The main objective of this clinical audit was to evaluate the proportion of anaesthesia care provided by the anaesthesia technologists in comparison to the other anaesthesia providers within the four research centres. Eight different anaesthesia care tasks were selected to achieve this objective.

Table 3.3: Direct patient anaesthesia care tasks

Anaesthesia Task	Anaesthesiologist	Technologists	Technicians	Total
Selection of Anaesthesia Plan	1031 (66.1%)	526 (33.7%)	3 (0.2%)	1559 (100%)
Intravenous line insertion	0 (0) %	977 (62.7%)	582 (37.3)	1559 (100%)
Induction of Anaesthesia	781 (50.1%)	718 (46.1%)	60 (3.8%)	1559 (100%)
Anaesthesia assistance	0 (0%)	977 (62.7%)	582 (37.3%)	1559 (100%)
Placement of advanced airway	57 (3.6%)	291 (82.4%)	4 (0.2%)	353 (100%)
Monitoring of patient	190 (12.9%)	1269 (81%)	0 (0%)	1559 (100%)
Extubation and discharge	213 (13.6%)	1317 (84.5%)	29 (1.9%)	1559 (100%)
Postoperative care	262 (16.8%)	85 (5.4%)	0 (0%)	1559 (100%)

Out of the total 1559 cases 46.1% of the anaesthesia was provided by anaesthesia technologists. The anaesthesia technologists performed the majority of four tasks out of the seven tasks that were selected to represent the main objective of the study. These tasks included the intravenous line insertion in 62.7%, placement of advanced airway (82.4) monitoring and extubation of the patients were 81% and 84% respectively. While they provided anaesthesia assistance in 62.7% of the cases.

One way Anova test was conducted to test the significance of the results as below

Result Details				
Source	***SS***	***df***	***MS***	
Between-categories	1615873	2	807936.5	*F* = 5.84671
Within-categories	2901917.5	21	138186.5476	
Total	4517790.5	23		

The f-ratio value is 5.84671. The p-value is .009582. The result is significant at $p < .05$.

3.4 Secondary objectives / Anaesthetic and surgical procedures

Of the1559 cases that were included during the data collection period; 58% of the cases were performed at Wad Medani Maternity Hospital with an average of 11 surgical procedures per day while only 5% of the cases were performed at the National Centre for Paediatric Surgeries making an average of less than one procedure as presented in Table (3.4).

3.4.1 Types of surgical procedures.

Sixty two out of the 319 procedures that were performed in the WadMedani Teaching Hospital were excision of mycetoma followed by repair of anal fissure or haemorrhoid. At the maternity hospital 568 out of 879 cases were caesarean sections followed by 159 cases

of Evacuation and Dilation and Curettage D&C in comparison to only seven cases of uterine prolapse. Of the 85 cases performed at the paediatric surgery, 29 procedures were appendicectomy followed by 10 cases of laparotomy with less than 5 cases of excision of lipoma or abscess. Gezira centre for renal diseases and surgeries performed 285 cases. Most of the cases were urethroplasty and prostate surgeries including transurethral Resection or transvesical prostatectomy as shown in Table 3.4.

Table 3.4 Type and percentage of surgical procedures per centre

Wad Medani Teaching Hospital	**Wad Medani Maternity Hospital**	**National Centre for Paediatric Surgeries**	**Gezira Hospital for Renal Diseases and Surgeries**
Excision of Mycetoma	Caesarean section	Appendectomy	Urethroplasty
Anal fissure/ haemorrhoid	Evacuation / D&C	Laparotomy	Prostate surgery
Laparotomy	Laparotomy	Circumcision/ circumcision	DJ removal
Thyroidectomy	Inclusion cyst	Pyloric stenosis	Pyeloplasty
Splenectomy	Repair of vaginal tear	VP shunt	Nephrectomy
Hernia repair	Examination under anaesthesia	Paraphimosis	Testicular surgery
Mastectomy	Repair of fistula	Colostomy/ refusion colostomy	Laparotomy
Examination under anaesthesia	Vaginal hysterectomy	Repair of hernia	
Anorectal fistula repair	Uterine prolapse	Excision of lipoma/ abscesses	
319	**897**	**85**	**258**

Less than 20% of cases
21 – 40% of cases
41 -60% of cases
Above 60% of cases

3.4.2 Urgency of the surgical procedures

Out of a total number of 1559 surgical procedures that were performed, 1057 were elective and 472 were emergency surgical procedures. All paediatric cases were emergencies. Anaesthesia technologists provided anaesthesia for 93% of the total (472) emergency cases without the oversight or supervision of anaesthesiologists as shown in Figure 3.2.

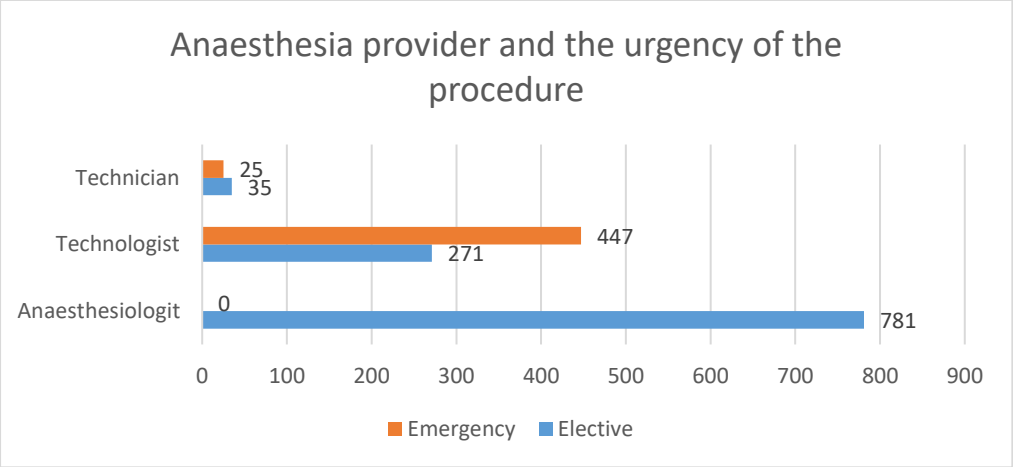

Figure 3.2 Anaesthesia provider in relation to the urgency of the procedure

3.4.3 Type of anaesthesia techniques.

Determining the type of anaesthesia techniques provided by anaesthesia technologists was one of the secondary objectives of this study. 1016 cases of spinal anaesthesia were placed at the different study centres during the study along with 400 general anaesthesia and 143 cases of procedural sedation. A 77% of the total spinal anaesthesia were place at the maternity hospital as shown in Figure 3.3

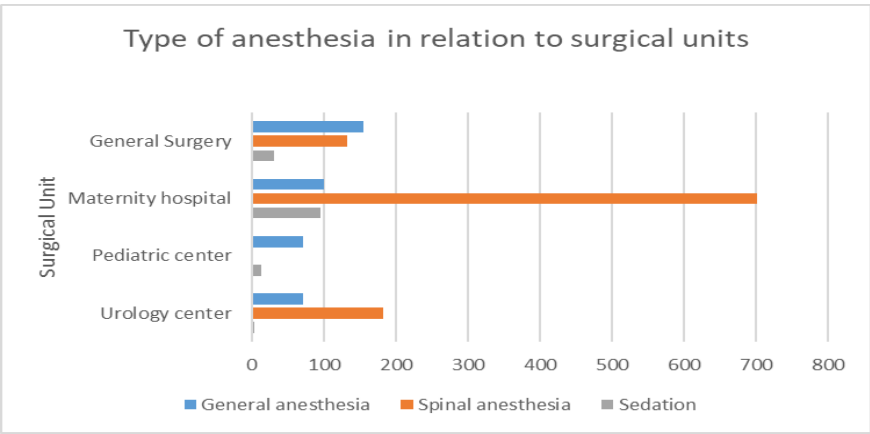

Figure 3.3 Type of anaesthesia technique in relation to the surgical units

This graph represents the number of different anaesthesia techniques administered in relation to the anaesthesia providers. Almost 60% of the general anaesthesia was provided by technologists along with 40% of the spinal anaesthesia cases and 57% of the total procedural sedation techniques. All making 46.1% of the total of 1559 cases. As presented in Figure 3.4

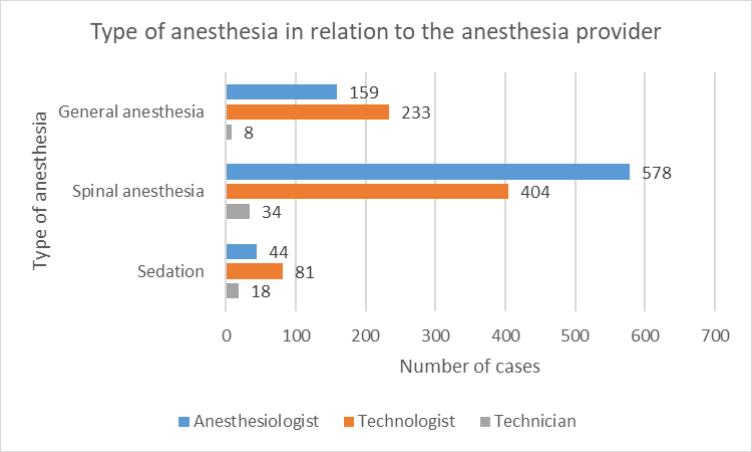

Figure 3.4 Distribution of types of anaesthesia technique in association to the provider

3.5 Safe anaesthesia practice indicators of anaesthesia technologists.

These parameters were collected to indicate the safety of anaesthesia care in the 718 cases provided by anaesthesia technologists without the of presence of supervising anaesthesiologists as shown in table 3.5.

Table 3.5 Indicators of safe anaesthesia practice as derived from the WHO

Indicator	Event occurred	Event did not occur	Total
Pre-operative visit	338 (47%)	380 (53%)	718
Modification of anaesthesia plan	17 (2%)	701 (98%)	718
Documentation	258 (36%)	460 (64%)	718
Incidence of adverse events	243 (34%)	475 (66%)	718
Request of senior/ anaesthesiologist consultation following the incidence of adverse events	69 (28%)	174 (72%)	243
Reporting of adverse events	17 (6%)	252 (94%)	269
Post-operative care	258 (36%)	460 (64%)	718

The practice of preoperative visit in anaesthesia care provided by technologists was reported in 47% of the cases. While modifying the anaesthesia plan in cases of difficulties in carrying out the initial plan or an unexpected extension of the surgical procedure was observed in 17 cases only. Documentation of the anaesthesia sheets was reported in 258 cases out of the 718 cases.

Incidence of adverse was reported in 243 cases, consultation for managing these adverse events was requested in 69 cases and only 17 cases of these events were reported. Postoperative cleaning and disinfection were practice in 511 cases.

Out of 585, 76% of the adverse events were reported in the maternity hospital and the general surgery respectively with cardiovascular events and haemorrhage to be the most dominant adverse events reported. While Delayed recovery and drug/ technique error or difficulty were most common in Paediatric centres. Cardiovascular events along with haemorrhage and respiratory events were the prominent adverse events that persuaded the practitioners to seek consultation from anaesthesiologists or senior technologists representing 67% of all consultations requested during the study period.

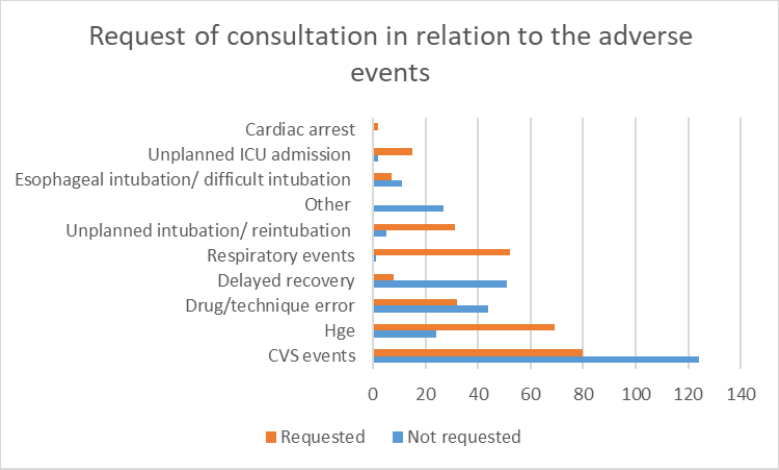

Figure 3.5 the incidence of requesting consultation when experiencing adverse events.

Discussion

Few publications discussed anesthesia training pathways and practice models in Sudan. The BSc graduates anaesthesia technologists are leaving their careers as anaesthesia providers and enrolling in full-time medical schools in search of a more secure career. This has, resulted in a noticeable lack in anaesthesia practitioners in Wad Medani and other rural areas of Gezira State, as well as other Sudanese states. This professional shift was expected to have a negative impact on the overall anaesthesia care in the near future, with the increasing shortage of anaesthesia providers. Along with that, it might result in a huge compromise in the provision of anaesthesia care following the current war as a result of voluntary or forced displacement. Which encouraged the researchers to conduct this clinical audit to determine the proportion of anaesthesia care provided by anaesthesia technologists in the State Ministry of Health tertiary hospitals in Wad Medani, central Sudan.

The analysis demonstrated that the independent practice of BSc anaesthesia technologists in Wad Medani had assisted in the provision of 46.1% of cases, or 718 out of 1559 surgical anaesthesia cases that presented to the study centres during the study period in a complete task shifting manner. Task sharing by BSc technologists was exhibited on 80% of the anaesthesia care tasks in the presence of anaesthesiologists, including advanced airway placement, patient monitoring, extubation, and the placement of intravenous lines, in addition to providing anaesthesia assistance tasks. The analysed data indicated that a total of 99 anaesthesia providers were reported at the study centres during the study period both PAP and NPAPs. The reported practitioners were 7 anaesthesiologists, 78 BSc technologists, and 15 diploma technicians. The study demonstrated that the majority (40%) of the three categories of anaesthesia providers studied were practicing in a maternity hospital, which may suggest a correlation with the highest proportion (58%) of surgical procedures performed at the maternity hospital out of the total 1559 surgical procedures performed at the four study centres during the study period. Caesarean sections made up 64% of the cases which presented at the maternity hospital and spinal anaesthesia accounted for 56% of all anaesthesia procedures.

To our knowledge, there has been no study on the status of anaesthesia in Sudan conducted in recent years. The OASIS, Current Status of Obstetric Anaesthesia Services in Khartoum, which was a cross-sectional observational study conducted between May 1st and 14th, 2016 by Ahmed et al., revealed that a significant number of obstetric anaesthesia services were provided by unsupervised anaesthesia technicians [14]. This emphasizes the role of NPAPs in anaesthesia provision not only in suburbs and rural areas but at the level of the capital. The OASIS study tested the equipment alongside the staff in Khartoum public obstetric hospitals, which is a major indicator of safe anaesthesia practice beside the workforce. Despite the fact that the OASIS did not include the number of NPAPs, it did state that there were only a number of 8 anaesthesiologists available to serve in 3 hospitals, with deliveries ranging from > 4000 to 1000 per year. similar total of 718 cases of obstetric and gynaecological anaesthesia were conducted during the 3-month study period. The other two anaesthesiologists were practicing in the general surgery complex of Wad Medani Teaching Hospital and the Gezia Hospital for Renal Diseases and Surgeries.

A previous similar study that was conducted in Amhara region of Ethiopia between 2019 and 2020 and was directed towards identifying the number and academic background of the anaesthesia providers and the quality of care with regard to the WFSA regulations. The Ethiopian study was a cross-sectional survey that included 36 hospitals and reported a number of 13 anaesthesiologists, along with a number of 37 MSc anaesthesia technologists, 153 BSc technologists, and 15 diploma technicians who voluntarily participated in the survey [11]. However, the actual number of practitioners was not obtained through the survey method in Ethiopia, in contrast to our study, in which we obtained the number and academic qualifications of the practitioners by directly interviewing the head departments. This study augmented the role of MSc technologist in the provision of highly specialized anaesthesia care in contrary to the case in Sudan where the MSc anaesthesia technologists were not employed by the health sector.

Highlighting that the majority of patients seeking surgical care were obstetric and general surgery patients, a finding which is well supported by the LCoGS reports [1,2,10,11] (2, 10, 11, 30). Caesarean sections represented 64% of the cases performed at the maternity hospital, comprising 37% of the total population, followed by evacuation and D&C.

The study demonstrated that patients under study were predominantly from Gezira State, accounting for 69% of all cases. 14 cases from outside Sudan presented for surgery in the Gezira urology centre and the paediatric centre. Previous publications that handled the status of anaesthesia in Sudan did not study the services provided to patients outside the Khartoum state, which adds to the strengths of our methodology. The presence of patients from outside Gezira State might be a leading factor in increasing the workload on anaesthesia teams due to the existing shortage of anaesthesia providers. It might also indicate shortages of surgical and/or anaesthesia care services in the corresponding patients' states. Either way, this may increase the delay in receiving surgical care as described by the LCoGS [10,11]. This case would get obscured by the displacement that took place after the current war and thus might further complicate the status of anaesthesia provision in other Sudanese states [47,48].

A total of 1239 of these patients were females. Excluding the 897 individuals who presented to the maternity hospital, 342 female cases were documented in the other three locations throughout the study period, compared to 318 male cases. This ratio correlates positively with a previous publication that described the ethnic and gender diversity of surgical patients in Africa. Which indicates that the ratio of patients approach to health or surgical care is not affected by gender type [1,2,14].

The data also indicated that despite the presence of a specialized centre for paediatric surgery, paediatric patients presented for specialized elective procedures in all centres under study, as shown in Table (3.2). This could be interpreted as a lack of paediatric surgeons with the expertise to perform these specific procedures, which needs extensive further investigation, especially after the recent conflict. The total paediatric population within the four centres made up 10% of the total cases. Paediatric surgeries were greatly compromised by the recent war.

A complete anaesthesia care task shifting pattern was observed in all emergency's surgical procedures in each centre under study as shown by figure 3.5. This would suggest the unavailability of anaesthesiologists' supervision during the afternoon/weekend shifts, although this is not confirmed by data from the current research and may require more examination. A similar finding was reported in other publications that assessed the

anaesthesia workforce in both HICs and LMICs and the delegation of tasks in emergency cases to NPAPs without the presence of a supervising anaesthesiologist [19,20], while it demonstrates that the international guidelines for safe emergency anaesthesia requirements though were completely not met [11,12,43].Similar practice of complete task shifting was reported in the anaesthesia care at the national centre for paediatric surgery.

A percentage of 81% of these tasks were performed by technologists in the presence of anaesthesiologists in a task-sharing manner as demonstrated by Table 3.3. The analysed practice shows that 84.5% of the 1559 cases were extubated and/or discharged by technologists. This finding aligns with other studies that examined task shifting in several African countries, including Uganda, Ethiopia, and Cameroon, where NPAPs handled 81% of anaesthetic cases [12,13].

Spinal anaesthesia was placed in 1016 cases, with the majority conducted in the maternity hospital, followed by the urology centre. General anaesthesia with muscle relaxants, intubation, and mechanical ventilation was performed in 400 cases in comparison to procedural sedation, which was performed in only 143 cases, as illustrated in figure 3.3. These statistics agreed with previous literature that evaluated other African countries in both minor and major procedures [12,13]. Unfortunately, all these findings completely contradict the WHO highly recommended safe anaesthesia for major and complex surgeries [49].

The WHO-WFSA has assigned a minimum highly recommended standards for safe anaesthesia practice. These standards describe the minimum expected responsibilities of the anaesthesia provider in the provision of safe anaesthesia. The data demonstrated that the adoption of preoperative visit practice was reported in 47% of the cases that were provided by anaesthesia technologists. This type of practice might negatively affect the safety and quality of practice by postponing procedures, especially in elective cases. In a similar study that evaluated the quality of NPAPs practice in Ethiopia; it was reported that 62% of the cases were not evaluated preoperatively. Based on the WHO-WFSA, RoCA and ASA, this practice is regarded as a poor-quality, high-risk, and unaccepted practice that increases the incidence of developing adverse events and prolongs the hospitalization period.

A total of 243 out of the 718 anaesthesia placements by technologists have developed adverse events. Among these events, cardiovascular incidents were at the top of the list, followed by haemorrhage, delayed recovery, and respiratory complications. Only 17 cases of these events were reported by practicing technologists. Cardiovascular events and haemorrhage were the most common events that persuaded anaesthesia technologists to seek senior technologists or even anaesthesiologists' consultation. This finding contradicts to some extent a previous clinical audit that assessed the quality indicators in anaesthesia practice, in which it was reported that respiratory complications dominated the type of adverse events, followed by cardiovascular events, and then bleeding [46]. A number of 17 initial anaesthesia plans were modified after placement by technologists either due to unexpected, complicated surgery or the development of adverse events.

Documentation was reported to not be a common practice among technologists (only 40%), despite being a minimum standard for safe anaesthesia practice. This resembles the Eshango et al. study, a regional study that was conducted in Ethiopia, which reported that documentation was reported by only 21% of the participating providers. Eshango also recommended that NPAPs be trained on the proper documentation of the anaesthetic sheet and the reporting of events.

The provision of postoperative care and pain control was also limited to 40% of the practicing technologists. This finding should be well addressed by the authorities in terms of providing unsupervised. safe anaesthesia care. Measures are defined as indicators of the quality of anaesthesia care.

Strengths of the Study:

The strengths of this study are that it was relatively easy to conduct and cost-efficient. The study design ensured that the sample was selected randomly, asserting that it represented the actual population. The study also accurately reported the actual statistical description of the data with a relative suggestion a cause-and-effect relationship between exposures and outcomes where relevant. The inclusion of paediatric population was one of the strengths of the study, as no publication was available regarding the NPAPs and anaesthesia of paediatrics.

Limitations of the Study:

The study was limited by the fact that the data collection region might well describe the urban areas of Sudan with similar socio-economic indicators at the time of the study but might not well describe marginal and rural areas in Sudan where the actual shortage of all anaesthesia providers has compromised the provision of anaesthesia and surgical care. The study design would have had a greater impact if it had been conducted as a survey of the anaesthesia providers in all of Gezira State instead of assessing the anaesthesia cases in selective centres similar to a previous Ethiopian study (11). The development of the current war, which started after the data collection was concluded, added to the limitations of this study. As of April 2023, 334,050 people were reported as internally displaced from Khartoum to Wad Medani and other Gezira state cities and towns. By December 2023, this number had risen to 3.02 million (48). These numbers weren't associated with an equivalent increase in the number of healthcare providers at Wad Medani Hospitals, which could result in a significant delay in getting surgical care [1,2]. Wad Medani was ravaged by conflict fires by the end of December 2023, resulting in large evacuation to other Sudanese regions with limited healthcare and surgical skills.

Conclusion and Recommendations

This study extensively investigated the provision of anaesthesia care in Wad Medani, Sudan, before the development of the recent conflict. The analysis confirmed that the number of anaesthesiologists in the study sites is significantly lower than the WHO's recommended sum, which is expected in Sudan, where the anaesthesiologists/patient ratio is 0.47:100,000. The study revealed that anaesthesia technologists performed the majority of anaesthesia care tasks in varying degrees, ranging from totally performing all tasks (task shifting) in 47% of the total cases to partially performing up to 80% of some other tasks in the presence of anaesthesiologists.

The importance of participation in the composition of the anaesthesia team in Sudan should be addressed regulated, protected and utilized. With proper training, anaesthesia safety and quality can be significantly enhanced to achieve the international recommendations. Countries with similar economic settings and, with the proper training and definition of the scope of anaesthesia care services, could benefit from the adoption of NPAPs.

A significant percentage of patients who presented to the study sites for surgical care were from Sudanese states other than Gezira which, besides adding burdens on anaesthesia providers, results in a significant delay in receiving surgical care, which is a major concern of the LCoGS and the WHO. The Ministry of Health, in collaboration with the University of Gezira and the WHO, is responsible for educating, training, and assisting in ensuring the future of the profession and specialty of anaesthesia in terms of quantity and quality.

Recommendations

Incorporating protocols that guide and govern the delivery of safe anaesthesia care services at Wad Medani would bring all providers to the minimum, highly recommended level of expected safe anaesthesia practice. Encouraging technologists and technicians to follow these guidelines, while creating the optimal scope of practice for each type of provider, including legal and financial liabilities, along with enhanced settlement plans supported by the government as a matter of enhancing the post war capacity building.

Training technologists on the measures of safe anaesthesia practice, including documentation of the anaesthesia sheet, reporting adverse events, provision of postoperative care, and the adoption of the WHO safety checklist, would greatly improve the provision of anaesthesia care. Providing CME courses in the anticipation and management of adverse events and anaesthesia complications would greatly enhance the patient's outcome.

Adoption of a well designed promotion strategies, career development path and the provision of satisfying financial incentives and medical insurances among other methods would assist in retaining the technologists and specially where task shifting is expected.

Another recommendation would be to strengthen and support existing anaesthetic services in order to improve the current standard of care for paediatric and emergency surgical procedures. The existing service may benefit from a unified program that trains current anaesthesia professionals to use the most recent measures of quality anaesthesia practices.

Further recommendations would be to undertake clinically relevant studies in order to identify modifiable burdens of providing safe anaesthesia practice other than staffing needs , which can be targeted for capacity building, adopting protocols, training, and education. Research should be also performed to determine the availability of anaesthesia providers in areas where displaced individuals reside as well as to register and track the prevalence of surgical care delays.

Another identified need is to recruit anaesthesiologists to work at the paediatric centre along with scheduling the anaesthesiologists in the other centres to be available to cover emergency cases and afternoon, night, or weekend shifts.

Finally, anaesthesia is an extreme high-risk specialty, and the presence of a qualified personnel throughout the conduct of anaesthesia is the first ASA recommendation for safe anaesthesia practice, so a defined employee disciplinary system along with strict penalties should be well implemented to assist in the provision of a safer practice.

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APPENDICES

- Consent form
- Data collections tools
- Ethics certificate
- Permission letters
- Turnitin Certificate

Global Surgery Division, Department of Surgery, Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa Block H53, Old Main Building, Groote Schuur Hospital, Groote Schuur Road, Observatory, 7925