ESTIMATION OF MET SURGICAL NEEDS AT HOSPITALS IN THE NORTH KIVU PROVINCE OF THE DEMOCRATIC REPUBLIC OF CONGO.

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LIST OF ABBREVIATIONS

CBM	Christian Blind Mission
CCS	Composite Capacity Score
COSECSA	College of Surgery of Eastern, Central and Southern Africa
DALY	Disability adjusted life year
DHIS	Demographic and Health Information System
DH	District Hospital
DRC	Democratic Republic of the Congo
DCP3	Disease Control Priority Third Edition
EESC	Emergency and Essential Surgical Care
FBOs	Faith-based organizations
FBHPs	Faith-based health providers
G4-Alliance	G4 Alliance for Global Surgery
GICS	Global Initiative for Children's Surgery
GIEESC	Global Initiative for Emergency and Essential Surgical Care
HAH	HEAL Africa Hospital
HICs	High-Income Countries
HZ	Health Zone, equivalent to Health District
ICU	Intensive Care Unit
IMEESC	Integrated Management of Emergency and Essential Surgical Care

IQR	Interquartile range
GDP	Gross Domestic Product
LCoGS	Lancet Commission on Global Surgery
LMIC	Low- and Middle- income Country
LIC	Low-Income Country
MSF	Médecins Sans Frontières
MDGs	Millennium Development Goals
MoH	Ministry of Health
MUHC	McGill University Health Centre
NFBHN	National faith-based health networks
NGO	Non-Governmental Organization
NK	Nord Kivu
NSOAP	National Surgical Obstetrical and Anesthesia Plan
OR	Operating Room
PAACS	Pan African Academy of Christian Surgeons
PNDS	Programme National de Développement Sanitaire
PSCGS	Program in Social Change and Global Surgery
RRH	Regional (or Provincial) Referral hospital
SADC	South African Development Community
SAO	Surgery, Anesthesia and Obstetrics Provider

SCDH	Surgical Care at the District Hospital
SOSAS	Surgeons Overseas Assessment of Surgical Need
SSA	Sub-Saharan Africa
UNFPA	United Nations Population Fund
UN	United Nations
USAID	United States Agency for International Development
VVF	Vesico-vaginal fistula
WACS	West African College of Surgeons
WOFSA	World Federation of Societies of Anesthesiologists
WHO	World Health Organization
WHA	World Health Assembly
ZGH	Zone General Hospital, equivalent to District Hospital

ABSTRACT

Introduction: There is a lack of data in the Democratic Republic of Congo on hospital capacity, surgical, anesthesia and obstetrics providers, surgical volume and met surgical needs. Without such data, a National Surgical Anesthesia and Obstetrical Plan is not possible.

Objectives: To assess the surgical capacity of all health sectors in the North Kivu province of the DRC and correlate it to the surgical burden in the province. To estimate the number of surgical interventions performed yearly and the rate of surgical interventions performed per 100,000 population. .

Methods: We conducted a cross-sectional survey of all hospitals performing major surgery in the North Kivu province in DRC from January to December 2017. Using the WHO -PGSSC hospital assessment tool and operating room registries, we determined hospital characteristics, surgical capacity score, surgical outputs and rates, types of surgeries, met and unmet needs.

Findings: Forty-three facilities were found performing surgery in the province, including 39 zone general hospitals and 4 regional hospitals. Faith-based/NGO hospitals comprised 56.8% of facilities. There were, per 100, 000 population, 78.4 hospital beds, 1.2 operating rooms, 0.4 surgical providers (including general surgeons, orthopedic surgeons and obstetricians), 2.2 general doctors performing surgery, 0.8 nurse-anesthetist, and no physician anesthetists.

The surgical rate per 100.000 population was 49 for children aged ≤ 18 years and 481 for adults. By specialty, 64% of all procedures were gynecological/obstetrical, 18.9% general surgical, 14.8 % trauma-related, and 2.3% eye and dental-related. These characteristics varied by rural/urban setting as well as by safe compared to unsafe areas. No reliable mortality data was available. The average surgical capacity score was 39 (SD 14.5). Between 1/2 and 1/3 of patients could not receive surgical care despite presenting to a hospital in a timely fashion.

Conclusions: Access and delivery of essential surgery is lower in the observed DRC study compared to other African settings. Investment in basic health-care facilities and surgical workforce and training is urgently needed. Faith-based/ non-public hospitals make a valuable contribution to surgical provision. The capacity of hospitals to provide care is low.

RÉSUMÉ

Introduction : Il manque de données sur la RDC concernant la capacité chirurgicale des hôpitaux, des chirurgiens, des anesthésiologistes et des obstétriciens, le taux de chirurgies et les besoins chirurgicaux. Sans ces données, il est difficile de mettre en place un plan national pour améliorer ces services.

Objectifs : Évaluer la capacité chirurgicale de tous les secteurs de la santé dans la province du Nord-Kivu en République Démocratique du Congo et la corréler avec le fardeau chirurgical dans la province. Évaluer le nombre d'interventions chirurgicales réalisées dans un an et le taux d'interventions chirurgicales pour 100 000 habitants dans tous les hôpitaux

Méthodes : Nous avons mené une enquête transversale auprès de tous les hôpitaux pratiquant des interventions chirurgicales majeures dans la province du Nord-Kivu en RDC de janvier à décembre 2017. L'outil du Programme de Chirurgie Globale et du Changement Social crée par l'Université Harvard et adopté par l'Organisation Mondiale de la Santé pour l'évaluation des hôpitaux et les registres des salles d'opération ont permis de déterminer le score de capacité chirurgicale, caractéristiques des hôpitaux, les taux de chirurgie, les types de chirurgies, les besoins satisfaits et non satisfaits.

Résultats : Quarante-trois hôpitaux ont été évalués dont 39 hôpitaux de référence de Zones de Santé, et 4 hôpitaux provinciaux. 56,8% étaient des hôpitaux confessionnels / des ONG. Il y avait pour 100 000 habitants 78,4 lits, 1,2 salle d'opération, 0,4 prestataires chirurgicaux pour (y compris les chirurgiens généralistes, les chirurgiens orthopédiques et les obstétriciens), 2, 2 médecins généralistes pratiquant la chirurgie, 0,8 infirmiers-anesthésistes et aucun médecin anesthésiste. Le taux de chirurgies pour 100 000 habitants était de 49 pour les enfants de 18 ans et moins et de 481 pour les adultes. Par spécialité, 64% des interventions étaient gynécologiques / obstétriques, 18,9% en chirurgie générale, 14,8% en

traumatologie et 2,3% en ophtalmologie. Ces caractéristiques varient selon le milieu rural / urbain ainsi que selon les zones sûres par rapport aux zones non sécurisées. Aucune donnée fiable sur la mortalité n'était disponible.

Le score moyen de capacité chirurgicale modifiée était de 39 (DS : 14.5). Entre 1/2 et 1/3 de patients ne recevront pas de soins chirurgicaux même s'il est arrivé à l'hôpital à temps

Conclusions : Selon l'étude réalisée en RDC, l'accès aux interventions chirurgicales essentielles, la main-d'œuvre nécessaire à ces interventions et les prestations correspondantes sont moins importants que dans d'autres pays africains, et il est urgent d'investir dans les établissements de soins de santé de base, le personnel chirurgical et la formation. Les hôpitaux confessionnels / non-publiques apportent une contribution précieuse à la fourniture de services chirurgicaux. La capacité des hôpitaux à fournir des soins chirurgicaux est faible.

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Dr. Luc Malemo: Development of study protocols, data extraction/collection, data analysis, drafting and revision of manuscripts

Dr. Dan Poenaru: Pediatric surgeon, supervision, development of study protocols, review of thesis

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PREFACE

This thesis, presented in traditional monograph format, addresses the need for evidence regarding the unmet surgical needs in the Democratic Republic of the Congo (DRC), a low-income country, in preparation for the National Surgical Obstetrical and Anesthesia Plan (NSOAP) that the MoH is committed to put in place no later than 2020. It takes into account the fact that surgery is still not incorporated in the National Health Plans priorities and might serve to enlighten the process and become an advocacy tool for more attention to addressing the identified low surgical capacity and low rates of surgical outputs in the hospitals. The study was approved by the DRC National Ministry of Health. This was purposefully done so that the MoH can participate in the results and recommendations. The development and validation process described within the thesis follows a rigorous approach that strives to be evidence-based, guided by local experts, and grounded in high quality data. The first abstract from this work was accepted for podium presentation at the 2019 Bethune Round Table. Also, the content of this work has been presented at the Yale University 2019 Global Surgery Annual Meetings. No manuscript has been submitted so far.

CHAPTER 1.

INTRODUCTION

1.1. STATEMENT OF THE PROBLEM

The delivery of surgical services in Sub-Saharan African countries has stagnated or regressed over the last 25 years(1, 2). As a result, 29% of the global population that currently lacks access to surgery reside in Sub-Saharan Africa and other low- and middle- income countries (1-3). One of the reasons for this situation is that for decades, African countries never considered surgery as an essential component of primary health care. Surgery was viewed by leaders and by the population as being expensive, a luxury and a non-essential component of health care. Therefore, surgical diseases, meaning diseases or conditions that can be alleviated by surgery, were absent in the strategic health plans of most African nations. In 2014 a systematic review analyzed the term "surgery" in the National Health Strategic Plans (NHSPs) of African countries. This review showed that 19% of them had no mention of surgery and 65% mentioned surgery five times or less. Of the total 4,064 health targets surveyed, only 2% were related to surgical conditions or surgical care(4). To understand the situation of the Democratic Republic of the Congo, we tried to find targets focusing on improving surgical care in the National Strategic Health Plans of the DRC from 2010-2020. We found that the only targets related to surgery in the DRC health plans are decreases in morbidity and mortality due to Cesarean section and pregnancy-related hysterectomy , surgical site infection rates, mortality due to road traffic accidents, and improving care for breast cancer, uterine cervix cancer and prostate cancer(4-7).

On the other hand, an acceptable target that should be used as a barometer has been suggested. A Sub-Saharan African country should aim at delivering at least 5,000 surgeries per 100,000 populations annually to meet the development goals(8-10), but currently there

are no data about the compliance of the DRC with these standards. The DRC has been named among the 57 countries designated by the World Health Organization (WHO) as in health workforce ‘crisis’(11).

Some hospital-based studies have reported the number of surgeries performed (12-23), but no studies have documented the surgical capacity of hospitals and the quantity, rate, or quality of surgical services at a province-wide or country-wide scale in the DRC. There is no data about the current surgical and anesthesia workforce ratios as well as the surgical outputs for the DRC (24).

1.2. HISTORY OF GLOBAL SURGERY, LANCET COMMISSION ON GLOBAL SURGERY.

The modern idea of global surgery emerged in the early 1980s(25), but it gained world-wide recognition in the beginning of the 21th Century. Global surgery or surgery as a global health issue is increasingly used to refer to surgery within geographical boundaries, and particularly within low-income and middle-income countries. Global surgery focuses on these countries mainly because they have the greatest inequity in access to and delivery of surgical services. Global surgery aims to improve health and health equity for all who are affected by surgical conditions or have a need for surgical care, with a focus on underserved populations in countries of all income levels as well as populations in crisis such as those experiencing conflict, displacement and disaster.

The global surgery community also focuses on surgery among individuals or sub-populations of developed countries who are also less likely to receive adequate, timely surgical care, such as indigenous or minority populations, the poor, the uninsured, the displaced, those affected by natural disasters. or those who live in remote areas.

The global surgery community recognizes that the causes of inadequate or inequitable surgical care and the solutions are interconnected and that the burden and responsibility for improving care should be collective and should extend beyond sovereign borders. Global surgery stresses the fact that clinical care for individual patients in surgery needs to also be complemented by population-level preventive approaches, such as the prevention of road traffic accidents etc.(26).

Historically, the primary barrier to developing surgical services has been the misperception that surgery is too expensive for the majority of low- and middle-income countries (27, 28). But this misconception was challenged by research in the early 2000s, when a lot of efforts produced evidence that led to the recognition of emergency and essential surgical care as a critical element to improving primary health care delivery, which led to the birth of global surgery. The first one was the publication by the World Bank of the second edition of Disease Control Priorities in Developing Countries (DCP, 2006), which provided the first clear economic evidence that surgical care could be a cost-effective strategy under certain circumstances when compared with other types of care, such as antiretroviral medications, vaccinations, and other primary treatments. Then, in the World Health Report 2008—Primary Health Care (Now more than Ever), the World Health Organization (WHO) included Surgery for the first time within the Primary Healthcare Spheres of Care (27-29).

In 2015, four notable events and publications led to a major evolution in global surgery : the publication of Disease Control Priorities 3rd Edition (DCP3) Volume 1 Essential Surgery (30); the publication of the Lancet Commission on Global Surgery in April 2015(2); the adoption of World Health Assembly (WHA) resolution 68.15—"Strengthening emergency and essential surgical care and anesthesia as a component of universal health coverage" on May 22, 2015(30), and the 5th Meeting of the Global Initiative of Essential and Emergency Care: the World Health Organization, Geneva, in December 2015.

The DCP3 was the most comprehensive global effort that evaluated the cost-effectiveness and population-wide effect of health interventions. It has involved the World Bank, the World Health Organization (WHO), the Gates Foundation and several other notable groups. The DCP3 defined the components of surgical care that should be the highest priority to implement globally, namely surgical care that addresses conditions that have very large health burdens and for which there are surgical procedures (and related care) that are highly-cost effective and that are feasible to promote globally. The 80 authors and editors of Essential Surgery defined a set of 44 procedures (or sets of procedures) that fit these criteria. These procedures primarily cover high burden conditions such as complications of pregnancy, injury, surgical emergencies (e.g. appendicitis), and several congenital anomalies (e.g. cleft lip, clubfoot, etc.). DCP3 estimates that if these procedures could be made available to everyone in the world, 1.5 million deaths could be averted each year. This is eminently feasible to do. These procedures are all very cost-effective, with most costing $10–$100 per disability adjusted life year (DALY) averted. This is in the same range as immunizations, bed nets for prevention of malaria, and several other interventions that are extremely cost-effective.

The World Health Assembly (WHA) which is the governing board of the WHO, requested actions by both the member states and WHO. It requests governments to carry out regular monitoring and evaluation of the emergency and essential surgical care and anesthesia capacity of health care facilities to identify unmet needs. Also, it requested the WHO to raise awareness of cost-effective options to reduce morbidity, mortality, and prevent or treat disability and deformity through improved organization and planning of provision of anesthesia and surgical care that is appropriate for resource constrained countries(31). These historic resolutions represent an important step towards national capacity building, health

systems strengthening and greater prioritization of essential surgical and anesthesia care for those in need, often at the community and district hospital level (27).

For more than a century before the concept of ‘global surgery’ was used , surgery in LMICs went through several evolving forms: surgery by missionaries, short-missions, long-missions, surgical platforms in global health etc. (27). The traditional model to deliver surgery to LMICs has been to send a Western-trained surgeon to the country's interior, generally a very remote setting with a small, poorly equipped hospital, hoping that the surgeon would make a career of it. Some examples include Dr. Albert Schweitzer and his hospital in Lambaréné in Gabon and Dr. David Livingstone in central and southern Africa. This model is still the prevailing paradigm throughout the developing world, especially among faith-based organization (FBO) hospitals.

An extension of this model and the basis for its continued survival has been the utilization of short-term surgeons who provided varying interims of service as either a stopgap measure or as recurring, but intermittent service. While this satisfies acute necessities, it often fails to provide long-term results, often positively impacting the surgeon much more than the local hospital or population. More recently, the concept of institutional “twinning” has become prevalent, where a Western university (often a single department) partners with a similar institution (or department) within an LMIC and develops academic relationships in surgical expertise and/or research(32, 33). This is the case for the McGill University Graduate Programs in Global Surgery and Global Health and several other examples (34, 35).

A newer model is one of developing surgical training programs within LMICs for training local physicians as surgeons to care for their own people in their own country. This model seems more durable and might become the standard practice for the future. These individuals are much more culturally aware, communicate in local dialects, become excellent

role models to local young people, and may not suffer the frequent psychological strains that affect expatriates. Examples include the Pan African Academy of Christian Surgeons (PAACS) that began general surgery training programs in Africa in 1996. PAACS now consists of eight 5year programs, training a total of 43 residents in six countries, with a stated goal of training 100 African surgeons by 2020(36). Each of these programs has full accreditation from the College of Surgery of Eastern, Central and South Africa (COSECSA) and/or the West African College of Surgeons (WACS). Additional training programs became active in Malawi, and Tanzania, and later, may start in Togo, Nigeria, Zimbabwe and the Democratic Republic of the Congo. There is enormous, unmet additional need for training programs in every specialty, but particularly in Obstetrics and Gynecology, Anesthesia and Orthopedic trauma, Pediatric surgery.

1.3. SURGICAL BURDEN AND NEED ACROSS THE GLOBE

In recent years the international medical community has come to recognize that at least 5 billion people worldwide have no access to essential and emergency surgery when required (26). In terms of the burden, surgically treatable conditions comprise between 11-32% of the world's overall burden of disease and account for an important proportion of the world's disability-adjusted life years (DALYs) lost each year. This came to a head in 2015 as a result of several major events listed above, especially with the release of the Lancet Commission Report on Global Surgery. The Lancet Commission drew together 25 Commissioners from throughout the world, along with many other consultants, to develop reports on the extent of the un-met need for essential and emergency surgery worldwide.

These reports showed that more people die each year due to the inability to access surgical care than from human immunodeficiency virus/acquired immune deficiency syndrome (HIV/AIDS), tuberculosis, and malaria combined (2, 37).The highest incidence results from (in decreasing order) accidental trauma (bone and soft tissue injuries), tumors,

obstetrical complications (including obstetric fistula), cataracts and glaucoma, perinatal conditions and congenital anomalies, male circumcision (prevention of HIV transmission) and a large group (19%) under the heading of "Other," which includes a variety of diagnoses such as hernia, gallbladder disease, infections requiring surgical care, etc.(3, 37-39). It estimated that in 2010, 16.9 million people unnecessarily died because of lack of access to timely surgery. When surgery is accessed, it is often poorly performed, and this can result in significant personal morbidity and mortality. In terms of mortality in SSA the most common surgically treatable conditions contributing to premature deaths or morbidity of populations include obstructed labor (40, 41); injuries (42, 43); intra-abdominal emergencies (44); correctable congenital anomalies, such as clubfoot and cleft lip or palate(45, 46), symptomatic hernias(47); cataracts(48); osteomyelitis(49, 50); and otitis media (51).

Surgical care can result in potential economic loss for communities: 33 million people per year suffer catastrophic poverty because of the fees they pay for surgery, when it is accessible, and this often occurs in some of the poorest countries and communities. There is a growing belief that there is a need to improve appropriate surgical access and overcome the delays in care. Improving access to surgery can raise a nation' GDP by 2% (2).

There are great discrepancies between the presence of large populations requiring surgery and the amount of the skilled workforce able to provide surgery. High-income countries have ten times as many operating theatres per person, and 14 to 100 times as many surgeons as do low-income countries (2, 52). Of the 313 million surgical interventions carried out each year, only 6 % are done in the world's poorest countries, where a third of the world's people live. One hundred and forty-three million additional surgical interventions are needed in LMICs globally each year. Also, 81 million people face catastrophic expenditures either paying for surgical care or for non-medical costs of accessing surgical care. If LMICs were to scale up surgical capacity at the rates achieved by the current best-performing

LMICs, 2/3 of countries would be able to reach a minimum of 5000 surgical interventions per 100,000 population (2).

1.4. SURGICAL BURDEN AND NEED IN AFRICA

1.4.1. Multi-level barriers to surgical care: limited infrastructure, workforce and finances.

One third of the global population who currently lack access to surgery reside in Sub-Saharan African nations(1-3). This lack of access to surgery varies widely across Africa and is the result of the co-existence of the 3 main barriers faced by patients of this continent: delay in seeking care, delay in reaching care, and delay in receiving care. Most African countries still lack the required infrastructure, workforce and financing needed for the delivery of adequate surgery and anesthesia. As a result, in Africa, 95% of the population does not have access to surgical care(1, 53).

Sub-Saharan Africa disproportionately suffers the gross inequalities existing in the rates of surgical care. Of the estimated 234 million surgeries performed per year around the world, only a quarter are performed in Sub-Saharan Africa and other LMICs despite the fact that they make up 70 % of the world's population(3). The lowest annual rate of surgeries is 148 per 100,000 in Ethiopia and the highest is in Australia with 28,907 surgical interventions per 100 000 population. These surgical rates per 1000 000 population are respectively 2,732 in China, 21,190 in Luxembourg, 21,197 in Denmark, 20,712 in Belgium(3, 54-56). These examples prove that the lack of access to surgical and anesthesia care in Africa remains a substantial concern.

The surgical infrastructures that are needed to provide essential surgical care are insufficient in SSA. Ninety percent of the population of sub-Saharan Africa has access to roughly one operating theatre per 100 000 people, and the few theatres that do exist have limited capacity to provide safe surgical care. For instance, up to 70% lack pulse oximetry, an

anesthetic monitoring standard(57, 58). Available data show that stable electricity is present in only 35% of 231 district hospitals assessed in sub-Saharan African countries (59). Running water is consistently available in 20% of hospitals surveyed in a county in Sierra Leone (60); oxygen sources are only available in 40% of surgical hospitals (61). Furthermore, only 64% of 11 surveyed county hospitals in Liberia had an in-house blood bank (61).

Several studies have shown that the availability of workforce is one of the single statistically significant determinants of the amount and quality of surgical services delivered in a country (62, 63). The huge population living in SSA and other LMICs is served by only 12% of the world's surgical workforce. This is a huge inequity between the need for surgery and the available trained surgical workforce. There is a shortage of trained anesthetists overall in Africa, but the needs vary in severity in different African countries. The World Federation of Societies of Anesthesiologists has set an interim goal to have 5 physician anesthetists per 100 000 population in Africa (64). This goal is still far from being reached because currently in sub-Saharan Africa, there are often less than 1 anesthesiologist available per 100,000 population(65). Developed countries, such as the United States of America and Germany, have 20 to 30 anesthesiologists for every 100,000 people. Zimbabwe has one of the highest numbers of anesthetists in SSA, while some countries have no physician anesthetists-like Somalia and the Central African Republic (66, 67). These countries do have nurses with basic training to anesthetize patients — 32 in Somalia (or 0.2 per 100, 000), for a population of about 15 million; 24 in Central African Republic for a population of 5 million (or 0.5 per 100,000)(64).

1.4.2. Surgical disease patterns specific to Africa

The prevalence of untreated surgical conditions at the community level has been estimated in some African countries. In Sierra Leone, 25% of respondents reported a surgical condition needing attention and 25% deaths of household members in the previous year

might have been averted by timely surgical care(68). In Rwanda, 41.2% of the population has had at least one operative condition during their lifetime, and 14.8% had an operative condition during the previous 12 months preceding the survey(69). In Uganda, the prevalence of untreated surgical conditions varied between 2-45% (70). On average 330 000 women die every year from childbirth; 15-20% of whom can be saved through safe essential surgical care. Two million women live with untreated obstetric fistula; almost all in low resource African settings. Five million people die from injuries every year; more than 90% of whom are found in low resource settings.

Inguinal hernia in the Ghanaian general population is 3.15% and the annual incidence of symptomatic hernias is 210 per 100,000 population. At the estimated Ghanaian hernia repair rate of 30 per 100,000, a backlog of 1 million hernias in need of repair develops every 10 years. The cost of repairing all symptomatic hernias in Ghana is estimated at US $53 million, and US $106 million would be required to eliminate hernias over a 10-year period. Nearly 5 million DALYs would be averted with the repair of prevalent cases of symptomatic hernia in Ghana(47).

Sub-Saharan Africa has an estimated 24% of the world's disabled population (71). This is due in part to that fact that Sub-Saharan Africa is one of the most conflict- affected regions in the world today(71), but also because of the backlogs of unmet corrective surgery and rehabilitative care for the disabled. More than six decades of conventional warfare, genocide, ethnic and regional based conflict and factional warfare have contributed to enormous human suffering, the displacement of families, civilian casualties, violence, economic instability and loss of infrastructure with an ever-worsening economic crisis. All these factors combined have led to this high prevalence of disabled people. In Africa, landmines are responsible for the killing, maiming and injuring of more than 12,000 people each year(71). There are an estimated 10–15 million landmines in Angola alone, 5.5 mines

for every child. Angola has the highest rate of amputees in the world, with more than 77,000, mostly women and children, injured by landmines(72). A typical landmine injury will result in the destruction of limbs, soft tissue injuries to the trunk, and facial injuries leading to deafness and blindness. Continuing landmine explosions remain a legacy of the preceding armed conflict (73). Unfortunately, injured Africans are not able to afford the costs of artificial limbs. In fact, a landmine can cost $3 - $10, and its removal $300 - $1000 (71).

Africa is the land for acute and chronic malnutrition, which both hinder wound healing. Nutritional studies in war-torn Mozambique and Ethiopia have shown stunted growth in up to 53% (chronic or long-term under-nutrition) and severe wasting in up to 7% (acute nutritional deficiency) of children less than 7 years of age(74). Twenty million people suffer from treatable blindness caused by cataracts. Millions of people suffer from correctable congenital deformities such as cleft lip and clubfoot. In 2010, the global burden of cleft lip/palate was estimated to be 1,143,269 patients but due to several factors Africa carries an important proportion of this backlog. Using estimates from 4000 new cases yearly for a population of 86 730 000 in 2019 (85, 281, 024 in 2018), and an average incidence of 1: 700, and the population of Africa in 2018, the backlog of cleft lip and palate can be extrapolated to 60 720 new cases across Africa each year. Many African children born with cleft lip/palate almost enter their adolescence with this disability since the mean age at primary surgery was documented to be 9.8 years in Africa(75).

The mortality related to surgical conditions is very high in SSA. In 2010, there were 896 000 deaths, 20 million years of life lost and 25 million disability-adjusted life-years from 11 emergency general surgical conditions reported individually in the Global Burden of Disease Study. The most common cause of death was complicated peptic ulcer disease, followed by aortic aneurysm, bowel obstruction, biliary disease, mesenteric ischemia, peripheral vascular disease, abscess and soft tissue infections, and appendicitis. Because of

the much larger population, 70 percent of deaths occurred in LMICs. Between 1990 and 2010, deaths from vascular disease rose from 15 to 25 percent of surgical emergency-related deaths in Africa and other LMICs. Unfortunately, surgical capacity to address this burden is suboptimal in these regions due to a combination of many barriers(44).

Finally, because of the poverty, patients who do receive appropriate surgical care often risk impoverishment secondary to out-of-pocket payments(76). It is important to note that children pay a huge burden of unmet surgical needs in LMICs and in SSA(77).

1.5. SURGICAL BURDEN AND NEED IN THE DRC

The DRC is a low-income African country, crossed by the Equator and sharing borders with nine countries (**Appendix 8**). The gross domestic product is 300 USD per capita (21) and 74% of Congolese live under the limits of poverty. The DRC is ranked as the 13th poorest country in the world (78). Because of its population size and the severity of the health status, the DRC represents an enormous concentration of surgical morbidity and mortality in the center of Africa. With an estimated 86.7 million inhabitants, DRC is the third most populous country in Sub- Saharan Africa (after Nigeria and Ethiopia) and the 16th most populous nation on the globe (79).

In 2004, the DRC was classified among the 57 LMICs that are in healthcare human crisis by the WHO, having fewer than 228 physicians, nurses, and midwives per 100,000 people(52). There is a shortage of surgical and anesthesia workforce in the Democratic Republic of the Congo (80, 81). There has not been a systematic count of the number of certified surgeons in the country, but data obtained from hospital managers across the country has shown a shortage of surgeons. The few that exist are general surgeons, with a huge lack of specialists (36, 82, 83).

In the DRC, populations have poor access to surgical care due to financial constraints. In fact, 90% of the Congolese population does not have health insurance, and this may result in delays to seek healthcare (6, 84, 85). Recurrent armed conflicts, isolation and culture are other barriers to care (86, 87). Surgical services in hospitals are poorly coordinated and erratic, and there is significant gender-based differences in treatment(12). Recent reports show that 90,000 people are estimated to die yearly of surgical problems in DRC (7), and most do not have access to treatment(69).

The DRC has been involved in one of the biggest humanitarian crises for the last 25 years including the presence of millions of refugees from neighboring countries, the volcanic eruption, and recurrent armed conflicts. The conflict continues and has affected the Ebola response. Decades of armed conflict in the country have also resulted in one of the world's largest internally displaced populations, with a significant burden of neglected surgical disease, trauma and gender-based violence. This humanitarian crisis has been compounded by a severely under-resourced health care system and limited access to appropriate care(12).

Armed conflicts worsen access to and delivery of care, as well as mortality and morbidity related to surgery in several ways. It is estimated that during war 5% of children's deaths results from direct trauma and 95% from starvation or illness, and that many are left with permanent disabilities that will require surgical interventions. Those that are not lost, abandoned or killed in combat die or chronically suffer from infections, which multiply the negative outcomes of surgery. An estimated 1 – 3% of children presenting for trauma surgery or medical care had radiological or other indirect signs of HIV infection(73).

The populations in war-torn areas sustain bullet, machete and shrapnel wounds. Other children are burned or sustain injuries related to motor vehicle accidents(73). Mutilated extremities commonly require amputation. Mismanagement of the initial injury may have devastating consequences. Many children require later surgery to correct healed but

malformed limbs. Landmines cause many medical catastrophes and have led to an increased need for war-related surgery. Program audits for Médecins sans Frontières operations during 2008 in war-torn Eastern DRC found that only 30% of surgical interventions were due to violence-related injuries; most interventions were for obstetric emergencies and accidental trauma (83). The commonest surgically treatable conditions contributing to premature deaths or morbidity of populations are likely similar to the patterns described in other SSA countries (40-51, 71).

1.6. ACTIONS TO DATE ACROSS THE WORLD AND IN AFRICA

A global campaign has begun to provide universal access to safe and affordable surgical and anesthesia care when needed in some of the poorest parts of the world. This campaign is made possible because of the support of the WHO which has made surgical care a priority and because surgery is now internationally recognized as integral to primary health care for the improvement of population health(88) (90). Surgery is credited with providing a critical role in achieving the United Nations Millennium Development Goals 4,5,6 : reducing child mortality, improving maternal health and combatting HIV/AIDS and other diseases (90) (89).

Strong evidence also shows that investing in surgical interventions in LMICs is as cost effective as more widely-recognized interventions such as vitamin A provision or the promotion of vaccine use (2, 90). Access to safe affordable surgery and anesthesia care when needed affects not only those requiring emergency general surgery but also affects maternal and child health, as well as the treatment of trauma and other emergencies.

Globally, it is now accepted that every human being is entitled to high quality, lifesaving, safe surgical, obstetric, trauma and anesthesia care performed in their communities. It is believed that significant improvements in surgical care and anesthesia,

which save lives and prevent life-long disability or life-threatening complications, can be sustainably and affordably integrated within existing health systems.

There are different actions and teams working to improve access to surgery across the globe and in Africa: the Emergency and Essential Surgical Care (EESC) of the WHO, the G4 Alliance for Global Surgery (G4-Alliance), Global Initiative for Children's Surgery (GICS), the World Federation of Societies of Anesthesiologists (WFSA), African governments, International NGOs, training programs including the College of Surgeons East, Central and Southern Africa (COSECSA), the West African College of Surgeons (WACS (91)) and others(64, 92-94). The EESC has published the book Surgical Care at the District Hospital (SCDH) in seven languages and produced the Integrated Management of Emergency and Essential Surgical Care (IMEESC) toolkit, a Compact Disc that contains the SCDH, a long list of best practice protocols, multiple point of contact posters, and several instructional videos(95). Ongoing research within EESC includes a large database of surgical hospital capacity throughout the developing world (>700), capacity building through educational programs, and periodic follow-up of existing programs.

The Lancet Commission recommended that research champions gather enough evidence to continue having the evidence necessary at country levels for supporting the efforts aiming to convince the governments to include surgery in their NSOAPs. Ongoing research should focus on the six core indicators for monitoring universal access to safe, affordable surgical and anesthesia care, namely: timely access to essential surgical care, specialist surgical workforce density, surgical volume, perioperative mortality, protection against impoverishing expenditure and protection against catastrophic expenditure (2).
Its goal is to advocate for an increased awareness of the issues that surgery faces 'on the ground' in resource poor and workforce poor LMICs (2). The Commission also demonstrated that even a moderate density of 20 specialist surgical, anesthesia, and obstetrical providers

per 100,000 population (compared with above 100 in many high-income countries) and a moderate volume of 5000 surgical procedures per 100,000 population (compared with above 10,000 in most high-income countries and even above 20,000 in some) would be enough to assure most of the needed surgical procedures. The Commission also developed a template national surgical plan (2).

The LCoGS suggested that, in dealing with these inequities of care, it is important to include surgery when strengthening health systems, to deal with workforce issues, to provide sustainable financing of surgical care systems, and to improve the quality and safety of surgery and anesthesia. The LCoGS encourages the recording of appropriate metrics of surgical care to measure the surgical capacity that can be built (2).

The Global Initiative for Children's Surgery has put in place the Optimal Resources for Children's Surgery document which make the standards and guidelines for infrastructure, equipment, pediatric surgery delivery in LMICs (96). The World Health Organization has recommended Sub-Saharan African governments to put in place urgent solutions and planning initiatives to help address this huge problem by prioritizing surgery in their National Surgical Anesthesia and Obstetric Plans with the target of 80% coverage of surgical needs by 2030(4, 10, 97-99).

In 2015, Zambia became the first African country to have a National Surgical Obstetrical and Anesthesia Strategic plan (100). In 2018, more countries including Ethiopia, Senegal, Zambia and Rwanda launched their NSOASPs. Still in the process are Madagascar, Nigeria Sierra Leone, Sudan, Zimbabwe, Malawi, Botswana, and Namibia(101).

Countries that do not have enough surgical workforce have utilized medical officers and non-physician surgery providers for less complex emergent essential surgical procedures especially in rural areas. They have played an important role in providing surgery especially

in several conflict zones across Africa since the most common surgical intervention, emergency obstetrical care, can with adequate training and supervision be safely performed by non-doctors (102). In low-income settings such as Niger, Malawi, and Mozambique, surgical task-shifting has resulted in an increased provision in essential surgical services (103-105). Similarly, most of these interventions were safely performed with spinal anesthesia or ketamine which are safer types of anesthesia to administer for nurse-anesthetists or anesthesia providers that are informally trained. The potential for non-surgeons to manage a substantial proportion of surgical needs in resource-limited conflict areas is an important consideration given the lack of local surgeons in resource-limited settings and the danger posed to expatriate surgeons (e.g. higher risk of kidnapping in certain contexts). In Somalia, where MSF expatriate surgeons are not allowed due to insecurity, some surgical procedures are performed by non-surgeons with an operative mortality <1%. Studies from other settings demonstrate that the training of general doctors with surgical skills and nurse anesthetists is possible, even in a conflict zone (105, 106).

1.7. ACTIONS TO DATE IN THE DRC

Currently, the DRC does not have a specific NSOAP (106, 107). However, the national health plans 2014-2020 have included a few surgical targets with the focus being to decrease the mortality and morbidity due to Caesarean section, those related to surgical site infection, road traffic accidents, prostate, breast and cervical cancers by 2020(5). While this is a good start, the ideal would be to include all the essential surgical conditions in a NSOAP. The Ministry of Health is committed to put a NSOAP as part of the next Congolese National Strategic Health Plan which will be developed in 2019/2020 and this study will contribute to it and will allow the prioritization of the other essential surgical conditions (80).

The country comprises 26 provincial divisions of health, which are further subdivided into 516 health zones. Out of the 516 health zones, 316 health Zones (76%) have a referral

general hospital and 25% do not have a single referral hospital. The DRC health system is centered on health zones which is a geographic space covering populations of 150 000 generally (range: 70 000 -500 000). Health zones in the DRC are the equivalent of health districts in other countries and ‘’ district hospitals ‘’ are called ‘’zone referral hospitals’’ (ZGH). Each zone is served by a ZGH which is a level one hospital and is the main surgical center in the area for emergencies and essential surgery. The ZGHs perform emergency surgeries with at least one physician provider with exposure to general surgical practice. At the top of the referral pyramid are major referral hospitals, which are the provincial referral hospitals, teaching hospitals and national referral hospitals(5). The delivery of complex non-essential surgery occurs mainly in major provincial or national hospitals in large cities. Between 55% and 80% of the DRC population lives in rural areas where access to specialized surgery is more difficult (5, 85).

Several charities or humanitarian platforms contribute to the delivery of surgery and have played a major role by serving as training hospitals. Examples include Médecins Sans Frontières and the Red Cross for conflict related emergencies, Smile Train and Operation Smile for cleft lip and palate, the Fistula Foundation and the United Nations Population Fund (UNFPA) for vesico-vaginal fistulas and other women surgeries, Christian Blind Mission, Cure International for clubfeet etc. The contribution of externally funded faith-based hospitals to deliver health services in general and for surgery is large (108). In 2014 for example, 47% of the budget for health was from external donors(6).

In terms of training of physicians, the country had three medical schools with surgical residency until the 1990s: The University of Kinshasa, University of Lubumbashi and University of Kisangani. In 2019, there are several medical schools (at least one in each of the 26 provinces)(109). Since 2014 Panzi hospital in Bukavu was approved to start the fourth residency program for general surgery, obstetrics and anesthesia. In January 2016, the

COSECSA surgical training program started at HEAL Africa Hospital in Goma , the capital city of North Kivu (93). The surgical residency program duration is 5 years (minimum 4 years). It is divided into the first part (2-3 years) during which the junior resident rotates in general surgery, trauma, orthopedics, urology, pediatric surgery. In the second part (2 years), the senior resident continues rotations, including in thoracic, cardiac surgery, maxillo-facial etc. At the end of the training, the general surgeon is equipped in all fields and is expected to practice as an orthopedic-trauma surgeon, pediatric surgeon etc. Unpublished sources estimate that on average 10 general surgeons graduate per year in the country. There is a scarcity of data regarding fellowship programs in the country(110).

Because of the scarcity of trained surgeons, especially in rural areas of the DRC, non-physician surgery providers have played an important role in providing surgery in many underserved rural areas. This is especially the case for cataract surgery, dental procedures, cesarean-section and recently trauma and orthopedic reduction of bone fractures. However, we did not find reliable data assessing their impact in the country, partly because for years the Government of the DRC never recognized this group as an official professional body. Recently, the DRC has integrated traditional healers and orthopedic officers as a recognized body of health providers, although their role to provide surgery is limited to ceremonial circumcision in the remote areas.

In order to alleviate the consequences of a limited orthopedic surgical workforce, HEAL Africa started the training of orthopedic officers. This training has been approved by the National MOH and each year 5-10 graduate orthopedic officers are deployed in the different provinces, where they are the main workforce in essential trauma and orthopedic care including the Ponseti method for clubfoot, fracture reduction, and external fixation of fractures(93, 111). Non-physician providers also play a major role in dental care and cataract

surgery. The training of non-physicians in general surgery is at its early stages in some cities and has not been supported by surgeons.

Traditionally, anesthesia is given by non-physician anesthetists. There is a scarcity of data about the training programs in the country. However, with the increasing number of highly trained surgeons and surgical fellows from abroad who can perform more complex surgeries, the limitations of non-physician anesthetists are becoming obvious. That is why the training of physician anesthetists started in the capital city of Kinshasa. As of 2019, three medical schools organize residency programs to train physician anesthetists. However, there is a scarcity of data about the number of graduates(110). In North Kivu, the first physician anesthetist just started in early 2019 at HEAL Africa hospital after graduating from Muhimbili Medical School in Tanzania(112).

1.8. THE REASONS BEHIND THIS STUDY

There is no large scale data on the met surgical needs, the surgical outputs and outcomes, the surgical capacity of hospitals in North Kivu and in the DRC. There is no accurate data about current surgical and anesthesia workforce in the DRC (52), and without this knowledge it is difficult to make appropriate plans aimed at improving national surgical programs. This study evaluates the current surgical capacity of hospitals and the gaps in the delivery of surgeries at various hospital levels. The knowledge gained from these surveys will be invaluable to design strategic interventions and policies aimed at improving surgery delivery and might inform surgical plans in the North Kivu province and in the DRC in general.

Several authors recognize a lack of reliable data on the surgical burden of disease in conflict settings like the North Kivu province in the DRC, except for the surgical care of

trauma (86). This study will be a small contribution on data regarding met surgical needs not only for trauma, but for all essential surgical conditions in a conflict zone.

1.9. THE SECTIONS OF THIS THESIS

This thesis is divided into an introduction, methods, results, discussion, limitations, conclusions and directions for future studies.

1.10 THESIS OBJECTIVES

The principal objective of this study was to assess the surgical capacity of all health sectors in the North Kivu province of the DRC and correlate it with the surgical burden in the province. Additionally, this study aimed to estimate the number of surgical procedures performed in a year and the rate of surgical procedures per 100 000 population that took place in all hospitals from all sectors in North Kivu province in 2017. This knowledge is needed to estimate how to increase the number of surgical interventions per 100 000 Congolese population per year.

1.11.HYPOTHESIS

We hypothesize that the surgical capacity and rate of surgical interventions per 100 000 population is lower in North Kivu compared to other SSA countries. Also, we hypothesize that children are more affected than adults because of the lack of pediatric surgeons and the lack of pediatric anesthetists in the province.

CHAPTER 2.

METHODS

2.1. SETTING

Our study was conducted in the North Kivu province in Eastern DRC. During the study period the population of North Kivu was 8,413,412 and all ratios in the results section will be based on this denominator. Of this population, it is estimated that between 900, 000 to 1.5 million people in North Kivu are internally displaced(113).

In North Kivu, health facilities are classified in various levels, organized in the following order: health centers, zone general hospitals and regional (provincial) referral hospitals. In North Kivu, a total of 33 health zones and 44 hospitals were surveyed, including 4 RRHs and 40 ZGHs. A HZ can have two ZGHs, generally a public ZGH and another non-public hospital with the same level of capacity or higher (**Appendix 9 and 10**). Some HZs in the North Kivu province experienced recurrent armed conflicts and they are referred to as war-zones, in which armed conflict was recurrent and led to regular disruption of service delivery in hospitals and in internal displacement of population from those areas toward other areas.

In terms of ownership, the health sector is comprised of public facilities, charity or faith-based facilities and private (for-profit) facilities. While there are 3 major cities in North Kivu, that is Goma, Butembo and Beni, there has been a shift in the local culture due to funding that has been attractive to local non-public organizations or associations. All private facilities in operation are under a local non-profit organization due to lower taxes, better access to donors etc. Therefore, in this study, we included private hospitals in the category of NGO/FBOs or non-public hospitals. That means we had two categories of hospitals in the ownership variable: public and non-public or NGO/Faith-based, rather than the standard three categories described in most of similar studies.

2.2. SURGICAL, ANESTHESIA AND OBSTETRICAL WORKFORCE

The ZGHs perform emergency surgeries with at least one physician provider who has some skills in essential surgical interventions. Most certified surgical providers (general, obstetric, orthopedic surgeons) are in cities and larger towns. It is estimated that 55-80% of the population lives in rural areas where there is no certified surgery provider (85). Eye surgeries are performed by medical officers and clinical non-physician officers with special training in cataract surgery. Dental-related surgeries are performed by medical officers and clinical officers with specialized training. Some international volunteer visiting surgeons join local efforts, but we did not include them in the study because their contribution is difficult to plan for and to document.

2.3. STUDY DESIGN

The study was a cross sectional survey of all institutions performing surgery in the 33 health zones of North Kivu, conducted from January 1st to December 31st, 2017. Using the WHO- Harvard Program for Global Surgery and Social Change - Surgical Assessment Tool(114) and operating theatre registries, we determined the surgical capacity of hospitals, total number of surgical procedures, surgical rates, types of surgeries, hospital characteristics and outcomes.

2.4. SURGICAL OUTPUTS

Surgical output was defined as the number of surgical interventions performed in the calendar year. We classified surgical interventions as essential or non-essential based on the definition by Disease Control Priorities Project 3rd Edition. ‘’ Essential surgical conditions can be defined as those that meet the following criteria: are primarily or extensively treated by surgical interventions and other surgical care, have a large health burden and can be successfully treated by a surgical procedure and other surgical care that is cost-effective and

feasible to promote globally''. These surgical conditions are also 'essential' because if they are treated, 80% of the surgical needs are covered (80). If an operation is more expensive and/or complex, and has less potential population impact, it is classified as an advanced or non-essential intervention. Based on this definition and by consensus, a group of 44 essential surgical conditions and the interventions have been identified. In most situations, interventions to treat these conditions, for example, cesarean section, can be done at first-level hospital—those that have 50–200 beds, serve 50,000–200,000 people, and have basic surgical capabilities(80, 115).

2.5. SURVEY PROCEDURES

Twelve research assistants who have proven experience in collecting data in the region for the local Medical School and the provincial Division of Health were trained for one week about the study protocol, procedures, ethical principles prior to their deployment. Then they were deployed in the selected 44 hospitals for 3 months. Thanks to enough funding from MUHC Division of general and thoracic pediatric surgery, Queen's University of Kingston Canada and Buffalo University in the USA, we were able to pay incentives to research assistants and a local data coordinator. Data were cross-checked by the local coordinator and the principal investigator for errors in order to allow the research assistants to verify the data and recollect the missing or erroneous data while still on the field. In the eventuality that errors were found after the research assistants have left the field, the hospital managers were called to cross-check and correct the mistakes whenever possible. At each hospital, the following key informants were asked to fill in their respective section of the hospital assessment tool: surgeons, obstetricians, and anesthetists, medical officers working in surgery, in-charge nurses from the operating rooms, wards, critical care, laboratory, radiology, statisticians, accountants and other administration staff. The rest of the data was extracted from operating room registers.

We collected data on patients' demographic and clinical characteristics, hospitals' characteristics, the number and types of surgical interventions performed within the study year, the number of operating rooms, equipment, number of personnel etc. We also divided the procedures into 5 categories according to the specialties: general surgery, trauma-related, non-traumatic orthopedic surgery, obstetrical, and gynecological, and eye/dental-related surgical procedures. The data from both the survey and the registers was entered in Microsoft Excel by the research assistants.

2.6. MODIFIED COMPOSITE SURGICAL CAPACITY SCORE

Capacity assessments serve as surrogates for surgical output in low- and middle-income countries where detailed registries do not exist. We assessed hospitals with the Composite Surgical Capacity Score (CSCS), which is calculated using the guidelines listing resources and capabilities considered to be essential or desirable at different levels within a healthcare system by the WHO and the World Bank Disease Control Priority Project, third Edition(62, 80, 116). The CSCS uses 25 categories of essential surgical care resources to obtain a score between 0 (no essential resource availability) to 75 (full and constant essential resource availability). Each of the individual variables is rated 0 to 3 (0: never available, 1: available less than 50% of the time, 2: available between 50-75% of the time, or 3: available more than 75% of the time). We also reported surgical specialty availability—in-hospital or on-call availability of general surgeons, obstetricians/gynecologists, orthopedic surgeons, etc.

In our study, two resource categories of the score were absent in all the hospitals surveyed, namely skin or skeletal traction and vascular injury. For some resource categories, not all elements within each category were recorded either because they did not exist or because the data was of very poor quality and difficult to collect. As unrecorded elements cannot be determined in any way, we assigned a 0-3 scale to each of the elements available on record and averaged the scores of all elements to give a final score for each category. Then

we summed the 23 categories to generate a modified composite capacity score, and the modified CSCS comprised 23 variables generating a maximum score of 69. The final score defining access to essential resources and capability in the surgical system was defined as always (100% of the time), almost always (76–99% of the time), most of the time (51–75% of the time), sometimes (26–50% of the time), rarely (1–25% of the time), and never (0% of the time)(62, 116).

2.7. DATA ANALYSIS

The key outcome variables were the number of surgical interventions performed by all hospitals in 2017, as well as the rate of surgical interventions per 100,000 population and the Composite Surgical Capacity Score of hospitals.

The hospital characteristics interrogated were: location is a war zone, urban or rural, ownership, level of facility, availability of workforce (general surgeons, obstetricians, orthopedic surgeons, and anesthetists), availability of pharmaceutical drugs used for surgery, availability of electricity, number of hospital beds and operating rooms. Patient-related clinical characteristics included age, sex, elective/emergent intervention, essential/non-essential interventions, and coverage by insurance.

The relationship between the Composite Surgical Capacity Score and surgical volume was investigated through a Pearson's correlation test. All analyses were performed using SAS version 9.4, and graphical reports produced through R Studio and Excel 2010.

2.8. ETHICAL CONSIDERATIONS

All data were anonymously recorded. No patient identifiers were collected. All patients' details were handled with confidentiality. At each hospital, consent was obtained from hospital authorities prior to accessing data sources and collecting data.

This study was approved by the ethical committee of the DRC National Ministry of Health (No. 059 CNES/BN/PMMF/ 2017), the approval of the Université Libre des Pays de Grands Lacs (ULPGL) Medical School of Goma and by the McGill University Health Center Research and Ethics Committee (No.2018-4322).

CHAPTER 3.

RESULTS

3.1. HOSPITAL INFRASTRUCTURE CHARACTERISTICS

The total dataset included 45321 patient records. After excluding 261 cases of incorrectly recorded date, our total study sample size was 45060. Forty-four hospitals were assessed, but only 43 were included in the assessment of surgical volumes and 42 in the assessment of surgical capacity. During the study period, of the 43 facilities included, 39 were zone general hospitals and 4 provincial/regional hospitals. Of these facilities, 24 (56.8%) were faith-based/NGO hospitals and 19 (43.2%) were public hospitals.

There was a total of 6, 580 hospital beds in all facilities combined, averaging 78.3 beds per 100 000 population. Among the hospital beds, 22% were being used for surgery purposes, which averaged 17.2 surgical beds available per 100 000 population. These surgical beds were distributed as follows: 1231 beds (85%) in ZGHs and 216 beds (15%) in RRHs. 557 surgical beds (38.5%) were owned by public hospitals and 890 surgical beds (61.5%) by non-public hospitals.

A total of 98 operating theaters are available in North Kivu, which averaged 1.16 ORs per 100 000 population. The distribution of operating rooms is as follows: 83 ORs (85.14%) in ZGHs and 15 ORs (14.86%) in RRHs. 63 functioning ORs (64.3%) were in faith-based /non-public hospitals and 35 (35.7 %) in public hospitals. The average number of beds and operating rooms equipped in each type of facility is compared in **Figure 1 below and Appendix 1**.

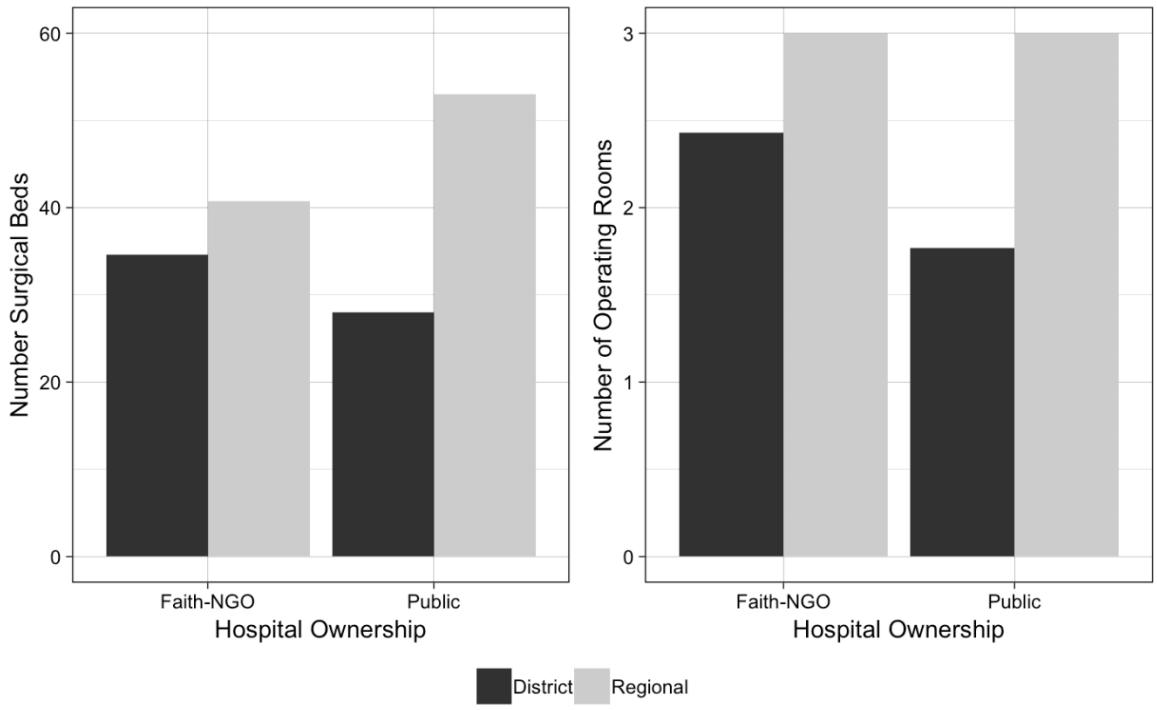

Figure 1. Average facility Characteristics of 43 hospitals in North Kivu.

3.2. SURGICAL INTERVENTIONS NUMBERS AND RATES

During the study period, a total of 45,060 surgical interventions were performed in North Kivu, which averages to 1,048 (range: 134-4888) surgical interventions per facility. Of these surgical interventions 40% were done in public hospitals and 60% in faith-based/non-public facilities. The median number of surgical interventions per year was 949 in public hospitals and 1,126 in non-public hospitals. The number of surgeries in 2017 calendar year was 36,395 (80%) in ZGHs and 8,665 (20%) in RRHs. There was a significantly statistical more patients aged 18 years and more compared to the patients aged below 18 years in ZGHs ($p< 0.001$), but the number were the same in RRHs ($p= 0.2384$). This means that most of pediatric surgeries take place in RRHs.

Seventy-eight percent of the patients who received surgery in our study period were women, and 22% were men. The average age of all patients was 28.4 years. There were 40,205

(89.2%) surgeries done among adults and 4829 (10.7%) among those under 18 years of age. The age was not specified in 26 patients' records (0.1%). The overall rate of surgeries in North Kivu was 535.6 per 100 000 population. The results for the surgical procedures performed per facility level and by age group in 43 hospitals performing surgery in North Kivu during the study period are summarized in **Figure 2 and Appendix 2**.

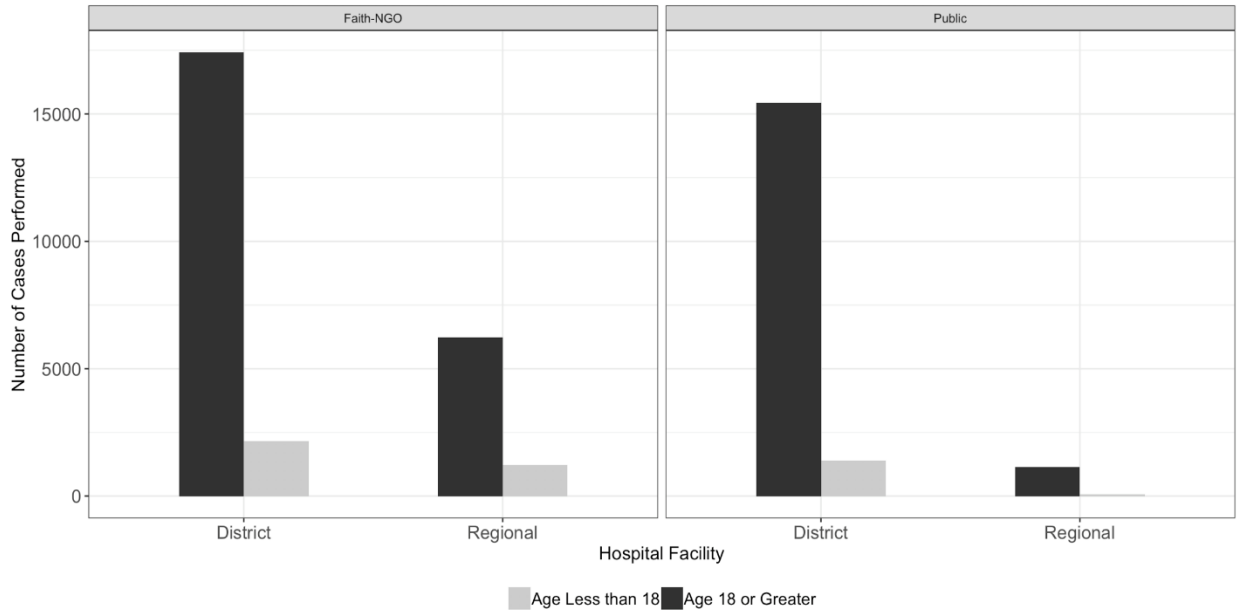

Fig 2. Number of surgical procedures per facility level and by age group in North Kivu

3.3. ESSENTIAL AND NON-ESSENTIAL INTERVENTIONS

Essential interventions represented 98.4% of all interventions performed during the study period. There were only 709 non-essential interventions (1.6%), consisting of uterine myomectomy, colporrhaphy, hip prosthesis, thyroidectomy, mastectomy, esophagoplasty and endoscopic third ventriculostomy plus plexus choroid cauterization for hydrocephalus. The results for the distribution of essential versus nonessential interventions in 43 hospitals performing surgery in North Kivu during the study period are summarized in **Fig.3**.

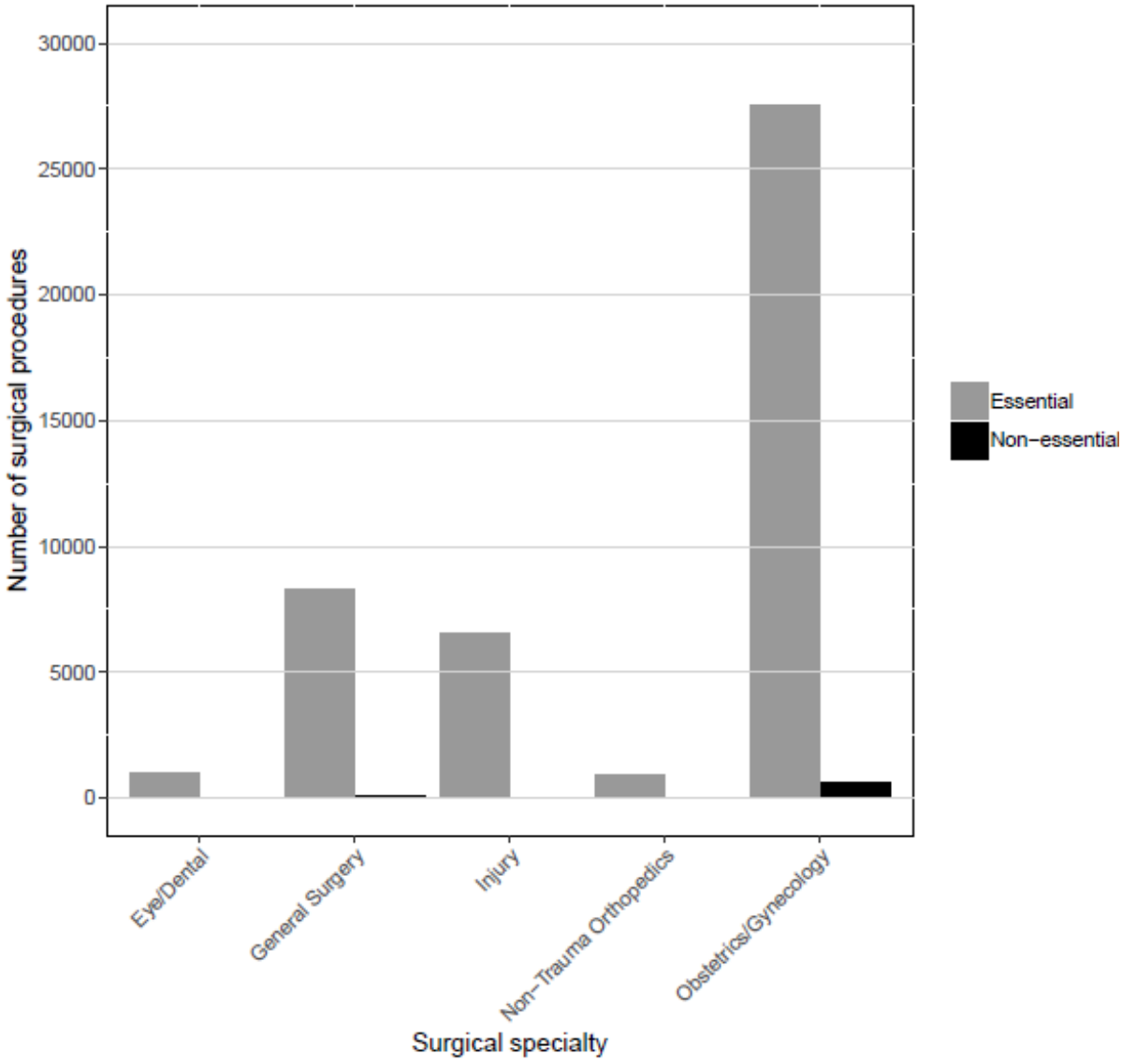

Figure 3. Distribution of essential vs. Non-essential surgeries by surgery category in North Kivu.

By specialty, 63.7% of all procedures were obstetrical and gynecological, 18.1% were in the general surgery category, 13.9 % trauma-related, 2.1% non-trauma orthopedics and 2.3% eye-dental related. The obstetrical and non-obstetrical procedures were respectively 60% and 40%. Cesarean section was the most common obstetrical intervention and alone represented 58.5% of all the interventions. The non-obstetrical commonest interventions in adults were trauma-related interventions (14.6%), hernia repair (5.2%), laparotomy (2.8%), mass excision (2.8%) and appendectomy (2.3%). The commonest trauma-related interventions were wound

debridement (10%) and fracture reduction and fixation (3%). The distribution of the 5 types of interventions are displayed in **Figure 4.**

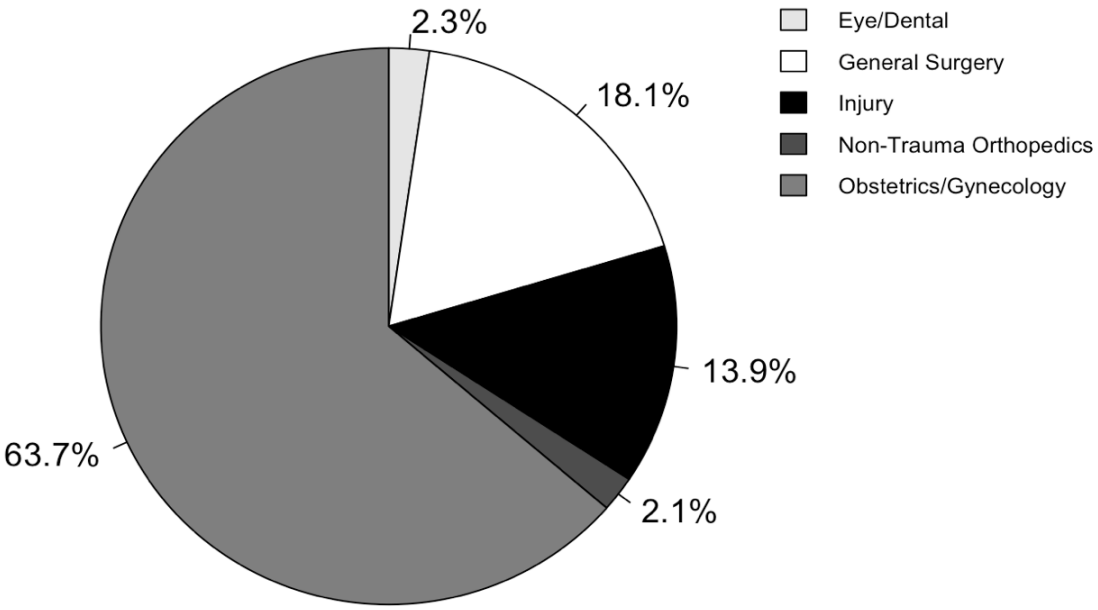

Fig 4. Distribution of types of surgical interventions in North Kivu province

3.4. EMERGENT AND ELECTIVE SURGICAL INTERVENTIONS

Two-thirds (61.2%) of interventions performed in the 43 hospitals were emergencies, while elective interventions represented 38.8%. The most common emergency surgeries were Cesarean section and wound debridement. The most common elective surgeries were colporrhaphy, repair of obstetric fistula, and myomectomy. The results for the distribution of emergent versus elective interventions in 43 hospitals performing surgery in North Kivu during the study period are summarized in **Fig 5.**

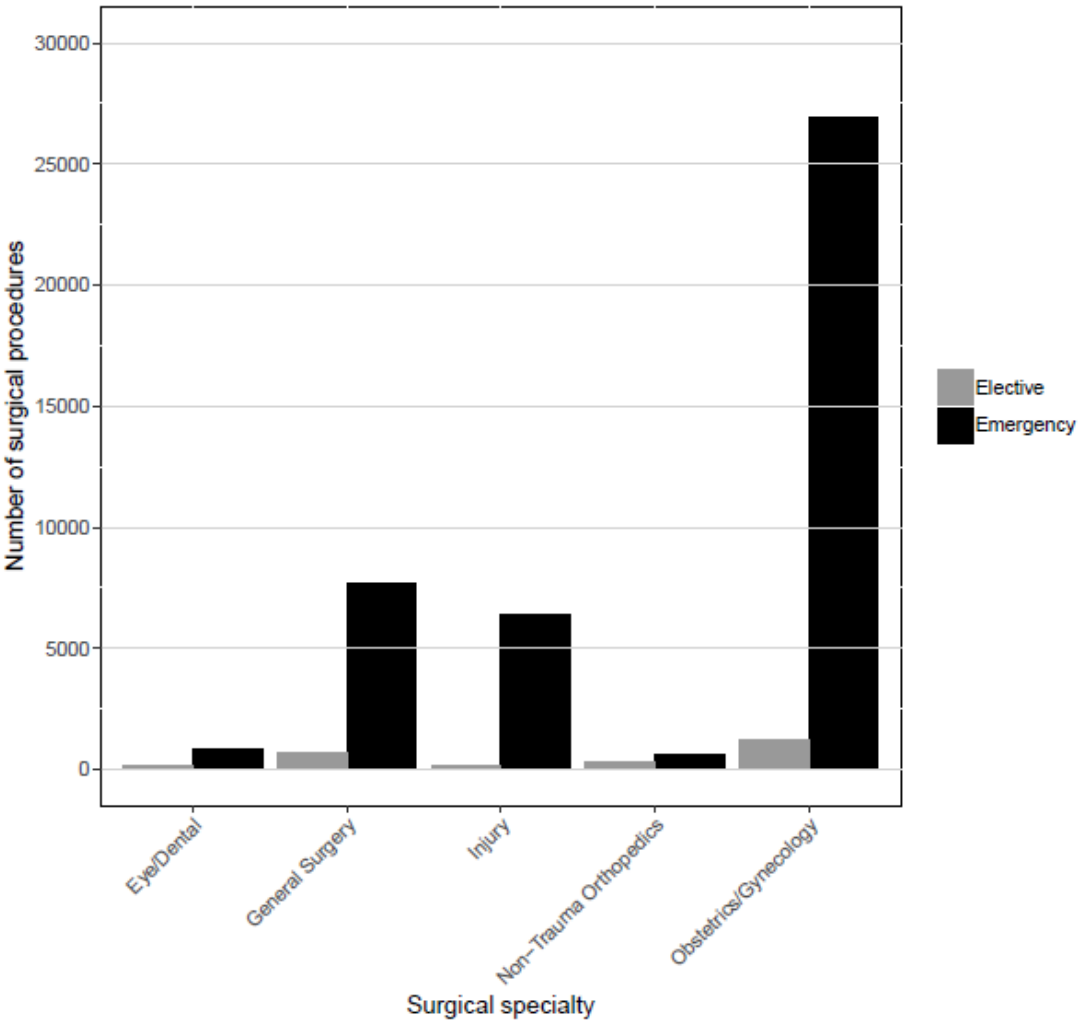

Figure 5. Elective vs. emergent surgical interventions in North Kivu.

3.5. SURGICAL WORKFORCE CHARACTERISTICS

During the study period, the province had 23 working surgeons, consisting of 9 general surgeons, 5 orthopedic surgeons and 9 gynecologists/obstetricians. This translates to a per 100 000 population density of 0.1 for general surgeons, 0.1 for obstetricians and 0.06 for orthopedic surgeons. The surgeon, obstetrician and physician-anesthetist (SAO) provider density was 0.27 per 100 000 population. All anesthesia procedures were done by nurse-anesthetists and in the above SAOs rate there is no single physician anesthetist. Of note, 5 surgeons (22%) worked in public hospitals and 18 (88%) worked in non-public hospitals.

Another 181 general medical officers also performed surgery in the province corresponding to a rate of 2.15 surgery-performing general doctors available per 100 000 population. All hospitals have general doctors available to perform surgery, but only 8 hospitals are staffed with specialized surgeons and 6 hospitals have gynecologists/obstetricians available. The results for the workforce characteristics of each type of facility in North Kivu province during the study period are displayed in **Figure 6 and Appendix 3.**

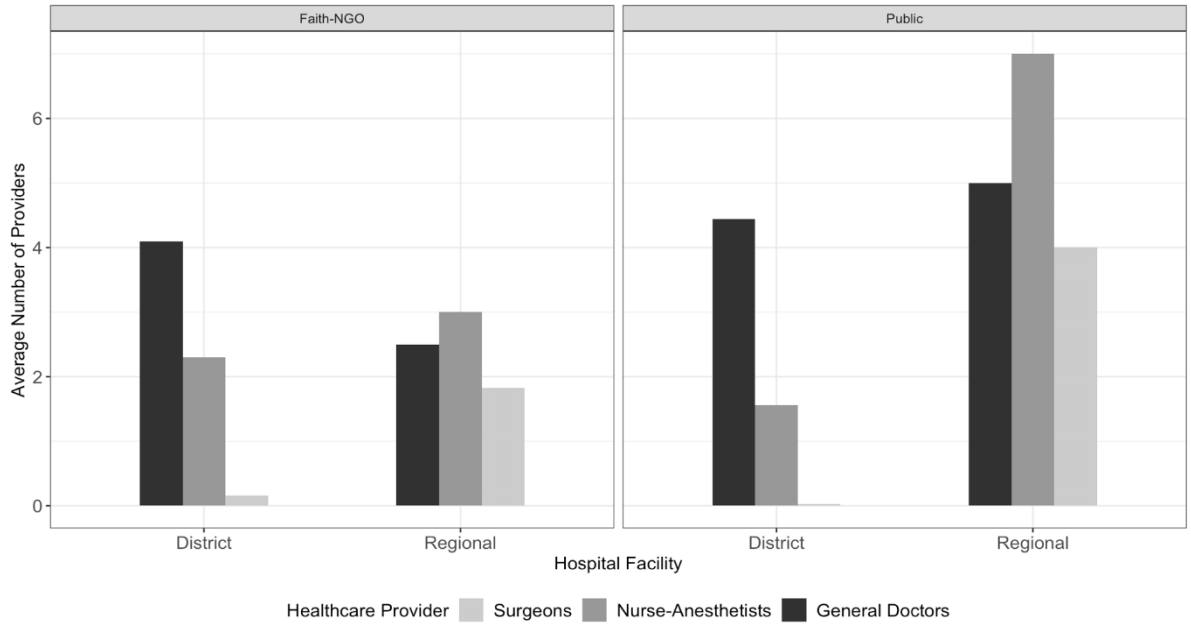

Figure 6. Average surgery and anesthesia providers statistics in 43 hospitals performing surgery in North Kivu.

3.6. ANESTHESIA PROVIDERS AND TYPES OF ANESTHESIA

There were no specialized physician anesthetists in the province. All 96 anesthesia providers were non-physician anesthetists (**Appendix 3**). The rate of non-physician anesthetists was 1.14 per 100 000 population. The anesthesia types in the facilities surveyed were as follows: 13% of procedures were done with inhalation general anesthesia with intubation, 36.7% with ketamine, 46.3% with spinal anesthesia and 4% with local

anesthesia/block. The distribution of types of anesthesia techniques used on surgery patients in North Kivu during the study period is displayed in **Figure 7**.

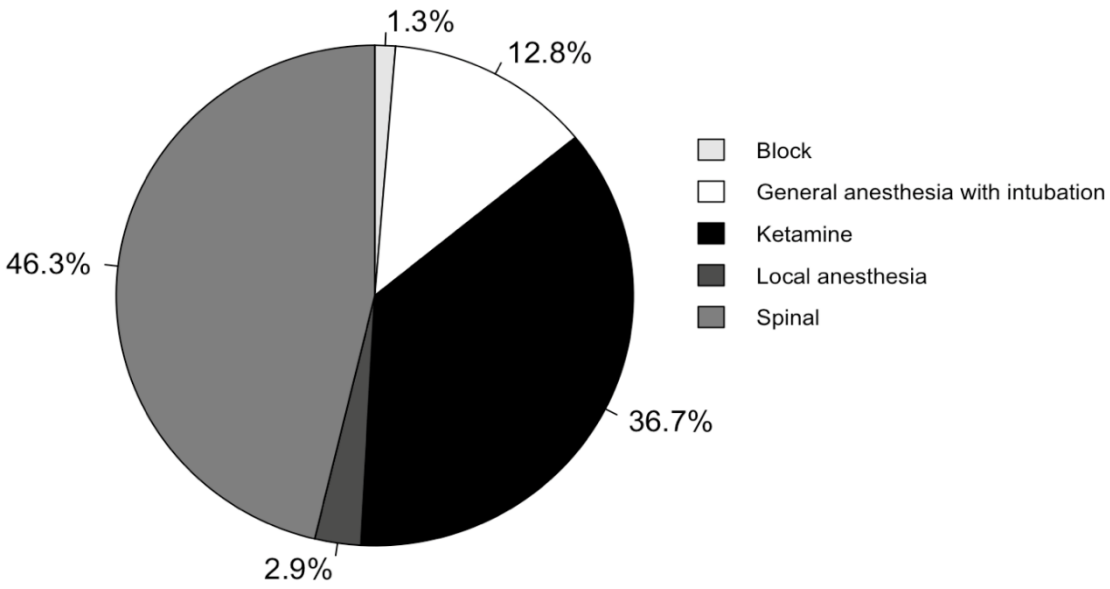

Fig 7. Distribution of types of anesthesia administered to patients in North Kivu.

3.7. COMPOSITE SURGICAL CAPACITY SCORE.

The mean modified composite capacity score in North Kivu hospitals was 39.0, with a standard deviation of 14.5. In percentage (56.5%), this capacity score falls in the most of time (51–75% of the time) category. That is, essential surgical care resources, capabilities and procedures were available most of the time (**Appendix 5**). Kanyabayonga hospital in the rural Kayna Health Zone had the lowest CCS (9.6) (**Appendix 5**). Urban facilities have an average CCS of 50.8, which is higher than the average CCS of rural facilities (32.8). Public facilities have an average CCS of 34.2, lower than the average CCS of faith-based non-public facilities (43.0). Average CCS of facilities located in war-zones is 39.0, and that facilities in non-war zones is 40.0 (**Appendix 6**). There was a generally increasing trend of surgical volume with

capacity score as shown in **Figure 8**. The Pearson's correlation is 0.61, and it is significant ($p<0.0001$).

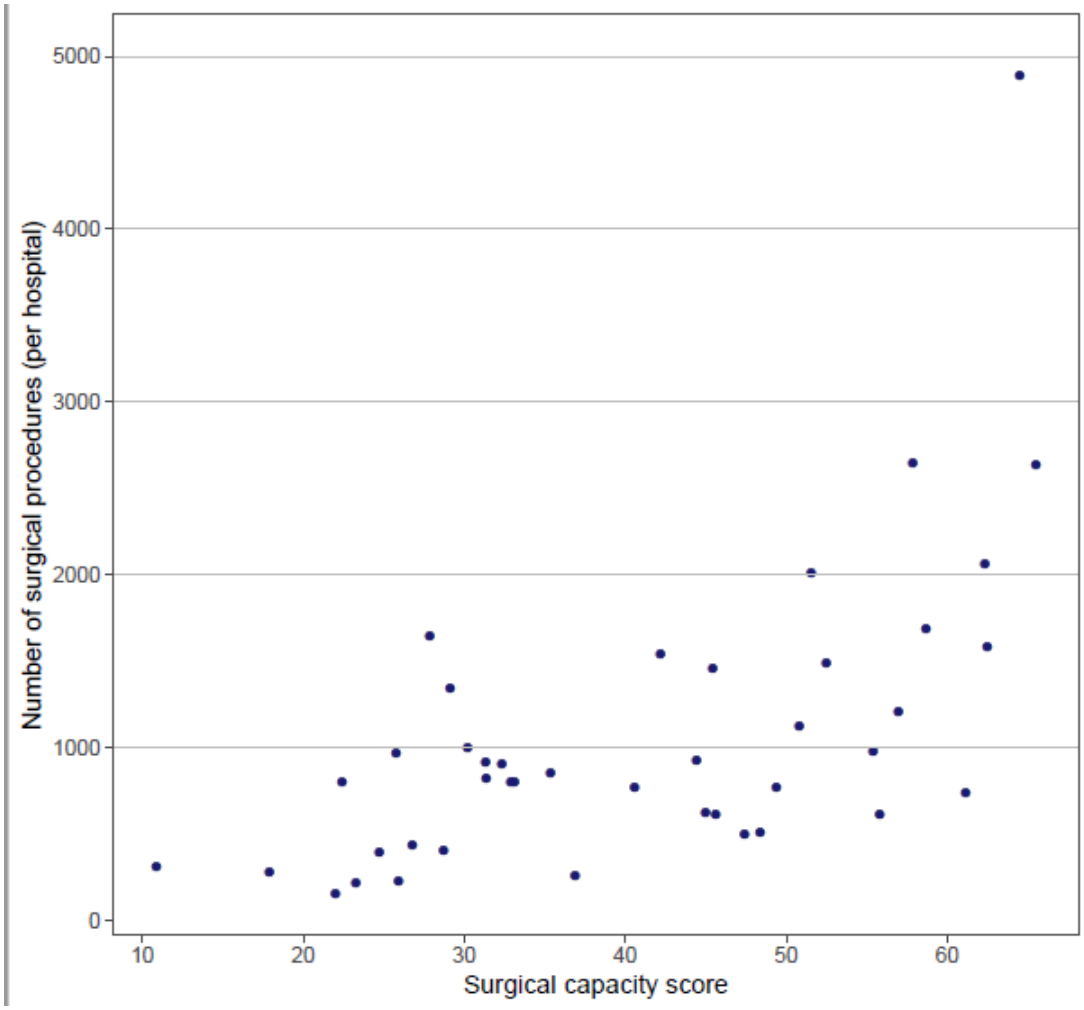

Figure 8. Number of surgical interventions performed in 2017 vs. modified composite surgical capacity score in NK hospitals.

3.8. SURGICAL INTERVENTIONS IN WAR ZONES COMPARED TO NON-WAR ZONES

Of the 43 hospitals and centers, 13 (30%) were in areas deemed unsafe, in which armed conflict was recurrent and led to regular disruption of service delivery in hospitals, internal displacement of population from those areas toward other areas. 10 973 interventions

(24%) were performed in unsafe areas, compared to 34087 interventions (76%) performed in non-war zones (**Figure 9 and Appendix 6).** The number of interventions per 100 000 population was 360 in war-zones and 655 in non-war zones but the difference was not statistically significant (p-value for chi square test is > 0.5). There was a statistical difference in the frequency of different types of surgical interventions, including trauma-related and number of surgical interventions per 100 000 population in favor of safe zones (p-value for chi square test is <0.001).

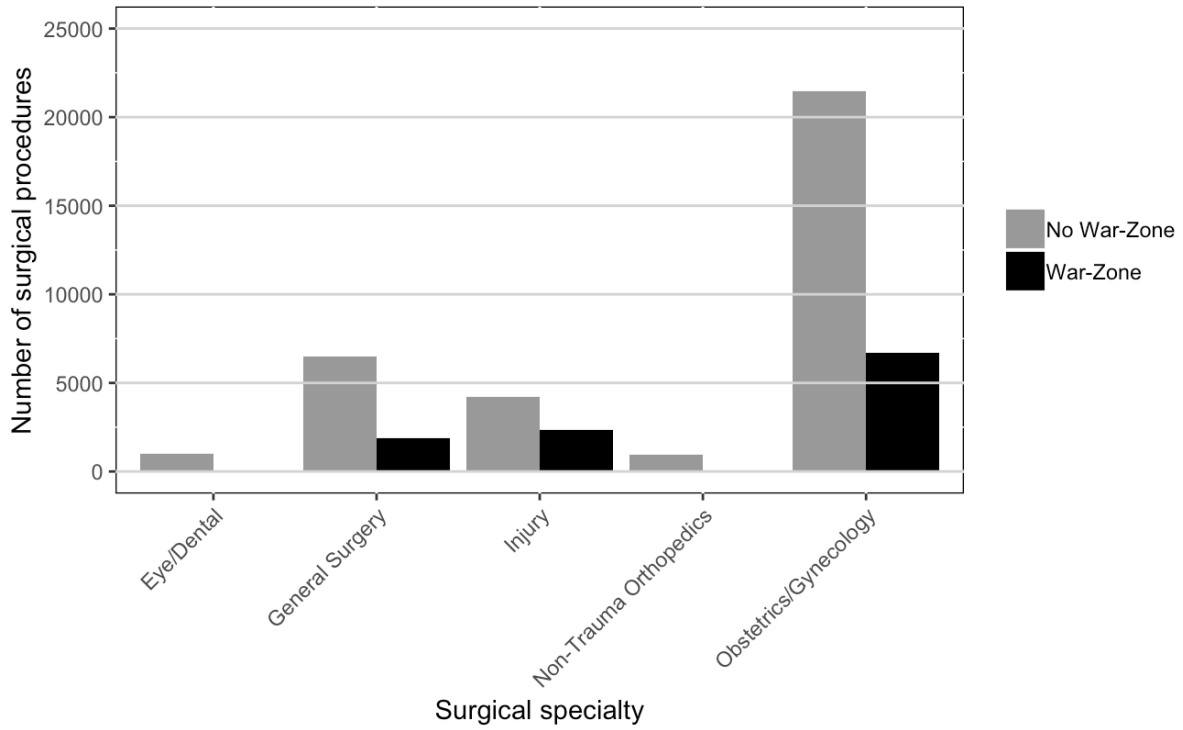

Figure.9. Distribution of the interventions non-war zones and war-zones zones.

CHAPTER 4.

DISCUSSION

The main objective of this study was to assess the surgical capacity of all health sectors in the North Kivu province of the DRC, to correlate it with the surgical burden in the province, to estimate the number of surgical interventions performed in a year, and the rate of surgical interventions per 100 000 population that took place in all hospitals from all sectors in North Kivu province in 2017.

We will discuss the characteristics of hospitals, the volumes and rates of surgical interventions found in our study, essential and non-essential interventions, elective and emergencies, surgical workforce characteristics, anesthesia providers and types of anesthesia, surgical capacity score and surgical outputs and the surgical services in war-zones compared with non-war zones. In the last paragraph, we will discuss the role of surgical platforms in a conflict zone like North Kivu, the limitations and a section on the conclusions and future directions.

4.1. HOSPITAL INFRASTRUCTURE CHARACTERISTICS

In the North Kivu province, the public sector owns less hospitals than the non-public sector. The latter include hospitals run by churches or by other non-public charity organizations. Also, in terms of productivity, in our study, non-public hospitals provided most of surgical volumes, a contribution which is higher than the average in other provinces of the DRC. We did not find a previous study of the contribution of non-public services to surgery specifically. However, this contribution is higher than the 40% National contribution of non-public sector to the delivery of all health services published by the Ministry of Health report and the 50% contribution reported by another source (108, 117).

The overall low rate of 0.8 beds per 1,000 people can be explained by the low budget allocated to the development of health infrastructure (5, 6). A study including hospitals from Tanzania, Uganda and Mozambique found a similar number of hospital beds per 1,000 population varying from 0.2 to 1(118). This is four to ten times less compared to the beds ratio per 1 000 reported in high income countries(119).

The number of 1.16 operating rooms per 100,000 population is close to a previous report stating that the number of ORs is suboptimal in LMICs, with fewer than one operating theatre per 100 000 inhabitants, whereas some HICs have more than 14 per 100 000 inhabitants (44). Our ratio is slightly higher than what has been reported in Uganda (116). However, a higher bed ratio per population in our study did not transform into higher surgical outputs, suggesting that ORs were not used at full capacity, for various reasons. Firstly, several studies have shown that even in the presence of enough infrastructure, without trained surgeons, the surgical outputs do not follow. In other words, the single statistically significant predictor of surgical volumes is the number of trained surgery providers including surgeons, anesthetists and obstetricians (62, 116, 120, 121).

In our study, most surgery providers were non-surgeon medical officers with limited skills. It is understandable that even when patients presented to them, patients would not receive the surgery they need because of the limited skill sets of non-surgeon medical officers. Secondly, some surgeons may be doing administrative tasks or other tasks instead of clinical surgical work. In some places, the involvement of surgeons in private practice has been found to a lower productivity of ORs. In our case this factor would not play a role because we could have captured the cases surgeons did outside his main OR given the fact that we included all the hospitals in the region. Thirdly, patients may not access surgical care even when the infrastructure is available because they do not have the income to afford transports to hospitals, other indirect and direct costs of surgery. In North Kivu and other

hospitals in the DRC, patients must pay for everything to have surgical care, given that 90% do not have health insurance. The National report about the health finances stated that in 2014, 42% of the budget for health was supported by direct out of pocket payment from patients (5, 6).

4.2. SURGICAL INTERVENTIONS VOLUMES AND RATES

The number of surgical interventions per facility in our study was lower than the one reported in Ghana (62) and in Uganda (116). The productivity of operating rooms (455 surgical procedures per OR per year) in our study was comparable with the average number of surgical procedures observed in Uganda, varying between the 422-652 surgeries per OR in Uganda (14, 116).

The overall rate of surgeries (**Appendix 2**) is far lower than the recommended rate of 5000 surgeries per 100 000 population per year (8-10). This translates to 89% of surgical needs being unmet. The rates in our study are higher than the ones reported in Madagascar(122) (191/ 100 000), but lower than the rates reported from a study in eight district hospitals in Uganda, Tanzania, and Mozambique that estimated that the scope of surgical procedures performed was narrow and included mainly essential and life-saving emergency procedures, at a rate of 450 major procedures per 100,000 people (118). Our rates are also lower than the ones reported in Liberia and Rwanda with reported rates of 330 and 428.9 major operations per 100 000 population- years respectively (116). They are even lower than the rates of 11,110 surgical interventions per 100 000 population reported in developing countries(123). The 89% unmet needs are in line with the findings that greater than 95% of the population in south Asia and central, eastern, and western sub-Saharan Africa do not have access to surgical care (1). Previous studies in North Kivu have identified distance to hospitals, poverty and gender as key

barriers to accessing surgery (12). Rural patients have reported being unable to visit hospitals because of long distance to hospitals and lack of transportation (85).

There a few surgical interventions observed for the population under 18 years of age. Given that more than half of the population in the DRC is under 18 years of age, this result implies that most children leave without access to surgical care and thus a significant unmet need for pediatric surgery especially because children are more prone to injuries and congenital anomalies. Currently, there is no target pediatric surgical volume per population to serve as a measure of the unmet need. One study estimated that up to 85% of children living in an urban area of the Gambia are likely to need a surgical procedure by age 15 years, generally minor surgery (16).

Several factors can explain these low rates of surgery among children. First, during the study period, there was no single permanent certified pediatric surgeon in North Kivu province. Most of pediatric surgeries were performed either by general adult surgeons or by medical officers. They cannot perform complex cases like severe congenital anomalies. Also, the fact that there was no physician anesthetist during the study period also could contribute to the small rate of pediatric surgery per population in North Kivu. It is estimated that 45,000 children die yearly of surgical problems in DRC (125) and most do not have access to treatment (69). In Uganda, one study reported annual surgical rates of 180 pediatric surgical operations per 100 000 population/year and most were emergency procedures (14). The higher rate reported in Uganda may be explained by the availability of pediatric surgeons and physician anesthesiologists capable of giving anesthesia to children. On the other hand, some hospitals in Uganda offer free surgical care in public hospitals. Even though families may share the cost, the financial barrier may be smaller than in the DRC where patients must pay 100% of the costs for surgery. In DRC there may be a lack of other essential equipment and supplies necessary for the delivery of pediatric surgery. The median availability of basic

airway management needed for general anesthesia was 1.6, showing that nearly 50% of the time hospitals do not have the ability to intubate pediatric patients. Most importantly, the composite surgical capacity score shows that between 1/2 and 1/3 of patients will not receive surgical care even if they arrived at the hospital in a timely fashion and even if they were able to pay for the services. The hospitals do not have the capacity to take care of them (**Appendix 7**).

The mean age of 28.4 years reflects the overall age pyramid of the population. Most patients undergoing surgeries were women (78%). Fifty percent of Congolese women aged 15 years and above have been victims of sexual violence (5), which is higher than the 45.60% reported in other SSA countries (122). One of the reasons is that during the armed conflicts, massive rape was used as a weapon of war, and an important international campaign attracted funding for women surviving rape or leaving with fistulas. This ongoing awareness campaign made an easier access to healthcare for women and to surgery following gender-based violence, surgery for vesico-vaginal fistulae and other types of surgeries specific to women(85).

4.3. ESSENTIAL AND NON-ESSENTIAL SURGICAL INTERVENTIONS

The fact that essential interventions were more than the non-essential ones may be explained by the fact that, by definition, interventions classified as essential are the commonest overall(80). Although we did not assess the cost per intervention, essential interventions are cheaper and most affordable. This also reflects the lack of subspecialties in the country (64). The few trained surgeons are all general surgeons, with few orthopedic surgeons and they all practice in cities: Goma, Butembo and Beni. Given the insufficient number of certified surgeons, most surgeries are performed by non-surgeons who do not have the skills to perform complex non-essential surgeries. The situation is worse in rural hospitals where medical officers perform all the procedures. Finally, the limited anesthesia capability does not allow the performance of some complex cases, like the repair of heart defects or other malformations.

The pattern of obstetrical and non-obstetrical procedures of 60-40% differs from the findings of a multicenter retrospective study including Uganda, Tanzania and Mozambique, which found a pattern of 40-60 % between obstetrical and non-obstetrical interventions (118). In these countries, obstetric operations were most common and included cesarean sections and uterine evacuations. The proportion of obstetrical interventions is 20% higher in our study. One explanation may be the local culture of early marriages, limited access to contraception and the high risk of early un-wanted pregnancies in the context of massive sexual gender-based violence. Between 1/3 to 1/2 of women in North Kivu are past victims of sexual violence (5, 7). Also, in general, maternal and child mortality is higher in conflict-affected and post-conflict countries than in least-developed countries not directly affected by conflict.

Among the non-obstetrical interventions, hernia repair and laparotomy were the commonest ones, like the pattern described in Uganda (116). Our series had higher frequencies of trauma-orthopedic cases than the ones reported in Uganda. The higher proportion of trauma-related surgeries in our series may be explained by the poorer quality of roads, the lack of seat belt-wearing policy enforcement and recurrent armed conflicts in our study setting.

The proportion of interventions considered as ‘’non-essential’’ by the DCP-3 classification was higher in provincial hospitals, especially in faith-based provincial hospitals. One reason is the availability of skilled surgeons and anesthetists, and the role of visiting surgeons from developed countries during short-term and long-term missions (126).

4.4. EMERGENT AND ELECTIVE SURGICAL INTERVENTIONS

More than two thirds of surgical interventions were emergencies (**Fig. 5**). This may be explained by the fact that poor families tend to spend the limited resources on the most vital needs including food and shelter. Seeking healthcare is not viewed as a vital need for elective conditions and often the condition becomes worse. Patients tend to consult the hospitals only

when the condition becomes an emergency and the patient is not able to postpone seeing the doctor. On the other hand, due to lack of health insurance, some patients are denied healthcare if their condition is not viewed as life-threatening, critical or an emergency. Only when an emergency presents then the hospital fee is ‘’waived’’ temporarily to allow the patient to get emergency care which may be extended to ‘’free emergency surgery’’. This predominance of emergent life-saving interventions in our study has been reported in many resource-limited Sub-Saharan countries (118). The recurrent conflicts in our setting are another reason why life-saving emergency surgical interventions are the commonest.

In addition, obstetrical emergencies make a big proportion of emergent interventions in our study. Young girls under 18 years with poorly developed pelvis are likely to deliver by cesarean or develop obstetric fistulas. Young girls are exposed to early pregnancy because contraception is not easily available. Finally, the ongoing epidemic of sexual violence without access to contraception is another contributor to early pregnancies and obstetrical emergencies (85).

Key barriers to the increase of surgical outputs included difficulty accessing surgical services due to distance, poor roads, and lack of suitable transport; lack of local resources and expertise; direct and indirect costs related to surgical care; and fear of undergoing surgery and anesthesia (56)

4.5. SURGICAL WORKFORCE CHARACTERISTICS

The general surgeon density in our study (**Appendix 6**) was lower than the density reported in current literature. Firstly, a systematic search and literature review regarding the number of surgeons, obstetrician–gynecologists, and anesthesiologists practicing in LMICs found a general surgeon density of 0.13 to 1.57 per 100,000 population (52).

Our obstetrician density (0.1 per 100 000 population) is in the range found in other LMICs: 0.042 to 12.5 per 100,000(52). Our SAO density (0.27 per 100,000 population) is lower compared to the Lancet recommendations of 20 SAO per 100 000 population and to the lowest African surgical workforce ratio of 0.7 SAO per 100 000 population (14, 89, 127). The scarcity of certified surgeons may be explained by the fact that the budget allocated to the training of health workforce in general is small: 1% of the MOH budget in 2014 (5). In fact, studies have established a direct relationship between the availability of SAO providers and the country's gross domestic product (2).

Since 2002, the budget allocated to the Ministry of Health has varied between 3-8% in 2014(5, 6). Between 2007 and 2013 this budget of the Ministry of Public Health represented 4% of the state budget on average and it is on rather downward trend. The National Health Strategic Plan 2011-2015's goal was to spend 10% of the national budget but the implementation rate was never achieved. The target of 10% was not achieved. Instead, the State spent 4.2% of its budget on health, or 0.7 %of GDP in 2013. This percentage is significantly lower than the commitment of Abuja in which African governments committed to spend 15% of their budget on health (128, 129). In 2015, the health budget from the MoH own resources mainly funded remuneration (73%) and functioning of the Ministry (14%). Only 3% was spent toward the functioning of hospitals and 1% to train health workforce. Recent reports have pointed that the funding might be reduced by 25% in 2019 because the overall budget for 2019 is lower (130).

Because of limited funding to education of health professionals, training programs have been relying on collaborations with medical schools from developing countries, which were excellent before the 1990s, mainly Belgium and France. Since the 1990s most of existing collaborations have been suspended due to several reasons including political instability, recurrent armed conflicts raising safety concerns etc. In contrast to stable

countries like Uganda and Rwanda where collaborations have been stable, the DRC has paid the cost. This has further slowed the number of residency programs.

Across the country there are several medical schools to train medical Officers (110), nursing schools to train nurses and midwives. However, the number of residency programs to train general surgeons and obstetricians in the country is insufficient. Unfortunately, these residency programs have not been expanded in size over the last 29 years. In the 1990s, only three Medical Schools could organize surgical residency programs: the University of Kinshasa, the University of Kisangani and the University of Lubumbashi. Nearly 30 years later in 2019, no expansion of surgical residency programs has occurred. For the last decade, the total size of residency programs across the country has been stagnating. Unpublished data report on average 6 spots per year in surgery, 5 spots per year in obstetrics-gynecology and 4 spots per year in anesthesiology. Unfortunately, there a scarcity of data about the current country-wide statistics for certified surgeons and obstetricians in the Democratic Republic of the Congo (52). We found only one source reporting the rate of anesthesiologists in the DRC (64). Based on estimates from incomplete data, the DRC must train 800 SAOs (320 surgeons, 320 obstetricians and 160 anesthesiologists) before 2030 to meet the requirement of 20 SAO providers /100 000 populations at a ratio of 2:2:1 SAO providers (surgeons, obstetricians and anesthetists per 100 000 population) (89).

This scarcity of trained surgeons explains another finding of our study: more than half of surgical interventions are done by medical officers. One implication of this situation is the fact that many patients who have complex surgical conditions are left untreated. This has been reflected in the fact that most surgeries happening are emergencies. For those who undergo surgery, the rate of complications is expected to be high. However, we were not able to gather data on complications.

The rate of medical officers performing surgery was higher than that of certified surgeons: 2.15 general doctors performing surgery per 100,000 population. The finding that most surgeries are done by non-surgeons is consistent with data from other LMICs, especially from war-torn countries. In many resource-limited conflicts areas, non-surgeons manage an important proportion of surgical needs with good outcomes. In Somalia, where MSF expatriate surgeons are not allowed due to insecurity, surgical procedures are performed by non-surgeons with an operative mortality of < 1% (21).

In our study, the proportion of non-physicians performing surgeries is negligible in provinces like North Kivu that has access to medical officers. However, their contribution is higher in rural areas. Many countries like Malawi, Niger, Mozambique, Tanzania etc. have put task-sharing programs in place to utilize the skills of non-physicians in surgery. In most of the above-mentioned countries, task-sharing programs have the support of the national government as well as the professional bodies (131-134). Unfortunately, in the DRC, task-sharing programs have not received the support from the surgeons nor from the government. In view of the shortage of surgeons in resource-limited settings, more emphasis should be placed on operational research to support the provision of essential surgical care by general doctors or non-physician clinicians, particularly because most essential surgical procedures required in conflict affected zones are relatively simple interventions (83).

4.6. ANESTHESIA PROVIDERS AND TYPES OF ANESTHESIA

North Kivu province had no physician anesthetist during data collection. As a country, the DRC has one of the lowest numbers of physician anesthesia providers in Africa with 0.13 anesthesiologists per 100,000 people (64). This contrast demonstrates that within the country, there is a wide variability of anesthetists' workforce. North Kivu does not seem to attract the few physician anesthetists practicing in the country. Insecurity may prevent

some physician-anesthetists from settling in North Kivu. Most physician anesthetists' practice in the bigger towns where bigger hospitals perform more complex surgeries and may offer better work and living conditions. On the other hand, the rest of the DRC is relatively safer than North Kivu. The National DRC rate is still too low compared to the rate of 5 physician anesthesiologist per 100 000 set by the World Federation of Anesthesiologist (WOFAS) (64) and more efforts are needed to improve the rates if better anesthesia care is to be achieved.

This rate in North Kivu and in the DRC is among the lowest in SSA where the anesthesiologist density ranged from 0 to 4.9 per 100,000(53). To make a sound comparison with African countries, it is important to remember that North Kivu as a province, with a population of 8, 413, 412, is comparable to the size of certain countries like Somalia, Somaliland, or the Central African Republic, in which one or none physician anesthetist have been reported (64). All the anesthesia procedures were performed by non- physician anesthetists, except for a few that were performed with the supervision of visiting physician anesthetists on short missions from developing countries.

The lack of physician anesthetists in the study setting may have several explanations. One possible explanation is that until the 2000s, 90% of surgeries were done by medical officers and they performed simple cases that were perceived not to require complex anesthesia. In rural areas, for example, many cases of circumcision are done by non-physicians during traditional ceremonies. In some major cities, circumcision may require skilled nurses but not an OR nor a surgeon. This perception has changed in the last 10 years with more certified surgeons performing complex cases that require advanced anesthesia skills that non-physicians are not able to offer. Such cases include thyroid surgery, cleft palate surgery, esophagoplasty, complex trauma surgery, hip replacement surgery etc.

The rate of non-physician anesthesia providers found by our study (**Appendix 3**) is similar to the average national rate of 1.42 non-physician anesthetists per 100 000 population in DRC published earlier in other parts of SSA 2017(53) and in Uganda (1.1/100 000 population) (14).

Spinal anesthesia and ketamine sedation are the commonest types of anesthesia capabilities found in the facilities. This may be explained by the fact that they are do not require complex equipment and they are doable by non-physician anesthetists like in many Sub-Saharan African countries. It is reasonable to continue to increase their skills and train more while expanding residency programs size to train more physician anesthetists as it is in neighboring countries.

Currently in the DRC, there are only 3 residency programs to train physician anesthetists: one in Kinshasa the capital city, another in Lubumbashi and a third one in Bukavu(110). In the three programs, the annual class size has not surpassed 20. These are 4-year programs. In Lubumbashi and Bukavu, training is delayed because they do not have permanent lecturers and they must rely on visiting lecturers after they finish their teaching obligations in Kinshasa. Because of this slow pace, the country has not surpassed 100 physician anesthesiologists by 2017(64). For the last decade, the total size of residency programs across the country has been stagnating, though we were not able to gather good data regarding the size of classes and the number of graduates each year. This contrasts with Uganda and Rwanda in which the anesthesiology residency programs are expanding (135-137)

4.7. SURGICAL CAPACITY SCORE AND SURGICAL OUTPUTS

Using the classification described previously, North Kivu's average surgical capacity score of 39/69 (56.5%, **Appendix 5**) means that essential surgical care resources, capabilities

and interventions were available 51–75% of the time (116). Between 1/3 and ½ of patients will not receive surgical care right away, even if they arrived in hospitals in a timely manner and were able to pay for surgical services. The met surgical needs are low because hospitals cannot providing surgery to all patients. Barriers to care are complex, as there are cultural, financial, and structural factors (62). This is not surprising given the low availability of essential WHO resources in most hospitals in the study and the limited number of interventions that most hospitals are able to perform. This composite score is similar to the one reported in Uganda (116), and lower than the one reported in Ghana (62).

Also, the lack of trained surgical providers in North Kivu is a major explanation of this limited capability to provide surgery. Consistently, among all individual variables of surgical capacity, the single most important determinant of surgical output that has a positive correlation with surgical output is the availability of trained surgeons according to many studies including the reports in Ghana and Uganda (116) (62). Because many studies have demonstrated the potential positive impact of specialty-trained surgeons, efforts to grow this segment of the workforce should be supported in North Kivu (62, 116).

4.8. SURGICAL INTERVENTIONS IN WAR ZONES COMPARED WITH NON-WAR ZONES

There was a statistical difference between the number of surgical interventions per 100 000 in war zones compared to non-war zones (p-value < 0.001). However, gunshot trauma was not the commonest indication for emergency interventions in war-zones as it might be assumed. There were statistically significant more trauma-related emergencies and other types of emergencies performed in non-war zones compared to war zones (p-value for chi square test is <0.001, **Appendix 6**). As in our study in both war and non-war zones, obstetric emergencies vastly outnumbered trauma-related emergencies. Previous studies in

the DRC found that mortality from obstetric emergencies and accidental injury in conflict was four times higher than that from direct armed conflict, suggesting that even in conflict-zones, civilian surgical needs are predominantly not related to combat (21).

This trend was confirmed by another multicenter study by MSF that showed that even operational data suggests that civilian surgical needs are predominantly not related to combat. This retrospective review of surgical services of Médecins Sans Frontières in six conflict settings found that only 22% (1050) of 4630 surgical interventions were due to conflict. Direct armed conflict represented less than half of all surgical interventions in conflict-affected areas in Pakistan (5%), South Sudan (21%), Chad (36%) and Somalia (41%). They found that the commonest emergencies needing surgery were obstetrical and that accidental injury and tropical infections accounted for another third (83, 138, 139).

In these conflict-zones, non-surgeon medical officers or non-physician surgery providers are faced with complex cases that they would otherwise attempt to operate as an elective case. But they are forced to perform life-saving complex surgeries beyond their skills because the closest certified surgeons are located at hundreds of kilometers and are not reachable. Life-saving obstetrical care is also among the commonest surgery performed by non-physicians with good outcomes.

At least 40 active armed groups are reported in and around North- Kivu (140). Many DRC political, natural and plagues-related crisis involved North Kivu, including the entry of millions of Rwandan refugees after the genocide in 1994, the ‘’ African biggest war ‘’ of liberation involving many neighboring countries in 1996, the recurrent rebellions between 1998 to date, the Nyiragongo volcanic eruption in 2001, the rapid expansion of gender-based sexual violence and the current Ebola epidemic. Recent data show that 900,000 people have been displaced by conflict and almost 1/3 to 1/2 of women are past victims of sexual violence (7, 141). Therefore, the province of North Kivu has been a permanent home for hundreds of

NGOs (106). This recurrent crisis led to a collapse of the health system, leaving health care delivery to non-public institutions and organizations. In these unstable parts of the DRC, the public health budget helps mainly to contribute to the payment of irregular and low salaries to health workers hired by the government in both public and non-public hospitals. In fact, the DRC was ranked the sixth failed state in the world because of its inability to provide public services (118, 120).

Faith-based organizations supported by international NGOs have expanded the number and size of non-public hospitals., making the contribution of non-public hospitals higher. Some organizations collaborate with local hospitals and are involved in clinical work by sending visiting health professionals on short missions: Médecins Sans Frontières and the Red Cross, Operation Smile. Some provide funding and investment, for example Cure International for clubfoot and hydrocephalus, Christian Blind Mission (CBM) for cataract and clubfoot surgery, Fistula foundation and UNFPA funding vesico-vaginal fistula, Smile Train for cleft lip/palate surgery. Most of the charities except for MSF work primarily with non-public hospitals.

Another important contribution of non-public sectors and charities is in providing scholarships to local doctors and in neighboring countries for residency training. This need became obvious because visiting specialists realized they could not stay forever. Since the 2000s, Congolese doctors have been sent to Uganda, Rwanda, Kenya, Tanzania, Benin, Senegal, Burundi, South Africa, Tunisia, and most came back. These skilled Congolese surgeons have taken over the work and they are revolutionizing surgical care in North Kivu. A few examples include the first hip replacement surgery in 2013, the first endoscopic third ventriculostomy in 2014, goiter surgery etc. The accreditation of HEAL Africa as the first hospital to organize the COSECSA surgical training program is perhaps the most recent important development that will have durable positive impact on the quality of surgery in the

region as well as the recent award of a Nobel Prize to Dr. Denis Mukwege, Director of Panzi hospital (108).

Despite that, it is important to point out that international NGOs have left some negative impacts in the health system. First, the "free care mentality" has been adopted by local communities because these NGOs often provided free surgery to the community since the Rwandan genocide in 1994. Local communities have been accustomed to free health care in general, and surgical care in particular, because it was funded in many hospitals by International NGOs. When these organizations stop funding free surgery, a national crisis may develop.

The distribution of hospitals between non-public and public sector is different across Africa and there seems to be a lack of strong reliable data. Some authors have claimed that non-public organizations do not disclose all the information relating to the extent of their budget, the origin of their funding and their partners. This has made it difficult to get a reliable picture of the real contribution of the non-public sector. Different authors have quoted different proportion of hospitals run by faith-based organizations, but they vary between 30-70% (100, 115). A systematic review of the contribution of FBOs or national faith-based health networks (NFBHN) showed a wide variability of their contribution: 30% or less in Sudan, Botswana, Sierra Leone, Central African Republic, Togo, Chad, 40% or more in Kenya, Tanzania, Malawi, Nigeria, Rwanda, Benin, 50% and more in the DRC and in Uganda (100, 106).

Apart from funding, various other reasons may explain why non-public hospitals contribute more than public hospitals. First, several studies including household surveys of patient’s satisfaction, found that in many SSA countries there is a perception of a higher quality of services in faith-based health providers (FBHPs) (100). Higher performance and

lower out-of-pocket costs have been reported in non-public compared to public health providers hospitals (100, 115).

4.9. LIMITATIONS

Before drawing conclusions, we would like to recognize some challenges limitations of this study in collecting data, assuring completion of data, completeness of medical records. Firstly, the retrospective design of the study made it difficult to document some variables. However, using a permanent non-changeable OR register improved the quality of information recorded. Secondly, there is no standardized database system to record hospital data in North Kivu. Most data were manually entered in operating registries and transcribed in excel sheets, and errors may occur during the process of transcription. We minimized this bias by collecting data from as many areas involved in delivery of surgery as possible, and we verified some information by calling key responders.Thirdly, the capacity scores were estimated by asking some health personnel questions about what was available and functional, and this may vary depending on who is asked.

Another limitation of the study is that there were missing data observed in two of the hospitals. One hospital was missing certain critical assessment records and a capacity score could not be calculated. The exact hospital surgical record in another hospital was unobtainable due to the location of the hospital. Despite the two facilities missing records, the study still contains a large amount of records. Less than 500, or approximately 1.1% of the surgical records missing most likely did not affect the validity of the study. This is the largest study regarding surgical care delivery in an entire sub-Saharan region.

CHAPTER 5.

CONCLUSIONS AND FUTURE DIRECTIONS

The goal of this research was to assess the met and unmet surgical needs in North Kivu Province, DRC. This work is the largest study to date regarding surgical care delivery in an entire sub-Saharan region. We successfully gathered data on all the hospitals in the region and gathered pertinent patient data on more than 98% of all the surgeries performed at these hospitals during the study time period. We have compared our data to international standards and where possible have referenced comparable statistics from other sub-Saharan countries.

It is abundantly clear from our results that the delivery of surgical care in North Kivu falls far short of the minimum goals set forth by international agencies and in many cases, it is worse than in other countries that have comparable economic situations. We have attempted to assess the surgical infrastructure utilizing a recognized scoring system and have assessed the currently available human resources by specialty. Even accounting for the limits of our information, it is apparent that there are huge unmet needs in both physical resources and human resources that contribute to the extraordinary unmet surgical needs of this province.

We feel it is important to recognize that despite having a population of more than eight million people located in a largely rural and war-torn region and hampered by limited infrastructure, there are amazingly dedicated healthcare professionals working to provide surgical care to these people. Almost all providers are under-resourced, and most have limited surgical training. In many cases they are courageous and even heroic in their efforts. We also want to recognize the ongoing efforts of NGO's and faith-based organizations which

are contributing a large percentage of the surgical care as well as surgical training to this province. Without them, the situation would be even direr.

This study demonstrates the urgent need to put in place plans for improving surgical services in North Kivu Province as well as the entire country of DRC. The needs are great for adults and children, but we have highlighted the even more acute and specific need for pediatric surgery. The infrastructure needs are largely unmet and will require a much larger commitment of resources from the national government. We hope the surgical needs will be incorporated into the long-term planning of the Ministry of Health and that their budget will reflect those priorities.

The international community is currently committing substantial resources to the Ebola epidemic. We are hopeful that the outbreak will be controlled soon but we also hope that some of the resources that are brought in to fight Ebola can be utilized to improve the healthcare infrastructure of North Kivu going forward. An effort should be made to coordinate short-term plans that could be a platform to build on for the future.

Additionally, we hope that in the future political stability can be restored to this province. If the violence can be brought under control it will be easier to attract international development aid that can be used for long-term infrastructure rather than short-term relief aid. We believe that both short term and long-term planning for surgical delivery is urgently needed and we hope that this research will contribute to making that planning occur.

All of sub-Saharan Africa struggles with having enough adequately trained doctors and there is a recognized acute need for trained surgeons particularly in light of the information that we highlighted showing that essential surgery needs are as important and cost-effective as other primary medical needs such as vaccines and mosquito nets. Groups such as COSECSA have brought this need to the attention of the global surgery community

and are putting plans in place to address this. They are working with groups such as the American College of Surgeons. Recognizing the difficulty of training adequate numbers of fully trained surgeons in time, they have developed a tiered system of training with full five-year residency programs as well as two-year programs that can more quickly train surgeons who, although not trained to do complex procedures, can safely perform essential surgical procedures. We think this is a model that needs to be encouraged in DRC.

Recognizing that even two-year surgical training programs will take substantial time to produce results, we think that a short-term approach needs to be developed to impact surgical care as soon as possible. This will necessarily involve improving the training of those professionals who are currently available and currently providing surgical care. Since more than 50% of surgeries are being performed by non-surgeons, we need to develop hands-on workshops to augment the training of these providers. Additionally, we need to find a way to train current anesthesia providers in safe airway management and fluid management and make sure they are adequately trained in regional anesthesia. These programs do not currently exist, but we feel they should be developed and implemented urgently. We do see a possibility for developing these programs as a compliment to existing programs such as those for Fistula Awareness, Cleft lip and palette repair programs, orthopedic officer training programs and others.

The findings of this study will be presented to the North Kivu Health Division and we hope it will inform surgical planning with the aim of improving surgical care in the province. We hope that this study and the North Kivu surgical plan can then be implemented in other provinces and lead to a national surgical obstetrical and anesthesia plan. Given the current providers of surgical care documented in this study we hope that the public and private sector players including NGO's and faith-based organizations can be encouraged to make this a

priority and seek ways to develop a comprehensive and achievable plan to improve the delivery of surgical services to the people of North Kivu and DRC as a whole.

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Appendix 1: Table of Number of Inpatient Surgical Beds and ORs in NK

		Inpatient Surgical Beds			Operating Theaters	
	Number of Facilities	Total (n)	Median (Range)	Proportion[c]	Total (n)	Median (Range)
Public						
ZGH[a]	18	504	22.5 (1 - 80)	0.20	32	2 (1 - 3)
RRH[b]	1	53	-	0.26	3	-
Faith-NGO						
ZGH[a]	21	727	25 (2 - 80)	0.23	51	2 (1 - 6)
RRH[b]	3	163	48 (25 - 90)	0.27	12	4 (3 - 5)
Total	43	1,447		0.22	98	
Total per 100,000 population		17.20			1.16	

[a]ZGH: zone general hospitals

[b]RRH: regional referral hospital

[c]Proportion of surgical beds among all inpatient beds

Appendix 2: Table of Number of Surgical Interventions Per Facility Level by Age in NK

		Age <18 Yrs			Age >=18 Yrs			Age Not Specified	
	Facilities	Procedures	Median	Range	Procedures	Median	Range	Procedures	*p*-value[c]
Public									
ZGH[a]	18	1,386	29.5	8 - 453	15,425	784.5	212 - 2196	11	< 0.001
RRH[b]	1	66	66	-	1141	1141	-	1	-
Faith-NGO									
ZGH[a]	21	2,157	63	5 - 319	17,411	767	149 - 2412	5	< 0.001
RRH[b]	3	1,220	290	21 - 909	6,228	1,768	489 - 3971	9	0.2384
Total	43	4829			40205			26	45060
Total Surgical Procedures per 100,000 population		57.40			477.87				535.57
[a] ZGH: zone general hospitals									
[b] RRH: regional referral hospital									
[c] Welch two-sample t-test									

Appendix 3: Table of Number of Surgery and Anesthesia Providers in NK.

		Surgeons				Anesthesia Providers[c]	
		Surgeons[d]		General Doctors			
	Number of Facilities	No.	Median (Range)	No.	Median (Range)	No.	Median (Range)
Government							
ZGH[a]	18	1	-	80	3.5 (1 - 14)	28	1 (0 - 7)
RRH[b]	1	4	-	5	-	7	-
Faith-NGO							
ZGH[a]	21	7	0 (0 - 2)	86	3 (2 - 11)	49	2 (0 - 7)
RRH[b]	3	11	1.5 (1 - 4)	10	3 (1 - 6)	12	4 (2 - 6)
Total	43	23		181		96	
Total per 100,000 population		0.27		2.15		1.14	

[a] ZGH: zone general hospitals

[b] RRH: regional referral hospital

[c] No physician anesthesiologists in any of the 43 facilities

[d] General surgeons, orthopedic surgeons, and gynecologists

Appendix 4: **Table of Essential surgical resources and capabilities assessed in NK**

Resource and Capability	**Item**
Personal protective sterile attire equipment	Sterile gloves, facial mask, gloves, gowns, eye protection
Basic airway management	Facemask bag valve, Magill forceps, stethoscope, oropharyngeal airway
Suction device	Nasogastric tubes, Suction machine
Advanced management	Laryngoscope, Endotracheal tube
Spine immobilization	Spinal fractures
Oxygen supply	Oxygen availability
Tube thoracostomy	Tube thoracostomy, water seal device
Pulse oximetry	Pulse Oximeter
Mechanical ventilator	Functional ventilators availability
Blood transfusion	Blood accessibility
Hemoglobin	Frequency of complete blood count
X-ray	accessibility to functioning X-ray machine
Ultrasound	Accessibility to functional ultrasound
Anesthesia machine	Presence of anesthesia machine
Minor surgical	suture of tears or lacerations, drainage of abscess/septic arthritis, circumcision, hydrocelectomy
Major surgical	Gallbladder diseases, Appendectomy
Obstetric and gynecologic	Cesarean-section, Ectopic pregnancy, dilation and curettage, Tubal ligation, Hysterectomy
Urologic	Relief of urinary obstruction, Vasectomy
Closed reduction	Fracture reduction
******Skin or skeletal traction	
Minor orthopedic	Drainage of septic arthritis, Irrigation and debridement of open fractures, Debridement of osteomyelitis, Repair of clubfoot
Major orthopedic	Amputation, fasciotomy
******Vascular	
Burn and plastic	Skin grafting, Escharotomy/fasciotomy

Minor neurosurgical	Burr hole, Shunt for hydrocephalus, Treatment of spinal fractures

***Scoring:**

3 - for equipment available >75% of time, or procedure performed

2 - for equipment available 50% to 75% of time

1 - for equipment available 1-50% of time

0 - for equipment unavailable, or no surgery performed

****: No data for skin or skeletal traction and Vascular.**

Appendix 5: Table 5 of Capacity score of *42 facilities in NK

Hospital No.	Hospital Name	Cap. Score
1	Itebero	25.7
2	Kibua	17.099784
3	Masisi	57.474026
4	Mweso	50.956169
5	Walikale	26.486364
6	Binza	38.347078
7	Rutshuru	55.274351
8	Rwanguba	48.738312
9	Kibirizi	28.982576
10	Nyiragongo	31.419481
11	Kirotche	43.32381
12	Mabalako	27.542208
13	Beni	45.262013
14	Beni Nyakunde	52.829004
15	Musienene	26.21526
16	Vuhovi	27.52381
17	Kalunguta	15.513636
18	Oicha	32.491775
19	Butembo-UCG	61.931818
20	Katwa HGR	51.440693
21	Mangurejipa	40.744156
22	Biena	25.294481
23	Kanyabayonga	9.6133117
24	Lubero	31.122511
25	Masereka	21.286364
26	Beni Breche	43.859632

27	Butembo- HGR Kita	29.816558
28	Butembo- Matanda	63.465909
29	Kyondo	45.293831
30	HEAL Africa	62.715909
31	Goma-Kyeshero	47.52987
32	Bambo	36.202922
33	Goma-Charité	38.557251
34	Birambizo	22.478896
35	Alimbongo	25.990909
36	Kayna	29.608983
37	Goma-Prov.Hosp	56.918831
38	Karisimbi-Virunga	61.219156
39	Goma-Bethesda	59.784091
40	Karisimbi II	54.086039
41	Katwa II	33.097078
42	Mutwanga	45.462013
	Mean Score	**39.25 (SD: 14.54)**

Appendix 6: Mean capacity score by location, level and ownership of hospitals

Safe(n=30)	**Unsafe(n=13)**
35.8(9.6-63.5)	38.3(22.5-57.5)
Urban(n=15)	**Rural(n=28)**
52.9(29.8-63.5)	29.3(9.6-57.5)
Public(n=19)	**Non-public(n=28)**
29.6(9.6-57.5)	44.6(15.5-63.5)

Appendix 7: Frequency of surgical interventions in war zones and non-war zones.

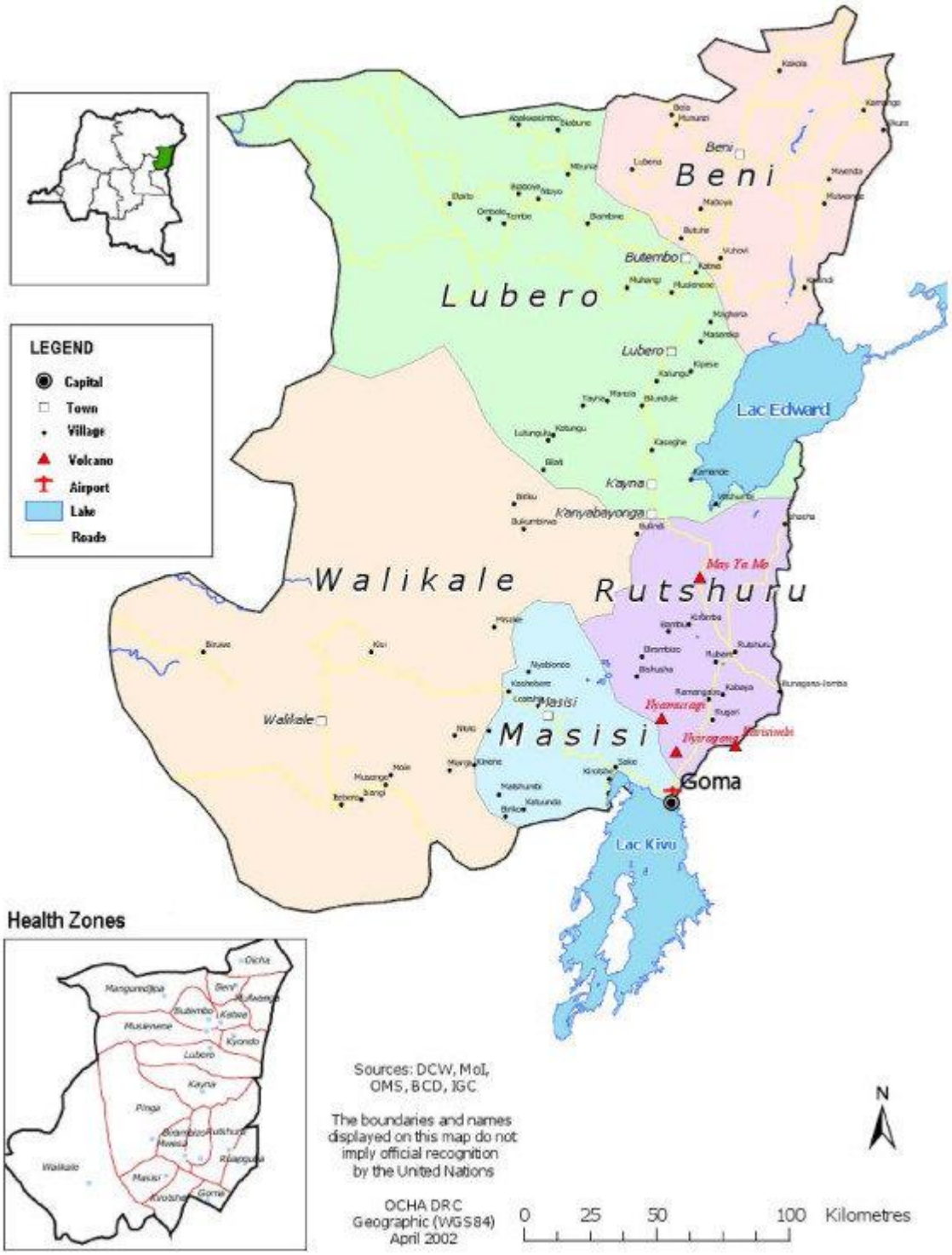
	Non-war zones	War-zones	% in non-war zones	% in war zones
Amputation	90	42	0.26%	0.38%
Anal dilatation	14	0	0.04%	0.00%
Anoplasty	53	0	0.16%	0.00%
Appendectomy	855	181	2.51%	1.65%
Biopsy	1080	165	3.17%	1.51%
Burr hole	9	0	0.03%	0.00%
Cesarean birth	19890	6473	58.38%	59.06%
Cervical lesions inspection	225	0	0.66%	0.00%
Circumcision	180	33	0.53%	0.30%
Colostomy	116	13	0.34%	0.12%
Colporrhaphy	345	0	1.01%	0.00%
Debridement of osteomyelitis	18	15	0.05%	0.14%
Dental caries	167	0	0.49%	0.00%
Drainage of abscess	492	369	1.44%	3.37%
Ectopic pregnancy	90	28	0.26%	0.26%
Eye surgery	859	0	2.52%	0.00%
Fracture reduction/fixation	1297	225	3.81%	2.05%
Hemorrhoidectomy	14	0	0.04%	0.00%
Herniorrhaphy	1815	538	5.33%	4.91%
Hip prosthesis	12	0	0.04%	0.00%
Hysterectomy	142	17	0.42%	0.16%
Laparotomy	802	450	2.35%	4.11%
Manual vacuum aspiration	172	67	0.50%	0.61%
Mastectomy	14	4	0.04%	0.04%
Myomectomy	226	44	0.66%	0.40%

Oophorectomy	35	9	0.10%	0.08%
Osteotomy	81	0	0.24%	0.00%
Other Ob-Gyn	7	9	0.02%	0.08%
Other general surg.	237	0	0.70%	0.00%
Other non-trauma orthopedics	585	4	1.72%	0.04%
Prostatectomy	34	0	0.10%	0.00%
Reimplantation of ureters	34	0	0.10%	0.00%
Relief of urinary obstruction	72	34	0.21%	0.31%
Removal of foreign	35	16	0.10%	0.15%
Repair of cleft lip	164	0	0.48%	0.00%
Repair of clubfoot	234	0	0.69%	0.00%
Repair of fistula in-ano	7	0	0.02%	0.00%
Repair of hydrocele	175	57	0.51%	0.52%
Repair of obstetric fistula	285	0	0.84%	0.00%
Shunt for hydrocephalus	27	0	0.08%	0.00%
Skin grafting	114	75	0.33%	0.68%
Suturing laceration	110	25	0.32%	0.23%
Thyroidectomy	62	0	0.18%	0.00%
Tubal ligation	22	37	0.06%	0.34%
Tube thoracostomy	89	60	0.26%	0.55%
Undescended testis	75	17	0.22%	0.16%
Traumatic Wound debridement	2463	1930	7.23%	17.61%
Z plasty	143	23	0.42%	0.21%
	34087	10973	76.00%	24.00%

(p-value for chi square test is <0.001).

Appendix 8: Map of the DRC

Appendix 9: Map of North Kivu Province.



Appendix 10: Map of the location of hospitals assessed in North Kivu health Zones