Mortality, morbidity, and associated complications in paediatric anaesthesia in Mongolia

Zolzaya Chinzorig MB.

Faculty of Medicine and Health

The University of Sydney

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ABSTRACT

Over the past decades, there has been a consistent rise in the need for paediatric anaesthesia services in Mongolia, propelled by population growth and socio-economic advancements. Furthermore, paediatric procedures requiring anaesthesia are being conducted in varied locations, from tertiary children's hospitals to remote provincial hospitals.

While individual cases of anaesthesia related complications are documented on paper-based records, there are presently no hospital, regional, or national initiatives in Mongolia dedicated to systematically collecting and analysing data on anaesthesia and surgical morbidity and mortality rates. Consequently, there is a lack of comprehensive information regarding the underlying causes of these issues. It is imperative to urgently establish mechanisms for gathering data on mortality, morbidity, and associated complications in paediatric anaesthesia, along with obtaining detailed insights into common causative factors. Such information is crucial for informing clinical practitioners, policymakers, and stakeholders in Mongolia.

The objective of this study is to assess the incidence of paediatric anaesthesia related mortality and morbidity with the aim of enhancing preventive measures against these complications in paediatric anaesthesia in Mongolia.

We conducted a retrospective cross-sectional study across multiple centres, analysing data on anaesthesia related complications. The data were sourced from the National Centre for Maternal and Child Health of Mongolia and five provincial hospitals, which were chosen due to their higher volume of paediatric surgery cases, thus representing the landscape of paediatric anaesthesia services in Mongolia. Study period spanned from January 1, 2018, to December 31, 2022. A data collection tool was developed based on review of existing literature and input from experienced paediatric anaesthesiologists. Data were collected through chart reviews and specific inquiries from anaesthesia related paper records, encompassing recovery room and intensive care unit documentation. The study data were collected and managed using an electronic data capture tool provided by REDCap and hosted at the University of Sydney.

Following approval from the Research Ethics Committee of the Maternal Child Health of Mongolia and the ethics committees of the provincial hospitals, a total of 60546 anaesthesia related records were reviewed and analysed.

In total, 1160 anaesthesia related events, including 11 serious complications were reported from 637 patients' records. During study period, serious complications including cardiac arrest n=10 (1:1000), and severe neurological damage n=1 (0.1:1000) occurred.

The most common intraoperative complications were cardiovascular n=479 (79:1000 cases), including tachycardia n=169 cases of tachycardia, and 108 cases of hypotension. 283 (44:1000 cases) respiratory complications were noted the during anaesthesia period with laryngospasm being the most common (n=172 (13.9%)).

Cardiovascular and respiratory events were most common in the post anaesthesia period. Moreover, fever n=132 and vomiting n=37, as well as shivering n=50 complications occurred in peri and post anaesthesia period during study period.

The average fasting time before anaesthesia is 4 to 6 hours. 33.4% of patients with complications were fasted for 4-6 hours, and 30.8% were fasted for 6-8 hours.

386 anaesthesia related complications (68.8%) occurred in junior anaesthesiologist' care, whereas this number 175 (31.2%) occurred in senior anaesthesiologist' group who have been engaged paediatric anaesthesia field for more than 5 years.

The objective of this study of this study is to assess mortality, morbidity, and complications rates in paediatric anaesthesia in Mongolia, with the aim of enhancing patient care and establishing a continuous quality assurance program in Mongolian paediatric anaesthesia. There is a significant need not only to advance anaesthesia techniques but also to develop strategies, including safety improvement management, hospital and operating theatre management and advanced training, which could provide trainees with excellent learning experience while addressing limitations in essential paediatric anaesthesia equipment in Mongolia. Therefore, a prospective cohort study will be necessary in the upcoming years.

SUPERVISOR'S DECLARATION

As the supervisor of Zolzaya Chinzorig's master work, I certify that I consider his thesis "Mortality, morbidity, and associated complications in paediatric anaesthesia in Mongolia" is ready and to be suitable for examination.

Associate Professor Justin Skowno _____ MBChB, DA, FCA, FANZCA, PhD

Date ___29/10/2024_____

CANDIDATE'S DECLARATION

I, Zolzaya Chinzorig, confirm that this thesis is entirely my own creation. I have not utilised any other person's work, previously published materials, or content that has been recognised with a degree or diploma from any university or tertiary institution without proper acknowledgment, except where I have provided in-text references.

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…… 29/10/2024

Zolzaya Chinzorig Date

ETHICAL APPROVAL

This study approved by the academic and ethical commissions of all attended hospitals.

Attended hospitals are:

- Paediatric Hospital, National Centre for Maternal and Child Health of Mongolia (NCMCH)
- Sharav.Kh memorial diagnostic and treatment centre of Umnugobi province, Umnugovi, Mongolia
- Dornod Medical Centre, Dornod, Mongolia
- Bayan-Ulgii province General Hospital, Bayan-Ulgii, Mongolia
- Regional Diagnostic and Treatment Centre in Uvurkhangai province, Uvurkhangai, Mongolia Magsar.Ts memorial Bayankhongor province General Hospital, Bayankhongor, Mongolia

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Zolzaya Chinzorig

Wentworth point, Sydney, NSW, Australia

June 2024

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

WFSA	World Federation of Societies of Anaesthesiologists
NECTARINE	NEonate – Children STudy of Anaesthesia pRactice IN Europe
APRICOT	Anaesthesia PRactice in Children Observational Trial
PEACH	PEri-Anesthetic morbidity in Children
LMIC	Low- and Middle-Income Countries
MMC	Mortality, morbidity and associated complications
ASA	American Society of Anaesthesiology
NCMCH	National Centre for Maternal and Child Health of Mongolia
DTCUG	Diagnostic and treatment centre of Umnugobi province
DMC	Dornod Medical Centre
BUGH	Bayan-Ulgii province General Hospital
RDTCUKh	Regional Diagnostic and Treatment Centre in Uvurkhangai province
BKhGH	Bayankhongor province General Hospital

PUBLICATIONS AND PRESENTATIONS

Journal article

Some information in Chapter 1 of this thesis is published as:

***Zolzaya Chinzorig**, Pornarun Charoenraj, Dolgorsuren Adiya, Naiyana Aroonpruksakul, Khuanysh Ayatkhan, Oyun Bayarsaikhan, Odgerel Boldbaatar, Duenpen Horatanaruang, Urantuya Khorolsaikhan, Pornswan Ngamprasertwong, Tumenjargal Purev- Oidov, Solongo Tumur, Justin Skowno. Pediatric anesthesia in Mongolia and Thailand. Pediatric Anesthesia.2024 March 26; 00:1-9*

I have managed the project with my supervisor, collected information together with co-authors and wrote the drafts of the manuscript.

Oral conference presentations

1. Mongolian Australian Societies of Anaesthesia Annual Scientific Meeting, Ulaanbaatar, Mongolia, June 2023. “A Systematic Review of Mortality, Morbidity, and Associated Complications in Paediatric Anaesthesia”
   Zolzaya Chinzorig
2. Mongolian Australian Societies of Anaesthesia Annual Scientific Meeting, Ulaanbaatar, Mongolia, June 2024. “Mortality, morbidity, and associated complications in paediatric anaesthesia in Mongolia”
   Zolzaya Chinzorig

Poster conference presentations

1. Australian Society of Anaesthesiologists National Scientific Congress, Melbourne, Australia, October 2023. “A Systematic Review of Mortality, Morbidity, and Associated Complications in Paediatric Anaesthesia”
   Zolzaya Chinzorig
2. World Congress of Anaesthesiologists, Singapore, March 2024. “Mortality, morbidity, and associated complications in paediatric anaesthesia in Mongolia”
   Zolzaya Chinzorig

AUTHORSHIP ATTRIBUTION STATEMENT

This thesis contains material published in Charoenraj et al (Pornarun Charoenraj, 2024). These include sections 1.2; Figure 1 and Figure 2 and pages between 5 to 7. I am the corresponding author of the section that relates to Mongolian Paediatric Anaesthesia.

Pornarun Charoenraj, Zolzaya Chinzorig, Dolgorsuren Adiya, Naiyana Aroonpruksakul, Khuanysh Ayatkhan, Oyun Bayarsaikhan, Odgerel Boldbaatar, Duenpen Horatanaruang, Urantuya Khorolsaikhan, Pornswan Ngamprasertwong, Tumenjargal Purev- Oidov, Solongo Tumur, Justin Skowno. (2024). Pediatric anesthesia in Mongolia and Thailand. *Pediatric Anesthesia*, *00*, 1-9. https://doi.org/DOI: 10.1111/pan.14894

Dr Zolzaya Chinzorig …….3rd July 2024

As supervisor for the candidature upon which this thesis is based, I can confirm that the authorship attribution statement above is correct.

Associate Professor Justin Skowno ……..MBChB, DA, FCA, FANZCA, PhD

3rd July 2024

Contents

CHAPTER 1

INTRODUCTION

1.1 Research background

Working as a paediatric anaesthesiologist, the most common questions parents ask are “Please explain more about the risks of anaesthesia for my child?” or “If complications do occur, what will happen after that?”. Although data from other countries are available, local Mongolian data is currently not available.

Before the 1990’s, few studies on mortality and morbidity of paediatric anaesthesia were available (Marsha M. Cohen, 1990). After 2000, studies on particular subjects have increased with a focus on clarifying complication incidences and consequences of paediatric anaesthesia. Moreover, common and rare causes of complications have been studied during the last decades. The mortality and morbidity rates in paediatric anaesthesia have significantly decreased over the past few decades; however, there remain concerns within the field today (Jurgen C. de Graaff, 2013a). The incidence of these issues varies significantly among countries, healthcare settings, and medical specialties. Furthermore, they are linked to adverse socioeconomic and social consequences, as well as a significant financial burden. These events can be extremely distressing for both patients and their families, especially when complications during paediatric anaesthesia result in cognitive or educational impairments (Davidson, 2011).

In Mongolia, essential studies on incidence of anaesthesia related complications have not been done yet. There is no hospital, regional or national programmes of data acquisition and analysis relating to anaesthesia and surgical morbidity and mortality rates, nor any clear data on the drivers for these issues. There is a clear need for both data to inform future actions, and for systems to be set up to allow continuous quality assurance and improvement,

Despite the immense needs, Mongolia is constrained by the inadequacy of equipment and facilities and shortage of qualified human resources to lead such research initiatives, resulting in a failure to commence or continue such research.

1.2 Paediatric anaesthesia in modern Mongolia

Mongolia has the lowest population density of all countries, and is situated without coastal access between Russia and China (Lundeg, 2018). The importance of Mongolian anaesthesia extends throughout all healthcare services and encompassing a critical role in paediatric medicine.

1.2.1 Historical background

Following the Mongolian declaration of independence in 1921, the Soviet Union assisted in the introduction of a modern health service in Mongolia, while fostering a close relationship between the two nations that lasted for 70 years. The Soviet Union significantly influenced Mongolia’s social and economic situation. Nikolai Semashko’s health model, which is a primary health care system dominated by public health care facilities with extremely high level of government administration (Igor Sheiman, 2018), implemented during his tenure as Commissar of Health in Moscow, played a vital role in creating health services, including anaesthesia, in Mongolia (Lundeg, 2018).

The establishment of paediatric surgery in the late 1950's marked the unofficial beginning of Mongolian paediatric anaesthesia services. The foundation of this specialized service is generally recognised to be between 1960 to 1962 when Dr.G.Tsedmaa, working in a children's hospital after training under the supervision of Dr.F.F.Dragel (Soviet Union) and Dr.L.Lemont (Czechoslovakia). Substantial expansion and development began with the opening of the National Maternal and Children Health Centre in Ulaanbaatar in 1987, with formal structured training in paediatric anaesthesia commencing in Mongolia in 1998. (Ganchimeg, 2016).

1.2.2 Present day practice

In the early 2000's, rapid adoption of contemporary anaesthesia methods including sophisticated airway management, utilization of regional and peripheral nerve blocks occurred in anaesthesia practice. It is officially considered the beginning of the modern era of Mongolian anaesthesiology. These improvements were facilitated by collaborative efforts with various countries and organizations, notably the Australian Society of Anaesthetists and the Swiss Surgical team. In response to this, a six month paediatric anaesthesia fellowship training commenced for anaesthesiologists, while short courses designed for anaesthesia nurses were established in the late 1990's(Ganchimeg, 2016).

There was significant progress including neonatal thoracoscopy and laparoscopy in paediatric surgery leading to enhancement of anaesthesia practices aligned with international standards. Moreover, the advancement of paediatric anaesthesia availability and techniques has enabled the performance of paediatric open-heart surgery, angiography, and paediatric organ transplantation surgeries.

Simultaneously, the growing needs for advanced paediatric care and procedural skillset in and beyond operating rooms are being met by the paediatric anaesthesia workforce in Mongolia.

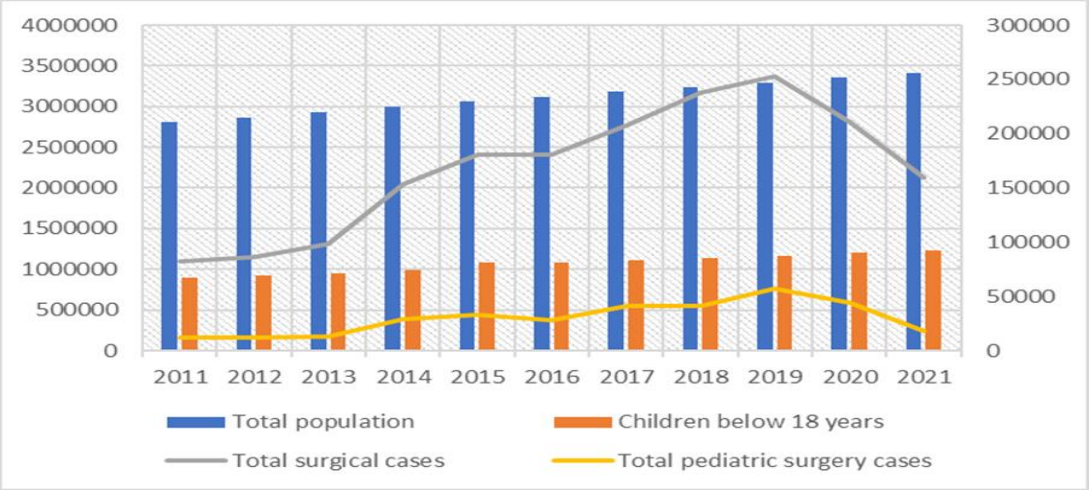
1.2.3 Challenges

There are three primary challenges in Mongolian health services, particularly in paediatric anaesthesia. These have featured throughout the initial establishment of the health care service during the socialist period (James W. Adams, 2007), and continue today.

1.2.3.1 Human resources paucity and centralized burden

Most African and Asian countries face a challenge with low ratio of medical practitioners to patients (Bösenberg, 2007b). In Mongolia, the significant scarcity of human resources is the primary impediment hindering the advancement of paediatric anaesthesia service. The surge in demand for paediatric anaesthesia services is primarily driven by population growth exceeding 1.5% annually and ongoing socio-economic development, as illustrated in Figure 1.

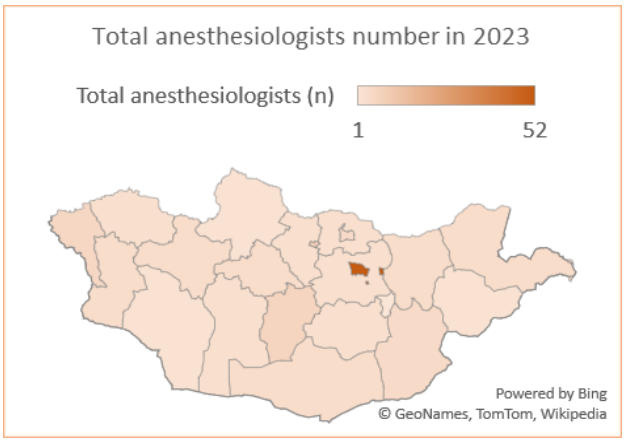
Figure 1: Mongolian total population and children under 18 years between 2011 to 2021(Service, 2023) . Total and paediatric surgical cases during this period (Dorjmyagmar.B, 2021)



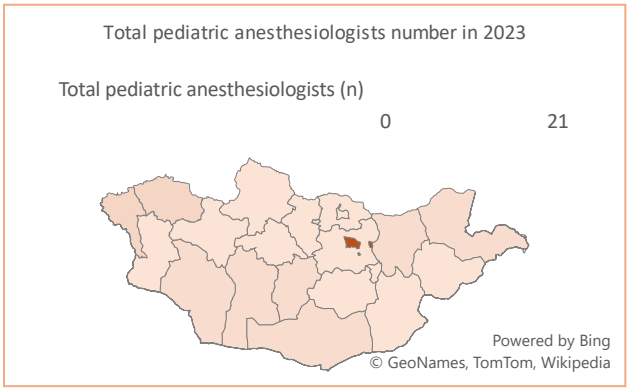
In Mongolia, there are 6.76 physician anaesthesia providers per 100.000 people, which is three times less than the anaesthesia safety benchmark suggested by the Lancet Commission on Global Surgery (LCoGS) (John G Meara & Johanna N Riesel, 2015). In contrast, the United States has 20.82 anaesthesiologists per 100.000 individuals (WFSA, 2021). The shortage is more pronounced for paediatric anaesthesiology teams, encompassing nurses and postoperative care units, particularly in rural areas. However, even in large, centralized hospitals, the availability of such teams may fall below ideal levels due to high patient volume. The situation is anticipated to worsen in the next five years as the relatively low income and heavy workload for Mongolia anaesthesiologists are prompting retirements, emigration, and exits from the profession.

Figure 2: a. Total number of anaesthesiologists by provinces b. Total number of paediatric anaesthesiologist by provinces (Pornarun Charoenraj, 2024)

a.



b.



Most paediatric surgical cases in provincial hospitals are redirected to tertiary level hospitals in Ulaanbaatar, resulting in a concentrated burden on paediatric anaesthesia services. While private hospitals have tried to alleviate this burden, the shortage of specialized paediatric anaesthesia and nursing team members (such as anaesthetists, scrub nurses, post-anaesthesia care nurses, intensivists, etc) hinders the progress of this field.

1.2.3.2 Equipment and medication availability

Essential for ensuring the safety of paediatric anaesthesia is the accessibility of contemporary drugs and equipment, a resource that tends to be restricted in low- and middle-income countries (Bösenberg, 2014). While there has been considerable improvement in Mongolia's access to modern anaesthetic agents like sevoflurane, propofol, ketamine, and isoflurane in most areas, the limited supply, influenced by economic conditions, often compels anaesthetists to resort to cheaper or generic alternatives. Challenges such as budget constraints, rigid supply chains, and the lack of alignment between hospital budgets and patient volume contribute to interruptions in the supply of various medications (Oyun, 2022). Anaesthetists frequently find themselves compelled to opt for alternative drugs towards the end of the fiscal year due to issues related to supply chains and budgets.

The World Federation of Societies of Anaesthesiologists (WFSA) published the initial International Standards for Safe Practice of Anaesthesia in 1992, subsequently reviewed by the World Health Organization's (WHO) Safe Surgery Saves Lives initiative in 2008. Validated by national anaesthesia societies and updated in 2010, these standards delineate the requirements for safe anaesthesia facilities and equipment, categorized as highly recommended, recommended, and suggested (W. W. M. Adrian W. Gelb, Walter Johnson, Alan F. Merry, on behalf of the International Standards for a Safe Practice of Anesthesia Workgroup, 2018). In the context of Mongolian paediatric anaesthesia practice, most but not all these minimum criteria are met, with significant variations depending on the location of practice. Notably, provincial hospitals, and occasionally even tertiary hospitals, lack essential items such as appropriately sized airway devices and monitoring equipment like pulse oximeters and blood pressure cuffs. However, although equipment and medical supplies shortage are emerging practically, we still do not have enough evidence that is studied about availability of anaesthesia equipment and medication availability in the country. In terms of this situation, there is an emerging demand to do study to collect and analyse important information about the current situation of available anaesthesia equipment and medications in provincial and tertiary level hospitals to be compromised.

1.2.3.3 Clinical research

In 2008, a development strategic plan was produced by a collaboration framework of Mongolian Society of Anaesthesiologists and Australian Society of Anaesthetists. It is towards 3 main objectives including advancement of basic anaesthesia training, improvement in postgraduate training and support for academic activities. As a result, patient safety has improved with surgical mortality decreased from 0.53% in 2000 (Total population was 2.388.299 in 2000) to 0.2% in 2015 (Total population was 3.026.864 in 2015) (Lundeg, 2018),(Mongolia, 2024).

However, the strategic emphasis on academic activities lags significantly behind practical clinical activities. Although annual and seasonal national conferences and training sessions are held by the Mongolian Society of Anaesthesiologists, often with international collaboration, research and academic activities cannot accelerate as a practical activity in a purely clinical environment. Officially, the only specialized journal which is named “Anaesthesia, intensive and critical care” publishes seasonal nationwide, yet research articles make up only 10-20% of all those sources. Although other journals such as surgical and medical science allow the publications of Mongolian anaesthesiologists, the number of publications remain low. Less than 10 research articles have been published in international level journals in the last decade. This is quite small compared with the number of clinical anaesthesiologists who are working in the country at present.

The academic aspect of Mongolian anaesthesia has obviously lagged behind the practical aspect in the clinical environment. There can be two main reasons strongly connected with this problem. Firstly, the shortage of human resources does not allow plenty of time for academic purposes of clinical practitioners. Secondly, lack of research and analytic ability could be another cause of academic lag. The increasing number of clinical cases hinders research by anaesthesiologists, and basic research skills such as how to establish research questions and, how correctly collect and analyse data are developed. Language barriers also contribute to the slow pace of improvement in academic anaesthesiology.

1.2.3.4 To Conclude

There is substantial interest not only to advance anaesthesia techniques, but also for developing strategies including safety improvement and mitigate workload imbalances. This involves active encouragement for evidence-based medicine, encompassing crucial and advanced academic research studies in the field of paediatric anaesthesia in Mongolia.

1.3 Importance of clarifying the incidence of anaesthesia related complications in Mongolia

The measurement of mortality and morbidity, and rates of complication are the first crucial steps on a process to continuously improve the quality of care in Mongolian Paediatric Anaesthesia.

Morbidity, mortality and complication rates in Mongolian paediatric anaesthesia are currently unknown. Although anaesthesia-related complications are noted case by case on records that are kept on paper, there are currently no hospital, regional, or national programs in Mongolia that gather and analyse data on anaesthesia and surgical morbidity and mortality rates, and there is a lack of clear information on the underlying causes of these issues.

Over the past decade demand for paediatric anaesthesia service has steadily increased in Mongolia, driven by population increases and socio-economic development. In terms of this growing situation, there is an urgent need to collect and gather data on mortality, morbidity and associated complications in paediatric anaesthesia and obtain the detailed information about common causes which is crucial for clinical staff, policy makers and other stakeholders in Mongolia.

1.4 Aim and scope of the study

This study aims to identify the incidences of anaesthesia-related mortality, and morbidity, to improve prevention of those complications in Mongolia.

Hospital records, including anaesthesia records, will be retrospectively reviewed to determine basic mortality rates in the intraoperative and immediate post-operative periods at the Maternal and Child Health Centre of Mongolia and five provincial hospitals which manage the majority of Mongolian paediatric anaesthesia cases.

Having collected and analysed particular data, we conclude by discussing common causes of those complications and how the quality and safety of paediatric anaesthesia service in Mongolia may be improved most.

1.5 Significance of the study

Complications from anaesthesia techniques can include major disability and death, and key factors contribute to this, such as of equipment, inadequate staffing and associated co-morbidity of children.

For hospitals in most developing countries, it is not always feasible to regularly monitor all vital signs using modern technology, and electronic medical records are limited or absent. Thus, it is imperative to carry out comparative analysis on complications written on the records year by year.

This study's primary outcome is to determine the incidence and type of anaesthesia related complications in the paediatric population who need surgical and other medical services with anaesthesia all around Mongolia.

Having defined complication rates during and after anaesthesia, future work will be included investigation of the causes and factors of those complications.

1.6 Overview of thesis structure

This thesis consists of five chapters.

Chapter one introduces the topic, including a summary of Mongolian paediatric anaesthesia history, and the goals of the study.
Chapter two includes the literature review covering paediatric anaesthesia mortality, morbidity and associated complications since the 2000's. This chapter is based on a systematic review on the topic.
Chapter three covers the research methodology and data analysis utilized in the study.

Chapter four includes the study results and conclusions.

Chapter five summarizes the discussion and future directions of the future work and research in this field.

CHAPTER 2

INTRODUCTION

2.1 Background of systematic review

The most asked question before surgery from parents to paediatric anaesthesiologist is "What are the risks of anaesthesia for my child?" Unfortunately, the studies that have examined the short and long term outcome after anaesthesia are limited (Marsha M. Cohen, 1990). However, anaesthesiologists may still need to discuss the possibility of complications and their approach to preventing these problems with the parents, based on clinical guidelines. Improving our knowledge in this area during the perioperative period is crucial and should start with review of current evidence such as literature review (Asadollah Mir ghassemi, 2015).

Although mortality and morbidity following paediatric anaesthesia have declined substantially over the past several decades, these are still significant issues in the speciality today(Jurgen C. de Graaff, 2015). There are substantial differences in their incidence in different countries, care settings and specialities. They are associated with poor socioeconomic and social outcomes and financial burden. They are highly stressful events for both patients and family members, particularly if cognitive or educational retardation occurs after some complication of paediatric anaesthesia.

Several studies have reported comparable results showing that the incidence of anaesthesia complications is higher in the paediatric population than adults. Children under 1 year of age, premature infants and children with history of prematurity are more at risk during anaesthesia compared with older children (Jurgen C. de Graaff, 2015), (Leopoldo Palheta Gonzalez, 2012).

In this chapter, we intend to collect incident information on anaesthesia related complications in paediatric anaesthesia based on studies conducted over the last two decades.

2.2 Aim

To provide an updated systematic review of mortality, morbidity and associated complications of paediatric anaesthesia.

2.3 Method

2.3.1 Protocol

This review has been performed using "The Preferred Items for Systematic Reviews and Meta-Analyses (PRISMA) "statement as a guide.

2.3.2 Literature Search

The literature search was performed based on MeSH (table 1) between October and November 2022. The following electronic databases have been used in the time frame between 2000 and 2022: MEDLINE (OVID interface), CINAHL (EBSCO interface), Cochrane and Pubmed.

Table 1: MeSH strategy for literature search

Concept 1: Anaesthesia **Key words:**	**"Anesthesia"[Mesh] OR "general anesthesia"[tw] OR "general anaesthesia"[tw] OR "pediatric anesthesia"[tw] OR "paediatric anesthesia"[tw] OR "pediatric anaesthesia"[tw] OR "paediatric anaesthesia"[tw] OR "regional anaesthesia"[tw] OR "regional anesthesia"[tw] OR "combined anesthesia"[tw] OR "combined anaesthesia"[tw] OR "spinal anesthesia"[tw] OR "spinal anaesthesia"[tw] OR "epidural anesthesia"[tw] OR "epidural anaesthesia"[tw] OR "anaesthesia"[tw] OR "anesthesia"[tw] OR "local anaesthesia"[tw] OR "local anesthesia"[tw] OR "mask induction" [tw] OR "intravenous induction" [tw] OR "total intravenous anesthesia"[tw] OR "total intravenous anaesthesia"[tw] OR "target controlled infusion"[tw] OR "sedation"[tw] OR "mild sedation"[tw] OR "moderate sedation"[tw] OR "deep sedation"[tw] OR "pediatric sedation"[tw] OR "paediatric sedation"[tw] OR "pediatric sedation"[tw] OR "paediatric sedation"[tw] OR "procedural sedation"[tw] OR "infant sedation"[tw] OR "inhalation anaesthetic*"[tw] OR "volatile anesthetic*"[tw] OR "anaesthetic*"[tw] OR "anesthetic agent*"[tw]** **MeSH: "Anesthesia"[Mesh]**
Concept 2: Paediatric **Key words:**	**"Anesthesia"[Mesh] OR gestational age[tw] OR "pediatric*"[tw] OR "paediatrics patient*"[tw] OR "early childhood" [tw] OR "postmenstrual age"[tw] OR "infant"[tw] OR "full term infant"[tw] OR "term infant"[tw] OR "preterm infant"[tw] OR "premature infant"[tw] OR "newborn"[tw] OR "neonate"[tw] OR "toddler"[tw] OR "preschool age"[tw] OR "middle childhood" [tw] OR "school age" [tw] OR "tween*" [tw] OR "adolescence" [tw] OR "teen*" [tw] OR "teenager*" [tw]**
Concept 3: Complication **Key words:**	**("Morbidity"[Mesh]) AND "Mortality"[Mesh] OR "mortality"[tw] OR "death"[tw] OR "morbidity"[tw] OR "complication*"[tw] OR "problem*"[tw] OR "threat to life"[tw] OR "harm"[tw] OR "adverse event*"[tw] OR "anesthesia related event*"[tw] OR "serious event*"[tw] OR "serious complication*"[tw] OR "airway injury"[tw] OR "airway management difficulty*"[tw] OR "abnormal laboratory value*"[tw] OR "cardiac arrest*"[tw] OR "cardiopulmonary complication*"[tw] OR "sever hypoxia"[tw] OR "hypoxemia"[tw] OR "neurological complication*"[tw] OR "nervous system injury*"[tw] OR "other injury*"[tw] OR "operating room fire"[tw] OR "medication event*"[tw] OR "drug error*"[tw] OR "wrong drug"[tw] OR "medication error*"[tw] OR "medication event*"[tw] OR "allergic reaction"[tw] OR "equipment issue*"[tw] OR "eye injury*"[tw] OR "malignant hyperthermia"[tw] OR "disability"[tw] OR "organ function"[tw] OR "disfigurement"[tw] OR "impaired neurologic function"[tw] OR "impaired cognitive function*"[tw] OR "regional anesthetic block"[tw] OR "regional anaesthetic block"[tw] OR "temporary paralysis"[tw] OR "paraesthesia"[tw] OR "impaired auditory function"[tw] OR "impaired visual function"[tw] OR "neurophysiologic monitoring" [tw] OR "postoperative complication*"[tw] OR "perioperative complication*"[tw] OR "extracorporeal membrane oxygenation" [tw] OR "vasopressor"[tw] OR "inotropic"[tw] OR "postoperative ventilation"[tw] OR "wrong surgery"[tw] OR "pressure injury"[tw] OR "intraoperative recall"[tw] OR "intraoperative awareness"[tw] OR "unplanned inpatient admission"[tw] OR "unplanned intensive care unit admission"[tw] OR "additional procedure*"[tw] OR "central line insertion"[tw] OR "central line placement"[tw] OR "artery line"[tw] OR "intraoperative intubation"[tw] OR "required additional surgical treatment"[tw] OR "adverse effect*"[tw] OR "intraoperative complication*"[tw] OR "intraoperative diagnosis"[tw] OR "intraoperative complication*"[tw] OR "intraoperative complication*"[tw] OR "intraoperative mortality"[tw] OR "intraoperative therapy"[tw] OR "preoperative fever" [tw] OR "perioperative fever" [tw] OR "post operative fever" [tw] OR "sepsis" [tw] OR "septicaemia" [tw]**
Concept 4: Medical condition **Key words:**	**("Disease"[Mesh]) AND "Comorbidity"[Mesh] OR "medical history" [tw] OR "preoperative history" [tw] OR "perioperative history" [tw] OR "postoperative history" [tw] OR "recovery history" [tw] OR "medical condition*" [tw] OR "medical history" [tw] OR "previous surgery" [tw] OR "previous anesthesia" [tw] OR "previous complication*" [tw]**
Concept 5: Study **Key words:**	**"Research"[Mesh] OR "multicentre study*"[tw] OR "observational study*"[tw] OR "cohort study*" [tw] OR "prospective study*" [tw] OR "retrospective study*" [tw] OR "medical audit*"[tw] OR "clinical trial*" [tw] OR "RCT" [tw] OR "randomised clinical trial*" [tw] OR "systematic review" [tw]**

2.3.3 Eligibility and inclusion criteria

In this chapter, review was aimed to analyse some important information that has been reported in previous studies while updating systematic review of mortality, morbidity and associated complications of paediatric anaesthesia. Eligibility for review included availability of information about all complications, mortality and morbidity during and after all anaesthesia techniques that have been performed on paediatric patients (<18 years old).

Randomized control trials, retrospective and prospective cohort studies, as well as studies that have been performed with combined methods were included. All studies were peer reviewed in English language. Data regarding prevalence and incidence should be clearly mentioned in those studies.

2.3.4 Exclusion criteria

- Study population included adults
- No English translation
- No data regarding prevalence
- Too Specific (Compared two techniques or medications)
- Out of time frame (Before 1st of January 2000, after 1st of December 2022)

2.3.5 Study selection

Two level assessments have been done on all articles that are obtained after initial search. All research papers were evaluated by titles and abstracts in the first and basic assessment level which removed articles that were not relevant as per inclusion and exclusion criteria. Subsequently, the remaining studies and specific research articles were reviewed individually, to further assess their suitability for inclusion. The full text screening was done on remaining articles by the lead investigator. (Table 2)

2.3.6 Data collection

Following the development of a data collection form on Microsoft Excel, data extraction was performed from full texts. Basic information including title, author, publication year and journal name, study design and sample size have been extracted while study quality has been evaluated through the NewCastle-Ottawa Scale manual coding (Appendix A).

Morbidity includes perioperative and postoperative complications and mortality related data has been collected with variables such as age, gender, ASA classification, type of anaesthesia and surgery, as well as elective versus emergency.

2.3.7 Classification of extracted data

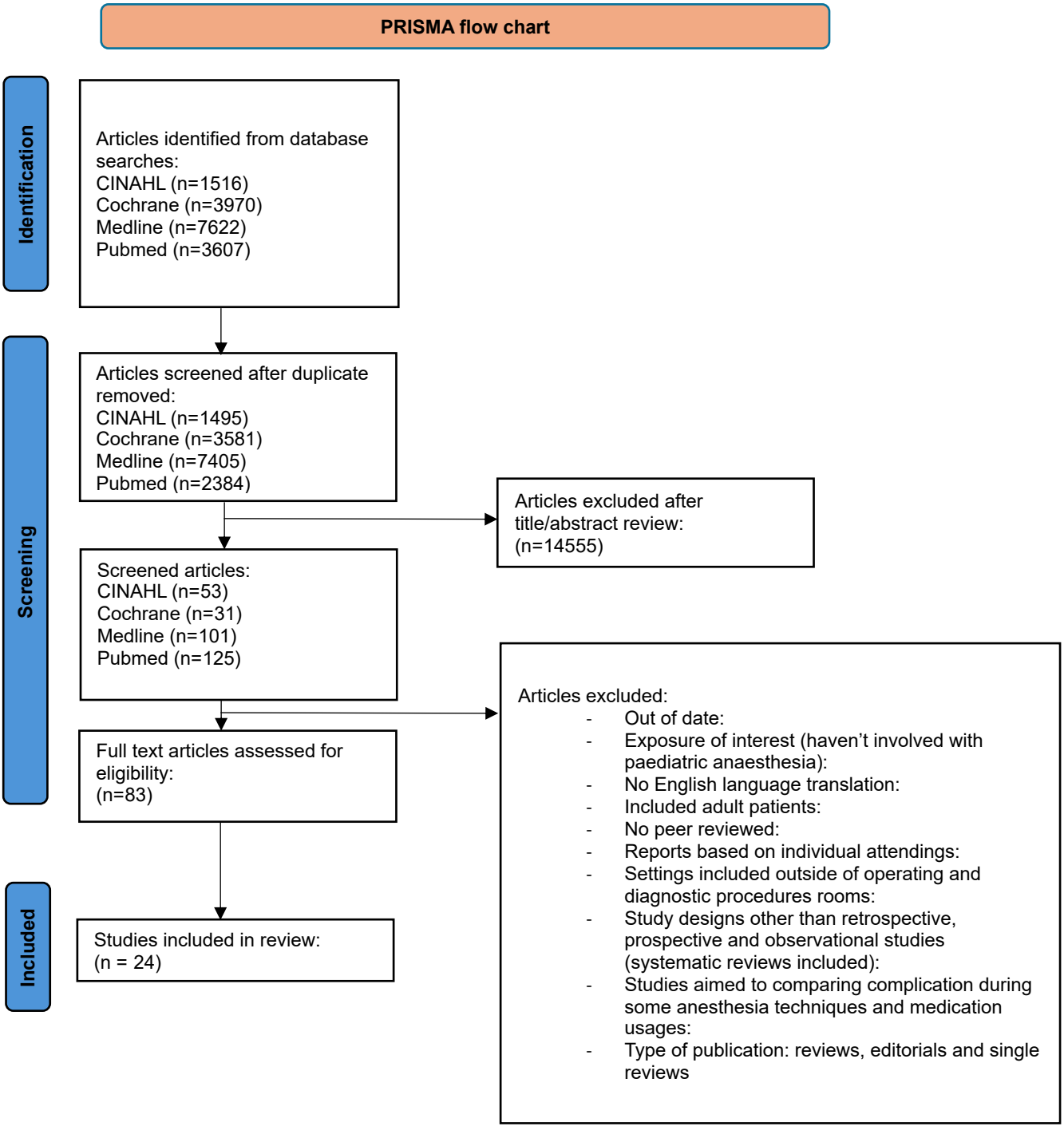
Heterogeneous studies have been collected in this study. Data classification was done using two different main groups:

- Organ and systems related complications
- Other complications

2.4 Result

Overall, 16715 published articles have been collected as an identification after advanced search on all searched platforms. 1850 publications have been removed after the duplicate detection process on EndNote 20, whereas 14555 articles have been excluded by title and abstract review. Based on inclusion and exclusion criteria 24 out of 83 studies which have been assessed by eligibility criteria are included in this review. (Figure 3).

Figure 3: PRISMA flow chart



2.4.1 Characteristics of included studies

Single and multi-centre studies were included in this study:12 single centre (1,2,3,5,7,8,9,12,15,19,22,24) and 12 multi-centres (4,6,10,11,13,14,16,17,18,20,21,23) respectively. Single complication papers numbered 10 (6,8,12,13,15,17,18,19,20), which have focused on cardiac arrest, death, awareness during anaesthesia, delirium after anaesthesia and general hypoxaemia, as well cerebral oxygenation. Multiple

complications have been described in 14 (1,2,3,4,5,9,10,11,14,16,21,22,23,24) included studies in this review. Included papers come from a variety of different countries and regions. Table 2 illustrates characteristics of all studies.

Table 2: Characteristics of included studies of literature review

Study ID	Primary author	Sample size	Study design	Country	Number of centres
1	Edomwonyi et al. (2006) (N.P Edomwonyi, 2006)	270	Prospective	Benin	1 Multiple complications
2	Saynhalath et al. (2021) (Rita Saynhalath, 2021)	150	Retrospective cohort	America	1 Multiple complications
3	Kannampallil et al. (2021) (Thomas Kannampallil 2021)	78321	Retrospective cohort	America	1 Multiple complication
4	Walker et al. (2018) (Benjamin J. Walker, 2018)	91701	Prospective observational	America	Multi centre Multiple complications
5	Benzon et al. (2019) (Benzon, 2019)	35291	Retrospective	America	1 Death, seizure, prolonged LOS
6	Malviya et al. (2009) (Shobha Malviya, 2009)	1784	Prospective	America	Multicentre (3) Single complication (Awareness)
7	de Graaff et al. (2013) (Jurgen C. de Graaff, 2013b)	8852	Prospective	Netherlands	1 Hypoxia
8	Hohn et al. (2019) (Andreas Hohn, 2019)	36243	Retrospective cohort	Germany	1 Cardiac arrest
9	El-Metainy et al. (2011) (S. El-Metainy, 2011)	1465	Prospective cohort	Egypt	1 Multiple complications
10	Hansen et al. (2019) (Tom G. Hansen, 2019)	1520	Retrospective	European countries	Multicentre Multi complications
11	Engelhardt et al. (2019) (T. Engelhardt, 2019)	1520	Prospective observational	European countries	Multicentre Multi complications
12	Jansen et al. (2021) (Gerrit Jansen, 2021)	22650	Retrospective observational	Germany	1 Cardiac arrest
13	Olbrecht et al. (2018) (Vanessa A. Olbrecht, 2018)	453	Prospective observational	America, Australia, China and Italy	Multicentre Cerebral hypoxia
14	Disma et al. (2021) (Nicola Disma, 2021)	5609	Prospective observational	European countries	Multicentre Multiplication
15	Lee-Archer et al. (2021) (Paul F. Lee--Archer, 2021)	4424	Prospective observational	Australia	1 Delirium
16	Bunchungmongkol et al. (2007) (Bunchungmongkol, 2007)	25098	Prospective descriptive	Thailand	Multicentre Multiplication
17	Zoumenou et al. (2010) (Euge`ne Zoumenou, 2010)	512	Retrospective	Benin	Multicentre Cardiac arrest, death
18	Christensen et al. (2017) (Christensen, 2017)	26	Retrospective audit	America	Multicentre Cardiopulmonary arrest
19	Gonzalez et al. (2014) (Leopoldo P. Gonzalez, 2014)	10649	Prospective observational	Brazil	1 Cardiac arrest
20	Newton et al. (2020) (Mark W. Newton, 2020)	6005	Prospective cohort	Kenya	Multicentre Cardiac arrest
21	Michel et al. (2018) (Fabrice Michel, 2018)	621	Prospective observational cohort	European countries	Multicentre Multi complications
22	Murat et al. (2004) (Isabelle Murat, 2004)	24165	Prospective	France	1 Multiplication
23	Walker et al. (2022) (Suellen M. Walker, 2022)	876	Prospective observational	European countries	multicentre Multiplication
24	Tsuboi et al. (2022) (Kaoru Tsuboi, 2022)	75	Retrospective cohort study	Tokyo	1 Multiplication

2.4.2 Organ and systems related complications

Respiratory complication: Studies that have focused on respiratory complications have been included (7,8,9,15,16,17,20,22,27,29) in this review. Complications occurrence during different anaesthesia stages have been described in 2 studies whereas 9 papers gave summarised information on respiratory complication incidences during anaesthesia. Incidences of respiratory complications are common in young age children, especially in premature babies. Moreover, other common factors included comorbidities such as obesity. Children with ASA 3 are more vulnerable for respiratory problems. 3 (22,27,28) out of 11 studies mention that aspiration is one of the main causes while 2 (27,28) of them describe those surgeries such as ENT and maxillofacial as factors associated with respiratory complications.
Outcomes have been described including post operative intubation and prolonged hospitalization in intensive care units. Although cause of mortality incidence is unclear, 3 (9,20,22) studies represent mortality incidence rate after hypoxic events. (Table 3).

Table 3: Studies on respiratory complications

	Design	n	Age	Prevalence	Factors	Outcome
Edomwonyi, 2006	Prospective	270	0-18 year	Periop-10.8% Postop-9.23%	Young age Prematurity UTI	Intubation Prolonged hospital admission
Saynhalath, 2021	Retrospective	150	0-18 year	12.8%	UTI, COVID-19	Intubation, ICU admission Oxygen
Kannampallil, 2021	Retrospective	78321	0-18 year	1.8%	Common factors	Mortality, No specific info
El-Metainy, 2011	Prospective	1465	2-16 years	31%	Comorbidities, UTI	Prolonged hospital admission
Hansen, 2019	Retrospective	1520	0-18 year	3.2%	No specific info	No specific info
Engelhardt, 2019	Prospective	1520	0-18 year	1.83%	Young age Prematurity UTI, Comorbidities	Intubation, ICU admission Oxygen, Pulmonary oedema Tracheostoma
Disma, 2021	Prospective	5609	Under 3 m	3.56%	Prematurity Other comorbidities	Mortality, NICU admission
Bunchungmongkol, 2007	Prospective	25098	0-16 year	1.1%	Aspiration, Prematurity UTI, Comorbidities	Mortality, ICU admission
Michel, 2018	Combined	621	3m-7years	Ind-4.02% Main-2.8% Recovery-4.14%	Aspiration, Prematurity UTI, Comorbidities, Surgery	Intubation, ICU admission Oxygen,
Murat, 2004	Prospective	24165	0-18 year	1.4%	Aspiration, Prematurity UTI, Comorbidities, Surgery	Intubation Prolonged hospital admission
Walker, 2022	Prospective	876	Neonates	11.4%	No specific info	Intubation, ICU admission Oxygen

UTI-Upper Respiratory Infection, ICU-Intensive Care Unit, NICU-Neonatal Intensive Care Unit

Cardiac complication: The most common cardiovascular complications were hypertension, hypotension, arrhythmia, bradycardia, and cardiac arrest in 8 studies (7,9,16,17,20,22,28,29) which have been included in this review. Young children, especially premature babies are vulnerable to cardiovascular problems during

anaesthesia. Importantly, hypoxemia (7,9,17,22,28,29) due to respiratory problems and aspiration (22,28) was the main cause of arrhythmia, bradycardia and cardiac arrest. Some comorbidities such as sepsis and dehydration were mentioned in two studies (17,20) as the main cause of hypotension and bradycardia. (Table 4).

Table 4: Studies on cardiovascular complications

	Design	n	Age	Prevalence	Factors
Edomwonyi, 2006	Prospective	270	0-18 year	Periop-27.7%% Postop-30.8%	Young age, Prematurity, Dehydration, Medication induced, Hypoxemia
Kannampallil, 2021	Retrospective	78321	0-18 year	2.2%	Common factors
Hansen, 2019	Retrospective	1520	0-18 year	14%	No specific info
Engelhardt, 2019	Prospective	1520	0-18 year	1.3%	Hypoxemia, Young age Prematurity, Sepsis, Dehydration etc
Disma, 2021	Prospective	5609	Under 3 m	60.7%	Prematurity Other comorbidities
Bunchungmongkol, 2007	Prospective	25098	0-16 year	3.9%	Hypoxemia, Prematurity UTI, Comorbidities
Murat, 2004	Prospective	24165	0-18 year	0.14%	Aspiration, Prematurity UTI, Comorbidities, Hypoxemia
Walker, 2022	Prospective	876	Neonates	16.9%	No specific info

UTI-Upper Respiratory Infection
Common cardiovascular problems during anaesthesia: Hypotension, Hypertension, Arrhythmia, Bradycardia, Cardiac arrest etc

Cardiac arrest and Mortality: 8 studies have focused on cardiac arrest, with some studies also reporting on mortality following arrest. Most studies have described perioperative cardiac arrest cases while 2 papers (7,22) gave the specific information about occurrence of cardiac arrest in particular stages of anaesthesia such as perioperative and postoperative. The main root causes of anaesthesia related mortality and cardiac arrest are linked to hypoxemia, congenital heart diseases, hypovolemic shock due to haemorrhage, comorbidities such as sepsis, as well as young age, especially premature babies. Additionally, the role of inadequate supervision of anaesthesia staff was identified as a contributor in one of the papers (24). (Table 5)

Table 5: Studies on cardiac arrest and mortality

	Design	n	Incidences of cardiac arrest	Incidences of mortality	Root cause and factors
Edomwonyi, 2006	Prospective	270	Induction-1, Intraop-1		Acute hypoxaemia, RDS
Jansen, 2021	Retrospective	22650	Perioperative-18	8	Septic and haemorrhagic shock, diff/airway, hypoxaemia, allergy
Disma, 2021	Prospective	5609	Periop-7	No intraoperative death, Postop death-173	Immaturity, congenital, hypoxia, CVS instability etc
Bunchungmongkol, 2007	Prospective	25098	Intraop-23, postop-33	58	No data
Zoumenou, 2010	Retrospective	512	8	5	Hypoxaemia
Christensen, 2017	Retrospective	26	26 (14 anaesthesia related)	1	Inadequate supervision
Gonzalez, 2014	Retrospective	10649	19	9	Sepsis, congenital disease, haemorrhagic shock
Newton, 2020	Prospective	6005	No dat	77	No data

RDS-respiratory distress syndrome

Neurological complications: Convulsion occurring during anaesthesia are described in 2 (16,22) papers whereas severe neurological damage (17), prolonged unconsciousness (F. E.Kelly) and cerebral desaturation (19) have been described in two separate studies. (Table 6)

Table 6: Studies on neurological complications

	Design	n	Prevalence	Complications	Common actions
Edomwonyi, 2006	Prospect	270	18.5%	Prolonged unconsciousness, restlessness, pain, shivering	Oxygenation, advanced control, ICU admission, pain management, warm up, in some instance-no action needed.
Hansen, 2019	Retro	1520	1%	Convulsion	
Engelhardt, 2019	Prospect	1520	2%	Neurological damage	
Olbrecht, 2018	Combined	453	43%	Mild Cerebral desaturation	
Bunchungmongkol, 2007	Prospect	25098	0.04%	Convulsion, coma	

ICU-Intensive Care Unit

Anaesthesia related delirium and awareness: Delirium in children after anaesthesia has been described in one study (21). (Table 6) Additionally, awareness has been described in a study (12) as a complication of anaesthesia. (Table 7)

Table 7: Studies on delirium and awareness

	Prevalence	Assessment	Outcome
Lee-Archer et al. (2021)	1.7% in 4424	Paediatric Aesthetic Emergence Delirium (57 cases)	Postoperative behaviour changes
		Cornell Assessment of Paediatric delirium (17 cases)	
Malviya et al. (2009)	0.8% in 1187	Questionnaire	Short term psychological distress

2.4.3 Other complications

Although anaphylaxis is rare severe complications are reported in two studies (17,22), and serious allergic problems have been mentioned in four studies (16, 17, 22, 28). Triggers included inhalation agents, antibiotics and muscle relaxants that are commonly used medication in the anaesthesia field. Some outcomes included neurological damage and prolonged intensive care unit admission.

Nausea and vomiting incidences were commonly described after ophthalmic and ENT surgeries, whereas insufficient fasting was associated with those problems in only one study (L. C. Finch). Aspiration incidences have been investigated in three studies (15,16,17). This complication was noted to be common in obese and overweight children during ENT surgeries. Problems such as pneumonia and desaturation are noted complications during and after aspiration.

Premature infants are vulnerable to hypoglycaemia and hypothermia problems (7,20) which occur more frequently during long cases in sick infants.
Virus infection and sepsis were common factors of fever during anaesthesia, but only in one study (2).

2.5 Discussion

This chapter aims to provide a qualitative synthesis of retrieved articles, with 24 studies included in this systematic review. This review demonstrates that the most common complications were respiratory events followed by cardiovascular problems in paediatric anaesthesia practice. Although most studies note the association with recent or current upper respiratory infection, comorbidities, and prematurity, two articles (10,22) did not give proper information about factors of respiratory events. Acute and severe hypoxic situations are often the cause of cardiac complications such as bradycardia, hypotension and arrhythmia which are reported in 3 studies (3, 14, 16).

In addition, additionally on above causes, aspiration, allergic reaction, haemorrhage during surgery and hypovolemia trigger cardiac problems during anaesthesia. Studies suggested that advancing standard monitoring including pulse oximetry, capnography and electrocardiography in all periods of anaesthesia and excellent assessment of patients can decrease anaesthesia related complications including mortality. Experience of anaesthetists (2) could be related with incidence of complication and inadequate supervision during critical event as reported by Christensen *et al.* is linked with increased mortality.

Findings about neurological complication included pain, shivering and convulsion are reported as preventable complications, by using continuous and cautious assessment of children throughout the perioperative period. Moreover, an important finding obtained during this review is mild cerebral desaturation is common (43%) in paediatric patients reported by Olbrecht *et al* but that severe cerebral desaturation was much less common (<2%). Performing regional anaesthesia techniques such as regional and peripheral blocks under general anaesthesia while considering the vulnerable age of children may be a safe way to prevent neurological damage and toxicity (4,10).

Awareness has long term effects including anxiety, sleep destruction and traumatic stress. Regarding reports from the Royal College of Anaesthetists, four in every ten patients who had awareness experience during anaesthesia have long term neurological and mental problems (Royal College of Anaesthetists, 2014). There were not any reviews including associated paediatric awareness and delirium in paediatric anaesthesia. Two studies that reported complications have been included in this review. Maintaining sufficient depth of anaesthesia and taking into account the procedural duration may reduce awareness and delirium during and after anaesthesia, because studies suggested that light anaesthesia (6), moreover short procedures (15) might lead to these psychological distresses.

Although comorbidities including obesity, sepsis and organ failure etc are additional common factors in serious events, surgical techniques and length, hospital level, time of day, and weekday versus weekend can affect anaesthesia performance and the rates of complications.

2.6 Limitations

This review has several limitations. The search strategy was designed with a wide variety of key words to include all relevant research, but invariably some studies may have been that should be potentially included in this review.

Most articles focused on respiratory and cardiovascular complications, which may explain why most common complication events were respiratory and cardiac. It may be considered as reporting bias.
Moreover, the filtering process based on research strategy can be the cause of missed information exclude non-English papers. Also, inconsistent reporting of significant complications, different ways of measuring and reporting systems of complications' rates can be considered as reasons for bias.

2.7 Conclusion

This review's findings suggest that improvements in clinical monitoring, and preoperative assessment of patients may be concrete, implementable ways to reduce the complications noted here. Specifically, improved access to standard and advanced methods of monitoring that are crucial for paediatric anaesthesia, may reduce possible complications. Additionally, assessing and evaluating a patient's condition through a more formal pathway may give us opportunities for prevention of some complications, and to be better prepared for the management of those complications should they occur.

2.8 Ethical approval

This review study does not require ethical approval from the board.

CHAPTER 3

RESEARCH METHOD AND ANALYSIS

3.1 Introduction

Multi centre research projects such as NECTARINE (NEonate – Children's Tudy of Anaesthesia pRactice IN Europe) and APRICOT (Anaesthesia PRactice in Children Observational Trial) in European countries have been successfully completed, and APRICOT and PEACH (PEri-Anesthetic morbidity in CHildren) studies in Asian countries are both in progress, with all focused on the study of risk factors and complications in paediatric anaesthesia. However, such large studies have not been conducted in Low- and Middle-Income Countries (LMIC).

In developing countries, the proportion of children in the population is more than 50% in particular countries, and about 85% of those children receive surgical care and treatment in some way before their 15th birthday. (Halliday, 2015). On the other hand, in high income countries, paediatric surgery and anaesthesia complications occur less than 1 per 10,000 children, and cardiovascular and respiratory complications are predominant (Jurgen C. de Graaff, 2021). Therefore, there is an increasing need for the study of paediatric anaesthesia complications in many countries, especially in LMICs. The study of mortality, morbidity and associated complications (MMC) can decrease risk factors and the number of complications themselves, whilst improving the quality of paediatric anaesthesia (Shobha Malviya, 2009).

Although anaesthesia methods, techniques, controls, and drug usages have improved significantly over the past few decades, MMC remains a major concern for this field (Jurgen C. de Graaff, 2013b). This is because the morbidity and mortality of children due to anaesthesia still varies in each country depending on the availability of specialized staff and the conditions that provide the care while it gives tremendous stress to children's families. In some cases, a mental and cognitive retardation occur after some anaesthesia complications (Davidson, 2011).

As the population of Mongolia increases every year, the number of children under the age of 18 in the population reached 1,338,033 in 2022 (Otgonchimeg.B;, 2022). Along with this, the number of children who receive health services including surgical care continues to increase every year. In 2022, the number of children's surgeries at the National Medical Centre alone reached 13,371. Along with these increases is the increases ability to deal with more complex pathologies (heart disease etc) and so the proportion of patients undergoing more high-risk anaesthesia will be expected to increase (Bunchungmongkol, 2007), (Tom G. Hansen, 2019).

Research into mortality, morbidity and complications in Mongolia is not only vital for anaesthesiologists, but also crucial for researchers, children's families, and other stakeholders. In Mongolia, the process of anaesthesia and related complications and risks are recorded on paper-based records that are difficult to access, and since there is no unified registration system, it has not been possible to measure it up till now.

Whilst the number of children's anaesthetics increases in Mongolia, there has not been any research into anaesthesia-related complications, morbidity, and mortality. Addressing this deficit is the focus of this body of work.

3.2 Summary about purpose of the study:

To identify and examine the type of complications that occur in the perioperative and postoperative periods of paediatric patients in Mongolia.

The main objective is determining the incidence of complications, their type and the contributing risk factors in paediatric patients having anaesthesia in Mongolia.

3.3 Hypothesis of study

We hypothesize that mortality, morbidity, and complications in Mongolian paediatric anaesthesia would follow similar patterns to those seen in LMIC. Respiratory complications would be a common issue around all anaesthesia period followed by cardiovascular problems. Although cardiac arrest can occur in all children, it has occurred more commonly in neonates which are regarded as the most vulnerable paediatric population.

The particular MMC in the pre and post operative period of paediatric anaesthesia are affected by the child's age, type of surgery, anaesthesia method and pre-anaesthesia physical status of children.

Pre-anaesthesia assessment, proper preparation for anaesthesia, anaesthesiologist's experience and, training have a positive effect on reducing the number of problems around the anaesthesia, whereas cold and harsh weather, comorbidity status and degree of morbidity will tend to increase the incidence of MMCs.

Predictors of MMC could be related to being under or overweight, gestational age and status of underlying diseases.

3.4 Method

Mongolia has been divided into five regions that are not integrated officially, but that have been used for economic development purposes since beginning of 2000's (Algaa, 2020), (Parliament, 2001).Regions include provinces that are in particular areas.

Regions and provinces are below:

- Western region (Bayan-Olgii, Gobi-Altai, Zavkhan, Uvs and Khovd)
- Eastern region (Sukhbaatar, Khentii and Dornot)
- Central region (Govisumber, Darkhan-Uul, Dornogovi, Umunugovi, Selenge and Tuv)
- Khangai region (Arkhangai, Bayankhongor, Bulgan, Orkhon, Uvurkhangai and Khuvsgul)
- Ulaanbaatar (Capital city is individually considered as one of region)

Multicentre retrospective cross-sectional study was performed at the main national children's hospital and five provincial hospitals with a paediatric surgical service. Anaesthesia related records between 1st of January 2018 to 31st of December 2022 have been studied for all these hospitals, representing the majority of paediatric anaesthetics in the country.

Gendenjamts.N memorial The National Centre for Maternal and Child Health of Mongolia (NCMCH) is the main hospital that specializes in professional health services

for children and women. This hospital represents paediatric anaesthesia service of the Ulaanbaatar region, because 19.8% to 41.3% of all paediatric cases, which is 4.5% to 6.9% of all cases of country including adult and children both were performed in this urban area centralized at NCMCH in the last five years before 2023. (Table 7)

Table 8: Number of performed surgeries (paediatric and adult) in Mongolia and NCMCH between 2018 to 2022 (Gantsetseg.Kh, 2018), (Gantsetseg.Kh;, 2019),(Dorjmyagmar.B;, 2020),(Dorjmyagmar.B, 2021), (Otgonchimeg.B;, 2022). Percentages are in comparison to the total of surgeries each year.

All surgical cases including paediatric cases between 2018 to 2022

	2018		2019		2020		2021		2022	
	n	%	n	%	n	%	n	%	n	%
All surgeries	237970	100%	252723	100%	211142	100%	159831	100%	152712	100%
Urban area	196801	82.7%	217595	86.1%	170392	80.7%	120033	75.1%	111632	73.1%
Provincial area	41169	17.3%	35128	13.9%	40750	19.3%	39798	24.9%	41080	26.9%
Paediatric cases										
	41170	17.3%	56791	22.5%	44615	21.10%	18075	11.30%	Not available	
The National Centre for Maternal and Child Health										
	11137	4.7%	11249	4.5%	10599	5%	7466	4.7%	10472	6.9%

About five provincial hospitals, selection criteria have been created based on three main indicators that are number of performed paediatric surgical cases, availability of specialized paediatric anaesthesiologists and complete records of incidents and number of surgical cases. (Figure 4) Two hospitals (Provincial hospitals in Bayankhongor and Uvurkhangai provinces) attended from the Khangai region. Regarding the number of cases and availability of specialised paediatric anaesthesiologists, selecting two hospitals from this region is beneficial for improvement of study sample quality. Moreover, anaesthesiologists who are performed as a paediatric anaesthesiologist by updated training curriculum are currently working.

3.4.1 Ethical approval

Two stages to obtain ethical approvals from all study attended hospitals have been gone through local regulation policy of clinical research successfully for 6 months. Firstly, we have introduced detailed information including advantages, disadvantages and how research projects will be processed in person and via telemedicine, as well as zoom meetings to academic commissions of all hospitals respectively.

After approval of academic commissions, we obtained ethical approval from ethical commissions at the particular hospitals. In this second stage, we had to inform them about all information relevant to research ethical issues.

Hospitals that are confirmed to give ethical approval:

- Paediatric Hospital, National Centre for Maternal and Child Health of Mongolia (NCMCH)
- Sharav.Kh memorial diagnostic and treatment centre of Umnugobi province, Umnugovi, Mongolia (DTCUG)
- Dornod Medical Centre, Dornod, Mongolia (DMC)
- Bayan-Ulgii province General Hospital, Bayan-Ulgii, Mongolia (BUGH)
- Regional Diagnostic and Treatment Centre in Uvurkhangai province, Uvurkhangai, Mongolia (RDTCUKh)

- Magsar.Ts memorial Bayankhongor province General Hospital, Bayankhongor, Mongolia (BKhGH)

3.4.2 Data collection:

The data collection tool was developed based on literature review and input from experienced attending paediatric anaesthesiologists. The study included all paediatric surgery cases that have used general, regional anaesthesia, and sedation techniques during study periods. Data was collected via chart review process and prespecified questions from all anaesthesia related paper records including recovery room and intensive care unit records.

All anaesthesia related records were manually gathered from hospital archives for data collection purposes. Research team has been settled to scan and skim the paper-based records for 3 months at the National centre for Maternal and Child Health of Mongolia. Study data were collected and managed using REDCap electronic data capture tools hosted at the University of Sydney.

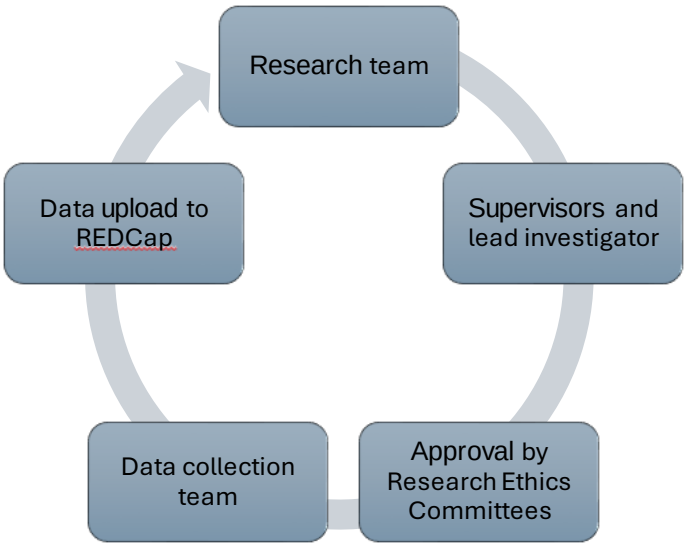
Anaesthesiologists working at provincial hospitals have collected data information of anaesthesia related complications after the video conference meeting on the data collection process. After Study data were collected on GOOGLE sheet (some anaesthesiologists do not have access to REDCap), using REDCap to manage data from provincial hospitals.

3.4.3 Brief information about role of the researchers:

Lead investigator plays the main role for collecting the main literature review information to create the data collection tool, as well as manage data collection process and analysis under professor's supervision (Associated Professor Dr. Justin Skowno and Dr. Reza Kahlaee).

Research team in Ulaanbaatar includes 6 members at NCMC to collect and upload data to REDCAP. Teams in provincial hospitals have two members to work on anaesthesia related records of previous years under supervision of the lead investigator. (Figure 4)

Figure 4: Team organization



3.4.4 Data Analysis:

More than 80 variables are reported from patient records with recorded complications during and after anaesthesia. Variables have been categorized in various groups. Groups are below:

- Complication types: respiratory, cardiovascular etc
- Time period: preoperative, intraoperative etc

All uploaded data has been analysed on Jamovi 2.3.21 statistical data analysing tool of The University of Sydney. We have done descriptive analysis on all categorical data. Frequency of complications has been calculated as dividing the number of complications by the total number of paediatric cases in study period. It has been calculated in special groups including age groups, ASA status groups and anaesthesia periods etc respectively.

3.5 Final paragraph:

Obtaining ethical approval and data collecting process have been carried out in accordance with the local and national policy and regulations. In the next chapter, we will discuss the results of data analysis in the subchapters which are related to common anaesthesia complications in Mongolia paediatric anaesthesia field individually.

CHAPTER 4

RESULT, CONCLUSION, AND SUMMARY

4.1 Introduction

The proportion of children in the population is around 50% or higher, and about 85% of those children receive surgical care and treatment in some way before their 15th birthday in developing countries (Bösenberg, 2007a). In Mongolia, although paediatric anaesthesia techniques, monitoring during anaesthesia and medications that we use routinely have improved and been updated, anaesthesia related complications still occur. There is thus a need to study the incidence of anaesthesia complication in Mongolia, because paediatric anaesthesia cases have increased, while the overall population has been expanding in recent decades.

In this chapter, results of this study will be illustrated in relevant subchapters, while tables and graphs are used to show comprehensive and complex outcomes.

4.2 Incidences of anaesthesia related complications in Mongolian paediatric anaesthesia

60546 cases were performed between 2018 to 2022 at the tertiary and provincial hospitals, and from those 640 anaesthesia records identified as having complications recorded in them. 50923 paper-based anaesthesia relevant records during the given period from the National Centre for Maternal and Child Health of Mongolia, whereas 9623 case records were from attended provincial hospitals examined in this study. 3 records have been excluded as insufficient notes from all 640 complication records.

Table 9 All and complication cases from hospitals by regions

Urban and Capital The National Center for Maternal and Child health		**East region** Dornot Medical center		**Khangai region 1** Regional Diagnostic and treatment center of Uvurkhangai province		**Central region** Regional Diagnostic and treatment center of Umnugobi province		**West region** Bayan-Ulgii province general hospital		**Khangai region 2** Bayankhongor province general hospital	
All cases	Complication	All cases	Complication	All cases	Complication	All cases	Complication	All cases	Complication	All cases	Complication
50923	379	3242	60	2225	52	924	68	1657	27	1575	54

ALL CASES	ALL RECORDED COMPLICATIONS	INSUFFICIENT RECORD
60546	**640**	**3**

4.2.1 General results

A total of 1160 anaesthesia-related complications were reported from 640 cases, and patient characteristics and surgical type were heterogeneous.
In terms of complication incidences, cardiovascular complications occurred (n=476, 74:1000) predominantly, followed by respiratory complications (n=283, 44:1000). 136 neurological complications in including pain and shivering etc (21:1000) have been reported and other complications such as fever (during anaesthesia period n=132, 21:1000, post anaesthesia period n=34, 5:1000) and vomiting (n=37, 6:1000) noted between 2018 to 2022.

Table 10: Characteristics of anaesthesia relate complications

Complications by organ systems	Incidences of adverse events by age group (Perioperative)									
	Age and complications	<1 month		1month-12 month		1year-8 years		8 years<		Total complications	
		n	%	n	%	n	%	n	%	n	%
Cardiovascular complications	Bradycardia	41	3.53	7	0.60	19	1.64	21	1.81	88	7.59
	Tachycardia	16	1.38	18	1.55	111	9.57	56	4.83	201	17.33
	Hypotension	40	3.45	8	0.69	25	2.16	53	4.57	126	10.86
	Hypertension	3	0.26	2	0.17	7	0.60	7	0.60	19	1.64
	Arrhythmia	22	1.90	1	0.09	3	0.26	4	0.34	30	2.59
	Cardiac arrest	9	0.78	0	-	1	0.09	0	-	10	0.86
	Other	0	-	1	0.09	1	0.09	1	0.09	3	0.26
Respiratory complications	Laryngospasm	46	3.97	32	2.76	81	6.98	28	2.41	187	16.12
	Bronchospasm	6	0.52	1	0.09	6	0.52	2	0.17	15	1.29
	Hypoventilation	19	1.64	0	-	11	0.95	8	0.69	38	3.28
	Apnoea	24	2.07	2	0.17	1	0.09	0	-	27	2.33
	Other	6	0.52	2	1.90	4	0.34	4	0.34	16	1.38
Neurological complications	Convulsion	3	0.26	1	0.09	0	-	1	0.09	5	0.43
	Neurological damage	0	-	0	-	0	-	1	0.09	1	0.09
	Prolonged unconsciousness	1	0.09	2	0.17	7	0.60	1	0.09	11	0.95
	Restlessness	2	0.17	0	-	7	0.60	0	-	9	0.78
	Pain	16	1.38	2	0.17	30	0.01	9	0.78	57	4.91
	Shivering	0	-	1	0.09	37	3.19	12	1.03	50	4.31
	Other	0	-	0	-	1	0.09	2	0.17	3	0.26
Other complications	Vomiting	1	0.09	1	0.09	8	0.69	27	2.33	37	3.19
	Aspiration	6	0.52	1	0.09	5	0.43	1	0.09	13	1.12
	Allergic reaction	0	-	0	-	8	0.69	5	0.43	13	1.12
	Hypothermia	25	2.16	2	0.17	0	-	2	0.17	29	2.50
	Hypoglycaemia	4	0.34	0	-	1	0.09	1	0.09	6	0.52
	Fever	4	0.34	15	1.29	91	7.84	56	4.83	166	14.31
All complications		294	25.34	99	10.26	465	37.51	302	26.03	1160	100.00

48.4% of all anaesthesia complications occurred in the population aged between 1 year to 8 years during the study period. Moreover, from the collected descriptive data emergency cases were likely to have high possibility of critical event incidences, 93.4% of all complications have been categorized as ASA 2 or above (American Society of Anaesthesiology) status.

Table 11: Patients' characteristics and detailed information of surgeries

	Number (n)	% of Total
Age (month and year)		
<1 month	84	13.20%
1 month to 1 year	62	9.70%
1 year to 3 years	129	20.30%
4 years to 8 years	179	28.10%
8 years <	183	28.70%
Gender		
Boy	362	56.8%
Girl	275	43.2%
ASA physical status		
1	42	6.60%
2	458	71.90%
3	104	16.30%
4	32	5%
5	1	0.20%
Elective and emergency status		
Elective	210	33%
Emergency	398	62.50%
Can not be delayed	29	4.60%
Body weight		
Low weight	48	7.60%
Normal	481	76.10%
Overweight	82	13%
Obesity	21	3.30%
Admission status		
Outpatients/home	244	38.30%
Ward	308	48.40%
ICU	26	4.10%
Emergency room	59	9.30%
Site of operation		
Cardiac	1	0.20%
Thoracic	25	3.90%
Neurology	2	0.40%
Maxillofacial	55	8.60%
Ear, nose, and throat (ENT)	47	7.40%
Eye	26	4.10%
Upper abdomen	38	6%
Lower abdomen	276	43.30%
Perineum-anus	54	8.50%
Extremity	82	12.90%
Bronchoscopy	7	1.10%
Esophagogastroscopy	8	1.30%
Genitourinary	16	2.50%
Hospital level		
Secondary or provincial	335	52.59%
Tertiary	302	47.40%

It is obvious from the table which gives information of surgeries, 43.3% of all complication's cases were abdominal surgery cases, whereas cardiac and neurological cases were occupied 0.2% to 0.4% which is the lowest number of cases in all anaesthesia related complication cases.

Table 12: Anaesthesia complications by perioperative period

Anaesthesia period	Number (n)	% of Total
Complication incidences in induction period	171	26.80%
Complication incidences in maintenance period	377	59.20%
Complication incidences during and after extubating	182	28.60%

The numbers of adverse events during the maintenance period of anaesthesia were 377 (59.2% of all complication cases), whereas 171 (26.8%) and 182(28.6%) patients had anaesthesia related problems in induction and after extubating period respectively.

4.3 Respiratory complications in Mongolian paediatric anaesthesia

The respiratory complications are one of the common adverse events reported during anaesthesia in Mongolia. According to the collected data, the overall incidence of anaesthesia related respiratory complications n=283 (44:1000 cases) were reported. Some of these events have occurred more than once during different periods of anaesthesia in the same patients.

In this subchapter, peri anaesthesia respiratory complications are reported in two different sections which are respiratory events during and post anaesthesia period. Moreover, common actions against the respiratory problems and outcome after events are noted individually at the end of this subchapter.

4.3.1 Respiratory complications during anaesthesia period

Laryngospasm events frequently occurred which were reported as n=172 (28:1000 cases) (27%) incidences followed by hypoventilation n=32 (5:1000) which are 27% and 5% of all complicated cases. Bronchospasm (n=14, 2.3:1000) and apnoea (n=19, 3:1000) took place in 2.2% and 3% of all complications. Hypoventilation and coughing with desaturation were considered as other respiratory complications which were n=11 (1.8:1000). These events were occupied 1.7% of all complicated cases (637 patients).

Table 13: Respiratory complications during anaesthesia period

Total complicated cases	n=637	100%
Laryngospasm	172	27%
Bronchospasm	14	2.2%
Hypoventilation	32	5%
Apnoea	19	3%
Other	11	1.7%
Total	248	38.9%

Occurrences of laryngospasm were highest (n=45 (18.14%) in scheduled, n=25 (10%) in emergency cases) in populations between 1 year to 8 years, classified ASA 1 and ASA 2, whereas n=22 (8.87%) in scheduled and n=14 (5.6%) in emergency cases in infant

population with ASA 3, 4 and 5 physical status. Infants who were classified in ASA 3,4 and 5 physical statuses are vulnerable for apnoea and hypoventilation events. In one word, 7 (2.8%) and 8 (3.2%) apnoea were reported in scheduled and emergency cases respectively, populations were under 1 months old with physical status ASA 3,4 and 5, whereas n=7 and n=10 hypoventilation cases occurred in particular populations.

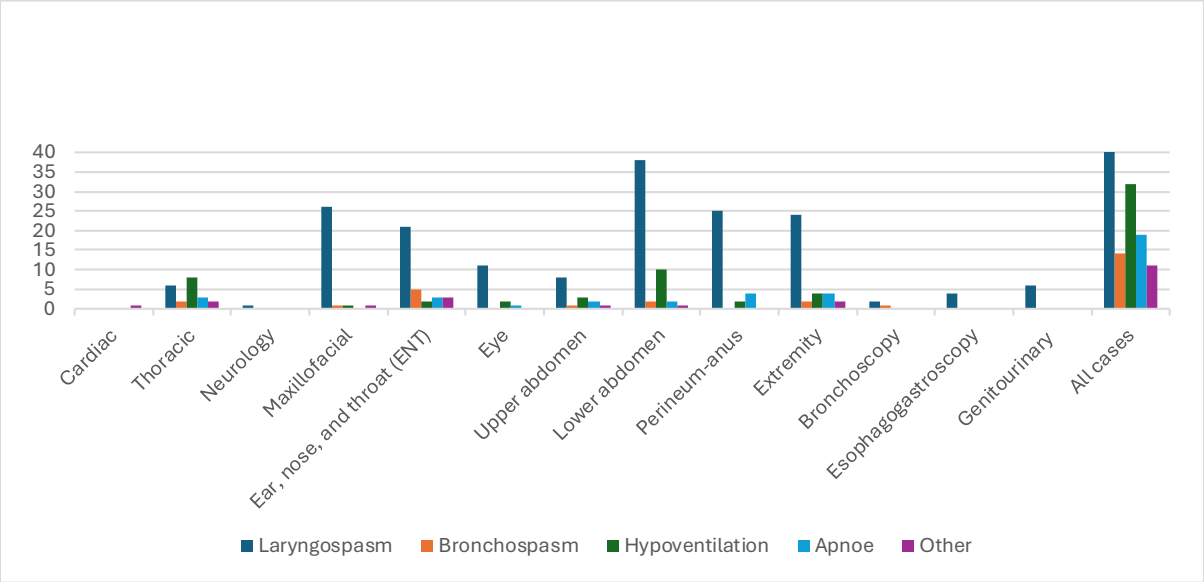
Table 14 Respiratory complications during anaesthesia by age, ASA and emergency status

		ASA 1 and ASA 2							
		<1 month		1month-12 month		1year-8 years		8 years<	
		n	%	n	%	n	%	n	%
Laryngospasm	Scheduled	2	0.8	11	4.43	45	18.14	17	6.85
	Emergency	1	0.4	11	4.43	25	10	11	4.43
Bronchospasm	Scheduled	0	0	0	0	3	1.2	1	0.4
	Emergency	0	0	1	0.4	1	0.4	1	0.4
Hypoventilation	Scheduled	0	0	0	0	7	2.8	0	0
	Emergency	0	0	0	0	3	1.2	5	2
Apnoea	Scheduled	1	0.4	1	0.4	1	0.4	0	0
	Emergency	0	0	0	0	0	0	0	0
Other	Scheduled	1	0.4	0	0	2	0.8	2	0.8
	Emergency	0	0	0	0	0	0	0	0

		ASA 3, 4 and 5							
		<1 month		1month-12 month		1year-8 years		8 years<	
		n	%	n	%	n	%	n	%
Laryngospasm	Scheduled	22	8.87	2	0.8	4	1.6	0	0
	Emergency	14	5.6	5	2	2	0.8	0	0
Bronchospasm	Scheduled	3	1.2	0	0	1	0.4	0	0
	Emergency	3	1.2	0	0	0	0	0	0
Hypoventilation	Scheduled	7	2.8	0	0	0	0	0	0
	Emergency	10	4	0	0	0	0	0	0
Apnoea	Scheduled	7	2.8	0	0	0	0	0	0
	Emergency	8	3.2	0	0	0	0	0	0
Other	Scheduled	1	0.4	0	0	0	0	1	0.4
	Emergency	2	0.8	0	0	0	0	1	0.4

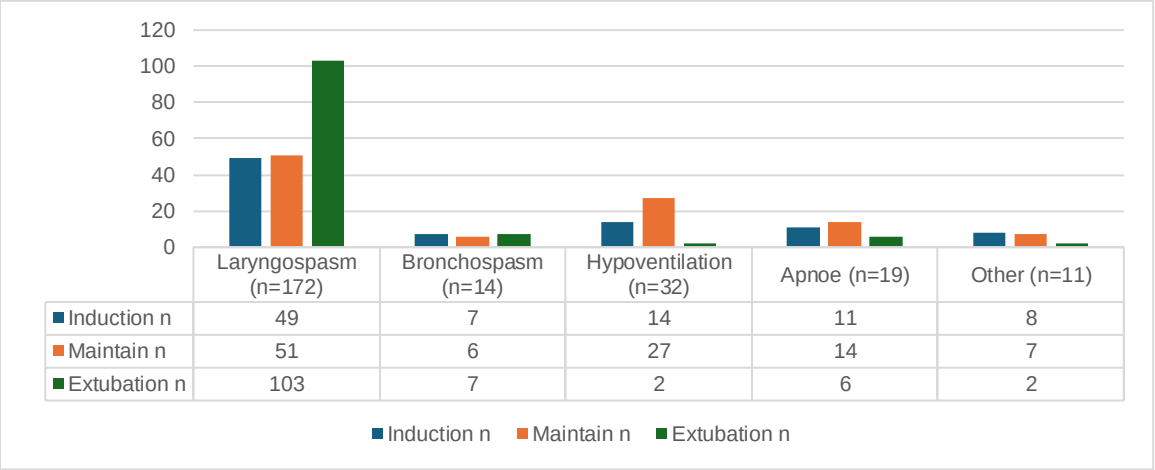
In terms of surgical procedures, all respiratory complications were common during abdominal cases, whereas maxillofacial, ENT and perineum-anal surgeries are considered as high-risk procedures for anaesthesia related respiratory problems, because several respiratory events were reported next to abdominal surgeries.

Figure 5: Incidence of respiratory complications by surgical procedures



There was a high incidence of respiratory complications especially laryngospasm (n=103,59.8%) during the extubating period of anaesthesia. On the other hand, induction period of anaesthesia is likely to be considered as risky phase, because laryngospasm (n=49, 24.5%), bronchospasm (n=7, 50%), hypoventilation (n=14, 43.8%) and apnoea (n=11,57.9%) have occurred during induction.

Figure 6: Incidences of respiratory complications by anaesthesia periods



	Laryngospasm (n=172)	Bronchospasm (n=14)	Hypoventilation (n=32)	Apnoe (n=19)	Other (n=11)
Induction n	49	7	14	11	8
Maintain n	51	6	27	14	7
Extubation n	103	7	2	6	2

4.3.2 Respiratory complications in post anaesthesia period

35 respiratory events are reported in the post anaesthesia period. This is 5.6% of all complications during the research period. Most common complications are laryngospasms n=15 (2.5:1000) followed by apnoea n=8 (1.3:1000) and hypoventilation n=6 (1:1000) which are 2.4%, 1.3% and 2.4% of all complicated cases respectively in after anaesthesia period. Only one bronchospasm (0.1:1000) case occurred in the post anaesthesia period, whereas occurrences of other complications including cough and hyperventilation are n=5 (0.8%).

Table 15: Incidences of respiratory complications after anaesthesia period

Total complicated cases	n=637	100%
Laryngospasm	15	2.4%
Bronchospasm	1	0.2%
Hypoventilation	6	0.9%
Apnoea	8	1.3%
Other	5	0.8%
Total	35	5.6%

The post anaesthesia events occurred during transfer of the patients (n=12) and in the recovery room (n=12), which are 34.1 % of all respiratory complications after anaesthesia respectively. Ten (28.4%) patients presented breathing problems in the intensive care unit (ICU) and only one respiratory problem was hypoventilation (2.8%) reported in the ward.

Table 16: Occurrence of post anaesthesia respiratory complications in specific area

	During transfer		Recovery room		ICU		Ward	
	n	%	n	%	n	%	n	%
Laryngospasm	8	22.8%	5	14.3%	2	5.7%	0	0
Bronchospasm	0	0	1	2.8%	0	0	0	0
Hypoventilation	1	2.8%	3	8.5%	1	2.8%	1	2.8%
Apnoea	3	8.5%	1	2.8%	4	11.4%	0	0
Other	0	0	2	5.7%	3	8.5%	0	0
Total	12	34.1%	12	34.1%	10	28.4%	1	2.8%

In terms of age groups, neonates are vulnerable to apnoea (n=8, 22.8%) problems, whereas hypoventilation events occurred in all age groups except the age group of 1month to 12 months, n=2 (5.7%) in neonates, n=3 (8.5%) in age group above 8 years and n=1 (2.8%) in age group between 1 year to 8 years respectively.

Table 17 Incidence of post anaesthesia respiratory complications by age groups

	<1 month		1month-12 month		1year-8 years		8 years<	
	n	%	n	%	n	%	n	%
Laryngospasm	7	20%	3	8.5%	5	14.3%	0	0
Bronchospasm	0	0	0	0	1	2.8%	0	0
Hypoventilation	2	5.7%	0	0	1	2.8%	3	8.5%
Apnoea	8	22.8%	0	0	0	0	0	0
Other	2	5.7%	0	0	2	5.7%	0	0
Total	19	54.2%	3	8.50%	9	25.6%	3	8.5%

4.3.3 Common actions during the respiratory events and outcomes

Call for help is the most common action for respiratory events taken by anaesthesiologists, anaesthesiologists seek help for n=105 cases which are 42.2% of all respiratory complication cases during anaesthesia. Reintubation or intubation as an additional procedure have been taken for n=99 (40%) cases.

Cardiopulmonary resuscitation (CPR) has been taken for n=14 (5.6%) cases during anaesthesia, whereas there were no incidences that required CPR in post anaesthesia

period. Moreover, n=10 patients which are 4% of all experienced kids with respiratory problems during and after anaesthesia have been admitted to ICU as an unplanned admission.

Table 18: Common actions for respiratory events during and post anaesthesia periods and outcomes

	Call for help		Intubation		Fluid challenge		Advanced monitoring		Additional procedures		CPR		Additional drug		ICU admission		Unplanned ICU admission	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Laryngospasm	59	23.8%	53	21.3%	12	4.8%	20	8%	14	5.6%	4	1.6%	69	27.8%	12	4.8%	3	1.2%
Bronchospasm	6	2.4%	6	2.4%	4	1.6%	5	2%	1	0.4%	1	0.4%	8	3.2%	6	2.4%	2	0.8%
Hypoventilation	17	6.8%	18	7.2%	17	6.8%	13	5.2%	7	2.8%	3	1.2%	19	7.6%	13	5.2%	2	0.8%
Apnoea	19	7.6%	17	6.8%	8	3.2%	7	2.8%	4	1.6%	4	1.6%	13	5.2%	8	3.2%	2	0.8%
Other	4	1.6%	5	2%	3	1.2%	2	0.8%	1	0.4%	2	0.8%	3	1.2%	3	1.2%	1	0.4%
Total	105	42.2%	99	40%	44	17.6%	47	18.8%	27	10.8%	14	5.6%	112	45.0%	42	16.8%	10	4%

	Call for help		Intubation		Fluid challenge		Advanced monitoring		Additional procedures		CPR		Additional drug		ICU admission	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Laryngospasm	9	25.7%	7	20%	0	0	1	2.8%	0	0	0	0	7	20%	3	8.5%
Bronchospasm	1	2.8%	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypoventilation	2	5.7%	2	5.7%	2	5.7%	0	0	1	2.8%	0	0	2	5.7%	2	5.7%
Apnoea	3	8.5%	2	5.7%	1	2.8%	1	2.8%	0	0	0	0	2	5.7%	3	8.5%
Other	2	5.7%	1	2.8%	2	5.7%	1	2.8%	0	0	0	0	4	11.4%	2	5.7%
Total	17	48.4%	12	34.2%	5	14.2%	3	8.4%	1	2.80%	0	0	15	42.8%	10	28.4%

4.4 Cardiovascular complications in Mongolian paediatric anaesthesia

A retrospective collected data showed that cardiovascular complications are the most common adverse events in preoperative and post anaesthesia period in Mongolia. Data shows that the overall n=476 (74:1000) incidence of anaesthesia associated cardiovascular morbidities are reported. Some patients have experienced more than one cardiovascular event during their hospital admission period.

In this chapter, cardiovascular complication incidences are illustrated in tables and graphs under two different parts which are named cardiovascular problems during and post anaesthesia period. Common action and some outcomes will be noted in a separated subchapter at the end.

4.4.1 Cardiovascular complications during anaesthesia period

Tachycardia is the most common cardiovascular problem reported n=169 (28:1000) which is 26.5% of all complications, followed by hypotension cases n=108 (18:1000) are reported, while bradycardia n=85 (14:1000), arrhythmia n=25 (4:1000) and hypertension n=19 (3:1000) which are 13.3%, 3.9% and 3% of all records of complications have been found during the study period.

Table 19: Incidences of cardiovascular complications during anaesthesia period

Total complicated cases	n=637	100%
Bradycardia	85	13.3%
Tachycardia	169	26.5%
Hypotension	108	17%
Hypertension	19	3%
Arrhythmia	25	3.9%
Cardiac arrest	10	1.6%
Other	3	0.5%
Total	419	65.80%

Neonates that are classified as ASA3,4 and 5 are vulnerable to all types of cardiovascular complications, whereas ASA 1 and 2 patients over 1 year of age did not have any reports of hypertension and arrhythmia. For example, bradycardia and hypotension are counted as n=22 (5.3%) and n=19 (4.5%) during emergency neonatal cases, while tachycardia incidences during emergency and scheduled surgeries are reported n=47 (11.2%) and n=49 (11.7%) in 1 year to 8 years old patients classified ASA 1 and 2 respectively. Holistic information regarding age group and ASA classification are illustrated in the below table.

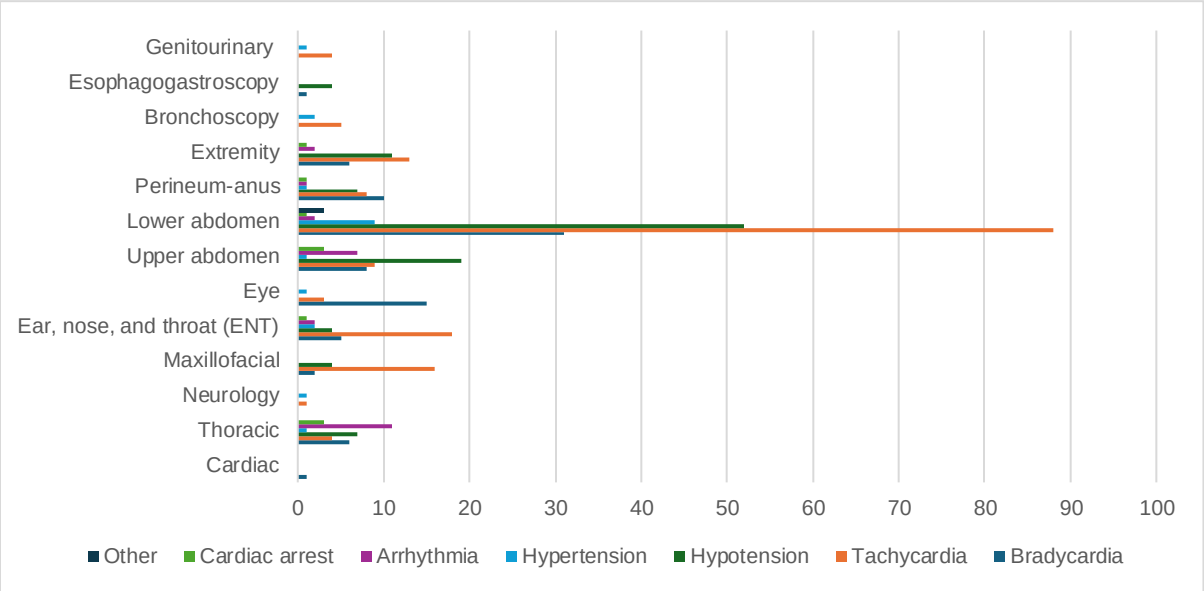
Table 20: Cardiovascular complications during anaesthesia by age, ASA and emergency status

		ASA 1 and ASA 2							
		<1 month		1month-12 month		1year-8 years		8 years<	
		n	%	n	%	n	%	n	%
Bradycardia	Scheduled	0	0	4	1.0%	13	3.1%	12	2.9%
	Emergency	0	0	1	0.2%	5	1.2%	9	2.1%
Tachycardia	Scheduled	0	0	4	1.0%	47	11.2%	14	3.3%
	Emergency	0	0	7	1.7%	49	11.7%	22	5.3%
Hypotension	Scheduled	1	0.2%	1	0.2%	10	2.4%	18	4.3%
	Emergency	0	0	1	0.2%	10	2.4%	23	5.5%
Hypertension	Scheduled	0	0	0	0	7	1.7%	1	0.2%
	Emergency	0	0	1	0.2%	0	0	5	1.2%
Arrhythmia	Scheduled	0	0	0	0	0	0	0	0
	Emergency	0	0	1	0.2%	0	0	0	0
Other	Scheduled	0	0	1	0.2%	0	0	0	0
	Emergency	0	0	0	0	0	0	1	0.2%

		ASA 3, 4 and 5							
		<1 month		1month-12 month		1year-8 years		8 years<	
		n	%	n	%	n	%	n	%
Bradycardia	Scheduled	17	4%	0	0	0	0	0	0
	Emergency	22	5.3%	1	0.2%	1	0.2%	0	0
Tachycardia	Scheduled	8	1.9%	2	0.5%	5	1.2%	3	0.7%
	Emergency	3	0.7%	0	0	3	0.7%	2	0.5%
Hypotension	Scheduled	17	4%	2	0.5%	1	0.2%	1	0.2%
	Emergency	19	4.5%	1	0.2%	1	0.2%	2	0.5%
Hypertension	Scheduled	2	0.5%	1	0.2%	0	0	1	0.2%
	Emergency	1	0.2%	0	0	0	0	0	0
Arrhythmia	Scheduled	9	2.1%	0	0	0	0	0	0
	Emergency	13	3.1%	0	0	0	0	2	0.5%
Other	Scheduled	0	0	0	0	0	0	0	0
	Emergency	0	0	0	0	1	0.2%	0	0

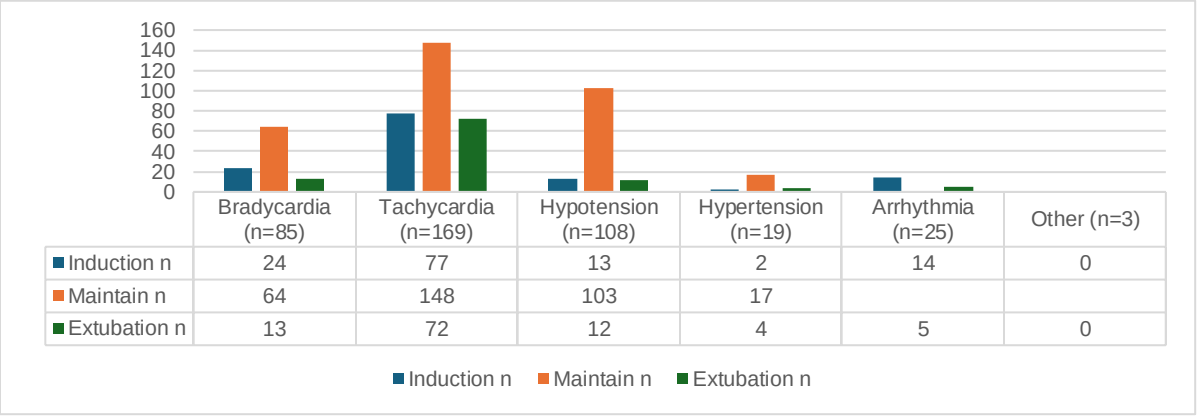
In terms of surgical procedures, tachycardia and hypotension problems are common during abdominal surgeries. For example, n=88 tachycardia incidents are reported in lower abdominal cases, whereas hypotension occurred as n=52 during these particular surgeries. Moreover, regarding thoracic surgeries, arrhythmia is frequently occurring (n=11) complication.

Figure 7: Incidence of cardiovascular complications by surgical procedures



During the maintenance of anaesthesia, cardiovascular problem occurrences were quite high, compared to incidences in other periods of anaesthesia. Cases that include tachycardia n=148, hypotension n=103 and bradycardia n=64 are described in the maintain interval. In terms of the beginning of anaesthesia, heart rate changes such as bradycardia and tachycardia are respectively noted as n=24 and n=77. In the extubating period, tachycardia incidences are counted almost the same as in induction n=72, whereas bradycardia n=13, n=12 and arrhythmia n=5 are reported in particular phases of anaesthesia.

Table 21: Incidences of cardiovascular complications by anaesthesia periods



	Bradycardia (n=85)	Tachycardia (n=169)	Hypotension (n=108)	Hypertension (n=19)	Arrhythmia (n=25)	Other (n=3)
Induction n	24	77	13	2	14	0
Maintain n	64	148	103	17		
Extubation n	13	72	12	4	5	0

Incidences of cardiac arrest will be discussed in future subchapter as serious morbidity related to anaesthesia.

4.4.2 Cardiovascular complications post anaesthesia period

Total n=57 (10:1000) cardiac complications which are 8.9% of all complications are reported retrospectively. In this period, tachycardia occurrences are noted as n=32 (5:1000) which is predominant than other events, followed by hypotension n=18 (3:1000). These events were occupied 5% and 2.8% of all complicated cases respectively. Information about hypertension hasn't been recorded at this anaesthesia period.

Table 22: Incidences of cardiovascular complications after anaesthesia

Total complicated cases	n=637	100%
Bradycardia	2	0.3%
Tachycardia	32	5%
Hypotension	18	2.8%
Hypertension	0	0
Arrhythmia	5	0.8%
Cardiac arrest	0	0
Other	0	0
Total	57	8.9%

In terms of post anaesthesia care units, incidences of tachycardia (n=23) were high in the recovery room, whereas hypotension problems (n=14) are common in ICU. In the ward, incidence of cardiovascular problems was not recorded after anaesthesia.

Table 23: Occurrence of post anaesthesia cardiovascular complications in specific area

	During transfer		Recovery room		ICU		Ward	
	n	%	n	%	n	%	n	%
Bradycardia	1	1.7%	1	1.7%	0	0	0	0
Tachycardia	0	0	23	40.3%	3	5.2%	0	0
Hypotension	0	0	2	3.5%	14	24.5%	0	0
Arrhythmia	1	1.7%	0	0	5	8.7%	0	0
Cardiac arrest	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0
Total	2	3.4%	26	45.6%	22	38.5%	0	0

Cardiovascular problems are noted common in the neonatal population, especially hypotension (n=15) occurred higher than other events after anaesthesia. Moreover, n=19 tachycardia cases are reported in the age group between 1 year to 8 years, which is the highest number of anaesthesia related problems post anaesthesia period.

Table 24: Incidence of post anaesthesia cardiovascular complications by age groups

	<1 month		1month-12 month		1year-8 years		8 years<	
	n	%	n	%	n	%	n	%
Bradycardia	1	1.7%	0	0	1	1.7%	0	0
Tachycardia	1	1.7%	2	3.5%	19	33.3%	10	17.5%
Hypotension	15	26.3%	1	1.7%	0	0	2	3.5%
Arrhythmia	5	8.7%	0	0	0	0	0	0
Total	22	38.4%	3	5.2%	20	35%	12	21%

4.4.3 Common actions during cardiovascular events and outcomes

During the anaesthesia period, additional medications are given when cardiovascular complications occur, which is reported as n=201, 45.7% of all cardiovascular events. Additional therapies and actions include fluid challenge n=140 (33.3%), followed by call for help n=104 (24.5%). Additional procedures including intravascular access, central venous catheterisation are done on n=49 patients, which is 11.5% of all cardiovascular cases. Overall, 82 (19.4%) patients admitted to ICU, 16 (3.7%) patients of them were unplanned admitted to ICU.

Table 25: Common actions for cardiovascular events during and post anaesthesia periods and outcomes

	Call for help		Intubation		Fluid challenge		Advanced monitoring		Additional procedures		CPR		Additional drug		ICU admission		Unplanned ICU admission	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Bradycardia	35	8.3%	32	7.6%	33	7.8%	25	5.9%	12	2.8%	7	1.6%	59	14%	18	4.3%	5	1.2%
Tachycardia	12	2.8%	7	1.6%	21	5%	17	4%	5	1.2%	1	0.2%	33	7.8%	7	1.6%	3	0.7%
Hypotension	25	5.9%	17	4%	57	13.6%	26	6.2%	16	3.8%	8	1.9%	69	14.6%	24	5.7%	5	1.2%
Hypertension	3	0.7%	2	0.4%	0	0	5	1.2%	2	0.4%	0	0	7	1.6%	3	0.7%	1	0.2%
Arrhythmia	19	4.5%	13	3.1%	21	5%	17	4%	9	2.1%	4	0.9%	22	5.2%	21	5%	1	0.2%
Cardiac arrest	10	2.3%	7	1.6%	8	1.9%	5	1.2%	5	1.2%	10	2.3%	9	2.1%	9	2.1%	1	0.2%
Other	0	0	0	0	0	0	0	0	0	0	0	0	2	0.4%	0	0	0	0
Total	104	24.5%	78	18.3%	140	33.3%	95	22.5%	49	11.5%	30	6.9%	201	45.7%	82	19.4%	16	3.7%

Regarding post anaesthesia care, overall, 18 patients are receiving additional medication treatment when cardiovascular problems occur, which is 31.4% of all complications after anaesthesia. Advanced monitoring used n=16 (28%) cardiovascular complication cases, followed by fluid challenges n=12 (20.9%) measured against the events.

Table 26: Common action for post anaesthesia cardiovascular events and outcome

	Call for help		Intubation		Fluid challenge		Advanced monitoring		Additional procedures		CPR		Additional drug		ICU admission	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Bradycardia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tachycardia	0	0	0	0	1	1.7%	0	0	0	0	0	0	4	7%	0	0
Hypotension	3	5.2%	2	3.5%	8	14%	12	21%	3	5%	0	0	9	15.7%	8	14%
Hypertension	0	0	0	0	0	0	0	0	0	5.2%	0	0	0	0	0	0
Arrhythmia	2	3.5%	1	1.7%	3	5.2%	4	7%	0	0	0	0	5	8.7%	4	7%
Cardiac arrest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0
Total	5	8.7%	3	5.2%	12	20.9%	16	28%	3	10.20%	0	0	18	31.4%	12	21%

4.5 Cardiac arrest and mortality incidences in Mongolian paediatric anaesthesia

Cardiac arrest during anaesthesia, mortality incidences related to anaesthesia are considered as serious complications of paediatric anaesthesia. Therefore, severe neurological damage belongs to this group of complications as well. All incidences of these events will be covered in this subchapter.

There were reported n=10 cardiac arrest cases reported during the study period. This is 1.6% of all complication cases. Prevalence of cardiac arrest complications is 0.1:1000, which means that 1 cardiac arrest case occurs in every 10000 anaesthesia care cases. This serious event commonly occurs in neonates (n=9, 90% of all cardiac arrest cases), which are the most fragile and vulnerable population of paediatric anaesthesia. 6 of these cases were scheduled and classified as ASA 3 and 4, whereas n=4 cardiac arrest cases were emergency surgery, patients were ASA 4 and 5 classified.

Moreover, n=7 of all neonates who have had cardiac arrest complications were premature babies and n=8 neonates were reported as having congenital diseases which need surgical treatments.

In terms of severe neurological damage, only 1 brain damage event was reported during the study period in Mongolia. 13-year-old patient who is classified in ASA 2 emergency for appendectomy surgery. Event occurred during anaesthesia with severe hypoxemia.

There was not any anaesthesia related mortality incidence information reported. Although some cardiac arrest cases are classified as ASA 4 and 5 emergencies, information that related to anaesthesia have not been noted on all anaesthesia records.

4.6 Neurological complications in Mongolia paediatric anaesthesia

The neurological problems during anaesthesia are less common compared to respiratory and cardiovascular events in the paediatric population. According to the investigation conducted by our team, overall n=136 (21:1000) neurological events are reported, which are 21.3% of all complicated patients.

Pain problem is the most common neurological event that occurred n=57 (9:1000) which is 8.9% of complicated cases during study period. Following the occurrence of neurological problems is shivering, n=50 (8:1000) which is 7.8% of all complicated patients have had shivering experience. There was only one neurological serious damage reported, which is 0.2% of all complications (0.1:1000).

Table 27: Incidences of neurological complications

Total complicated cases	n=637	100%
Convulsion	5	0.8%
Neurological damage	1	0.2%
Prolonged unconsciousness	11	1.7%
Restlessness	9	1.4%
Pain	57	8.9%
Shivering	50	7.8%
Other	3	0.5%
Total	136	21.3%

Children who are classified as ASA 1 or ASA 2 status are commonly experiencing neurological problems, n=96 cases reported in this group, which is 70.4% of all neurological events. In terms of age group, most neurological events (n=82, 60.1%) are reported in the population aged between 1 year to 8 years. Pain and shivering events are common in age groups above 1 years with n=30 (22%) and n=9 (6.6%) cases reported in age groups in 1 year to 8 years and 8 years and above respectively. Children aged between 1 month to 12 months showed fewer neurological problems during anaesthesia, n=6 (4.2%) neurological problems noted during study period, which is almost 3.5 times less occurrence in neonates.

Table 28: Neurological complications during anaesthesia by age and ASA status

	<1 month		1month-12 month		1year-8 years		8 years<		ASA 1 and ASA 2		ASA 3,4 and ASA 5	
	n	%	n	%	n	%	n	%	n	%	n	%
Convulsion	3	2.2%	1	0.7%	0	0	1	0.7%	2	1.4%	3	2.2%
Neurological damage	0	0	0	0	0	0	1	0.7%	1	0.7%	0	0.0%
Prolonged unconsciousness	1	0.7%	2	1.4%	7	5.1%	1	0.7%	10	7.4%	1	0.7%
Restlessness	2	1.4%	0	0	7	5.1%	0	0	6	4.4%	3	2.2%
Pain	16	11.7%	2	1.4%	30	22%	9	6.6%	37	27.2%	20	14.7%
Shivering	0	0	1	0.7%	37	27.2%	12	8.8%	39	28.7%	11	8%
Other	0	0	0	0	1	0.7%	2	1.4%	1	0.7%	1	0.7%
Overall	22	16%	6	4.2%	82	60.1%	26	18.9%	96	70.4%	39	28.5%

Most neurological events including pain, shivering and unconsciousness occurred after anaesthesia. Shivering and pain events are noted as n=50 (36.7%) and n=48 (35.3%) in the anaesthesia period, whereas just n=9 pain and n=1 particular problems are reported during induction. Only convulsion (n=4, 2.9%) and neurological (n=1, 0.7%) damage events were reported in the maintenance period.

Table 29: Incidences of neurological complications by anaesthesia period

	Induction		Maintain		After anaesthesia	
	n	%	n	%	n	%
Convulsion	0	0	4	2.9%	1	0.7%
Neurological damage	0	0	1	0.7%	0	0
Prolonged unconsciousness	1	0.7%	0	0	11	8%
Restlessness	1	0.7%	0	0	8	5.8%
Pain	9	6.6%	0	0	48	35.3%
Shivering	0	0	0	0	50	36.7%
Other	1	0.7%	2	1.5%	1	0.7%

4.7 Other complications in Mongolian paediatric anaesthesia

The other complications related to paediatric anaesthesia include vomiting, aspiration, allergic reaction and fever, as well as hypothermia and hypoglycaemia. The overall incidences of other events are reported as n=264, which is 41.4% of all complications. (see table 29).

Table 30: Incidences of anaesthesia related other complications

During anaesthesia			After anaesthesia			
Total complicated cases	n=637	100%		n=637	100%	Total number
Vomiting	16	2.5%	Vomiting	21	3.3%	37
Aspiration	10	1.6%	Aspiration	3	0.5%	13
Allergic reaction	12	1.9%	Allergic reaction	1	0.2%	13
Hypothermia	16	2.5%	Hypothermia	13	2%	29
Hypoglycaemia	6	0.9%	Hypoglycaemia	0	0.0%	6
Fever	132	20.7%	Fever	34	5.30%	166
Total	192	30.1%	Total	72	11.3%	264

All complications will be discussed separately in individual subchapters while descriptive tables will illustrate related information including patient's characteristic and occurrence in anaesthesia period specifically.

4.7.1 Fever

Data reveals that hyperthermia was the most common morbidity during paediatric anaesthesia in Mongolia. During the anaesthesia period, n=132 (21:1000) which is 20.7% of all patients with complications have had fever, whereas 34 (5:1000) patients had the same problem in postoperative period, which is 5.3% of all complications.

During anaesthesia period, children belonging to the age group between 1 year to 8 years who classified ASA physical status 1 or 2 are exposed to hyperthermia incidences. In this group, scheduled n=18 and emergency n=49 cases reported, which is highest compared to other age and physical status classification groups.

Table 31: Incidence of fever during anaesthesia period by age, ASA and emergency status

		ASA 1 and ASA 2							
		<1 month		1month-12 month		1year-8 years		8 years<	
		n	%	n	%	n	%	n	%
Fever (During anaesthesia)	Scheduled	1	0.8%	3	2.3%	18	13.6%	12	9%
	Emergency	0	0	7	5.3%	49	37.1%	30	22.7%
		ASA 3,4 and ASA 5							
		<1 month		1month-12 month		1year-8 years		8 years<	
		n	%	n	%	n	%	n	%
Fever (During anaesthesia)	Scheduled	1	0.8%	1	0.8%	1	0.8%	0	0
	Emergency	0	0	2	1.5%	4	3%	3	2.7%

In terms of after anaesthesia period, hyperthermia incidences were common in the same groups of during anaesthesia period. Scheduled n=5 and emergency n=14 cases, which are 14.7% and 41.2% of all hyperthermia cases reported in the age group 1 years to 8 years with ASA 1 or 2 status. Following this, neonates who were assessed as ASA 3,4 or 5 exposed to fever, scheduled n=2 (5.8%) and emergency n=3 (8.8%) are noted in this group.

Table 32: Incidence of fever post anaesthesia period by age, ASA and emergency status

		ASA 1 and ASA 2							
		<1 month		1month-12 month		1year-8 years		8 years<	
		n	%	n	%	n	%	n	%
Fever (After anaesthesia)	Scheduled	0	0	0	0	5	14.7%	2	6%
	Emergency	0	0	1	2.9%	14	41.2%	4	11.8%
		ASA 3,4 and ASA 5							
		<1 month		1month-12 month		1year-8 years		8 years<	
		n	%	n	%	n	%	n	%
Fever (After anaesthesia)	Scheduled	2	5.8%	1	2.9%	0	0	1	2.9%
	Emergency	3	8.8%	0	0	1	3%	0	0

Overall, hyperthermia is reported as a common other complication in emergency cases. There is n=118 cases exposed to fever in emergency cases, whereas just n=48 was in scheduled surgeries.

4.7.2 Vomiting and aspiration incidences

Vomiting and aspiration problems have a high prevalence in paediatric anaesthesia of Mongolia, followed by hyperthermia. Overall, vomiting and aspiration incidents are reported n=37 (6:1000) and n=13 (2:1000) respectively, which are 7.9% of all complicated cases.

There were almost equal incidents of these during and after anaesthesia periods, even though vomiting occurred more than aspiration complications.

4.7.3 Allergic reaction

Allergic reaction is one of the less common complications which are reported during study period in paediatric anaesthesia field in Mongolia. Overall n=12 (2:1000) cases are noted, which are 1.9% of all complications. Of these, n=4 (0.6:1000) patients have had allergic problems in the induction period and n=8 (1:1000) patients are reported as having an allergic problem in maintaining the period of anaesthesia.

Only one allergic reaction occurred after anaesthesia care in the ward. However, there was not any reported information related to anaesthesia such as usage of anaesthetics or other medications and how long after it occurred after anaesthesia etc.

4.7.4 Hypothermia

Low core temperature is considered as one of the more common paediatric anaesthesia complications. In Mongolia, overall, 29 (5:1000) severe hypothermia complications were recorded in patients' histories, which is 2.5% of all complications between 2018 to 2022.

Peri anaesthesia period, n=16 (3:1000) hyperthermia is reported, all these cases occurred in the maintaining phase of anaesthesia. Regarding age group, n=14 (2:1000) patients were neonates, while 2 patients who were aged over 8 years, which were 87.5% and 12.5% of all peri anaesthesia hypothermia incidences.

After anaesthesia, all reported low body temperature cases were n=13, which are 2% of all complications. 11 of the total hypothermia cases belong to the neonatal age group, while other 2 cases are reported in the age group 1 month to 12 months. Regarding after anaesthesia care environments, the highest number of cases (n=8) were recorded in the ICU, whereas 3 incidences are noted in the recovery room.

4.7.5 Hypoglycaemia

Low blood sugar incidents reported only 6 (1:1000) overall, which are 0.9% of all cases. 4 (0.6:1000) of these patients were neonates and all cases are noted during the maintenance period of anaesthesia.

There was not any information about hypoglycaemia incidences in after anaesthesia care period.

4.8 Monitoring during the events of anaesthesia complication

Perioperative monitoring is one of the international standards for a safe anaesthesia practice, regarding standards of the World Health Organization (WHO) and World Federation

of Societies of Anaesthesiologists (W. W. M. Adrian W. Gelb, Walter Johnson, Alan F. Merry, on behalf of the International Standards for a Safe Practice of Anesthesia Workgroup, 2018). In terms of these standards, pulse oximeter, carbon dioxide detector of measurement and non-invasive blood pressure monitoring are considered as highly recommended, whereas electrocardiogram, temperature monitoring and other invasive monitoring techniques are required as recommended and suggested equipment during anaesthesia respectively.

Moreover, electrocardiography, pulse oximeter and non-invasive blood pressure monitoring are highly recommended monitoring techniques of safe anaesthesia after anaesthesia period.

We analysed collected data relevant to usage of monitoring techniques during anaesthesia with complication incidences peri and after anaesthesia period in Mongolian paediatric anaesthesia between 2018 to 2022. In this subchapter the results of data analysis of monitoring techniques, while relevant tables have been created to illustrate all information in a suitable way.

During the anaesthesia period, Pulse oximeter was the main monitoring approach that is used for all (n=637 cases, 100%) cases with complications. Following pulse oximeter measuring blood pressure by non-invasive technique was utilised for n=600 cases which were 94.2% of all complications. Electrocardiogram (ECG) and measuring body temperature monitoring methods have been applied for n=411 (64.5%) and n=222 (34.9%) cases respectively.

Although usage of carbon dioxide detectors is highly recommended monitoring techniques during the anaesthesia period, only 2 (0.3%) cases were operated with carbon dioxide monitoring. Invasive blood pressure monitoring and bispectral index measurements (BIS) are utilised for 2 (0.3%) cases respectively only.

Table 33: Monitoring during anaesthesia of cases with complications

	n	%
Pulse oximeter	637	100%
Electrocardiogram (ECG)	411	64.5%
Non-invasive blood pressure monitor	600	94.2%
End tidal CO_2 monitoring	2	0.3%
Temperature	222	34.9%
Invasive blood pressure monitoring	2	0.3%
Bispectral Index (BIS)	2	0.3%

Cases that are operated with only pulse oximeter were n=37 (5.8%), whereas combined monitoring techniques as two combinations (Pulse oximeter and Non-invasive blood pressure monitoring) and three combinations (Pulse oximeter, Non-invasive blood pressure monitoring and ECG) were n=600 and n=411 which are 94.2% and 64.5% of all cases of anaesthesia related complications.

Table 34: Combination of monitoring techniques during anaesthesia of complicated cases

	n	%
Cases with only pulse oximeter	37	5.8%
Cases with two monitoring techniques	600	94.2%
Cases with three monitoring techniques	411	64.5%
Cases with four monitoring techniques	222	34.9%
Cases with five monitoring techniques	2	0.3%
Cases with six monitoring techniques	2	0.3%

Cases with two monitoring techniques: Pulse oximeter and Non-invasive blood pressure monitoring
Cases with three monitoring techniques: Pulse oximeter, Non-invasive blood pressure monitoring and ECG
Cases with four monitoring techniques: Pulse oximeter, Non-invasive blood pressure monitoring, ECG and temperature monitoring
Cases with five monitoring techniques: Pulse oximeter, Non-invasive blood pressure monitoring, ECG, temperature and carbon dioxide monitoring
Cases with six monitoring techniques: Pulse oximeter, Non-invasive blood pressure monitoring, ECG, temperature and carbon dioxide monitoring, additionally invasive monitors

In the post anaesthesia period, additional monitoring including invasive techniques and measuring bispectral index were not used. Pulse oximeter (n=634, 99.5%) and non-invasive blood pressure monitoring (n=191, 30%) methods were commonly used, followed by measuring temperature (n=161, 25.3%) and electrocardiogram (n=104, 16.3%) techniques after anaesthesia.

Table 35: Monitoring after anaesthesia

	n	%
Pulse oximeter	634	99.5%
Electrocardiogram (ECG)	104	16.3%
Non-invasive blood pressure monitor	191	30%
Carbon dioxide detector	1	0.2%
Temperature	161	25.3%
Invasive blood pressure monitoring	-	-
Bispectral Index (BIS)	-	-

However, there were 3 (0.5%) cases operated without any monitoring system after anaesthesia. Single usage of pulse oximeter is in n=443 (69.5%) cases, whereas combined method of post anaesthesia period was two and three combinations were n=191 (30%) and n=104 (16.3%) respectively. Combination of four techniques of monitoring including pulse oximeter, non-invasive blood pressure, ECG and measuring temperature were reported as n=161 which are 25.3% of all complications.

Table 36: Combination of monitoring techniques after anaesthesia of complicated cases

	n	%
Without any monitoring	3	0.5%
Cases with only pulse oximeter	443	69.5%
Cases with two monitoring techniques	191	30%
Cases with three monitoring techniques	104	16.3%
Cases with four monitoring techniques	161	25.3%
Cases with five monitoring techniques	-	-
Cases with six monitoring techniques	-	-

Cases with two monitoring techniques: Pulse oximeter and Non-invasive blood pressure monitoring
Cases with three monitoring techniques: Pulse oximeter, Non-invasive blood pressure monitoring and ECG
Cases with four monitoring techniques: Pulse oximeter, Non-invasive blood pressure monitoring, ECG and temperature monitoring
Cases with five monitoring techniques: Pulse oximeter, Non-invasive blood pressure monitoring, ECG, temperature and carbon dioxide monitoring
Cases with six monitoring techniques: Pulse oximeter, Non-invasive blood pressure monitoring, ECG, temperature and carbon dioxide monitoring, additionally invasive monitors

Regarding the above result, although highly recommended monitoring techniques such as pulse oximeter by WHO-WFSA are utilised well in Mongolian paediatric anaesthesia field, some methods such measuring carbon dioxide are still not routinely used.

4.9 Common anaesthesia preparation approaches and fasting time

Preoperative preparation of anaesthesia includes patient assessment, preparing equipment and team, while preparing patients and their carers mentally (Matthew Harvey, 2021). Therefore, medications and fluid challenges are required as a perioperative preparation except mental preparedness in some situations.

In this subchapter, we are aiming to clarify what type of common medical preparations including fluid and antibiotic treatment etc, while estimating duration of fasting before anaesthesia as perioperative preparation in paediatric anaesthesia of Mongolia.

Overall, n=502 (78.8%) cases have received some preparation including fasting and medications as peri operative preparations, whereas n=135 (21.2%) cases are operated without any preparation. Common preparation medications are antibiotics that are administered for n=489 (76.8%) cases, followed by crystalloid drips that are given to n=317 cases which are 49.8% of all cases complication.

Table 37: Pre-anaesthesia preparation status

	n	%
Yes	502	78.8%
No	135	21.2%

Cardiopulmonary resuscitation occurred in 4 cases (0.6%) which are categorized in ASA 4 and 5 statuses before anaesthesia. Five (12%) patients had blood components as perioperative treatment and 12 (1.9%) patients had inotropic, and 8 (0.6%) patients had vasopressor treatment before the surgery. All these children were categorised in ASA 3,4 and 5 classifications.

Table 38: Common preoperative preparations

	n	%
Antibiotics	489	76.8%
Crystalloid	317	49.8%
Colloids	4	0.6%
Blood components	5	12.0%
Inotropic	12	1.9%
Vasopressor	8	0.6%
CPR before surgery	4	0.6%

Table 39: Common intravenous preparation ASA

	ASA 1 and 2		**ASA 3,4 and 5**	
	n	%	n	%
Colloids	-	-	4	0.70%
Blood components	-	-	5	0.80%
Inotropic	-	-	12	1.90%
Vasopressor	-	-	8	1.30%

Fasting is the main preparation method to prevent aspiration and vomiting the perioperative period. Our data reveals that 95.1% (n=606) of all complications' cases were fasted before the procedure, whereas 4.9% (n=31) of all incidences of complications have not been fasted. By emergency status, n=18 (2.8%) who are not fasted before surgery were in emergency status to operate.

Table 40: Frequencies of Fasting

Frequencies of Fasting		
	n	**%**
Fasting	606	95.1%
No Fasting	31	4.9%
Anaesthesia cases without fasting by ASA categories		
	n	**%**
ASA 1 scheduled	3	0.5%
ASA 2 scheduled	6	0.9%
ASA 2 emergency	10	1.6%
ASA 3 scheduled	3	0.5%
ASA 3 emergency	1	0.2%
ASA 4 scheduled	1	0.2%
ASA 4 emergency	6	0.9%
ASA 5 emergency	1	0.2%

Patients mostly consumed clear fluid (n=326, 51.2%), solid food (n=170, 26.7%) and breast milk (n=122, 19.2%) before the surgery. However, over 60% (n=409, 64.2%) of complication cases were fasted 4 to 8 hours.

Table 41: Oral intake before anaesthesia

	n	%
Clear fluid	326	51.2%
Breast milk	122	19.2%
Formula	19	25%
Solid food	170	26.7%

Table 42: Fasting time by numbers

Fasting time	Counts	% of Total
No fasting	25	3.9 %
1-2 hours	11	1.7 %
2-4 hours	106	16.6 %
4-6 hours	213	33.4 %
6-8 hours	196	30.8 %
More than 8 hours	86	13.5 %

Frequency of peri operative preparation including medication consumption and fasting are reported 78.8% and 95.1% in perioperative period. Fasting more than 4 hours and antibiotic treatments are commonly utilized for these complications before anaesthesia begins.

4.10 Common anaesthesia techniques that were used in anaesthesia related events

General anaesthesia is a commonly used technique of paediatric anaesthesiologists. Airway management options can differ in individual cases. Therefore, regional anaesthesia techniques can be combined with general anaesthesia in paediatric anaesthesia.

In Mongolian practice, we mainly use general anaesthesia techniques with various airway devices. Usage of regional and peripheral nerve block techniques have increased in the last two decades. In this study, we are aiming to clarify what anaesthesia techniques have been used as the main option in anaesthesia events during study period.

In terms of general anaesthesia, it was a main option of anaesthesia techniques of all anaesthesia events. Overall, n=578 (90.7%) cases performed under general anaesthesia, and n=250 (39.2%) of them proceed with endotracheal tube (ETT), n=207 (32.5%) and n=121 (19%) of all event cases used laryngeal mask (LMA) and mask as an airway device during study period.

Regional anaesthesia used individually for n=62 (9.7%) patients who were aged above 10 years. Moreover, regional anaesthesia techniques which are combined with general anaesthesia were noted n=39 (6.1%).

Table 43: Common anaesthesia techniques

	n	%
General anaesthesia with ETT	250	39.2%
General anaesthesia with LMA	207	32.5%
General anaesthesia with Mask	121	19%
Regional anaesthesia with or without general anaesthesia		
General anaesthesia with regional techniques	21	3.3%
Regional	62	9.7%
General anaesthesia with ETT and Regional techniques	16	2.5%
General anaesthesia with LMA and Regional techniques	2	0.3%

There was n=128 (20.1%) difficult airway access cases occurred in all reported complication events. However, the reasons of difficulties of airway access are not documented in all anaesthesia records. Based on written notes, n=32 (5%) cases evaluated as Mallampati class 3 and 4, mouth open limited less than 3 cm cases were noted n=26 (4%) in all anaesthesia related events cases.

Table 44: Airway access

	n	%
Normal	509	79.9%
Difficult	128	20.1%

Table 45: Difficult airway access

	n	%
Mouth opening <3cm	26	4%
Thyromental distance <6cm	29	4.50%
Mallampati class 3 and 4	32	5%
Obstruction	24	3.70%
Neck mobility limited	8	1.20%

General anaesthesia techniques with various other techniques such as different airway devices or regional anaesthesia techniques used for all anaesthesia events cases during study period. Therefore, difficult airway access that required a special method of airway management from anaesthesiologists occurred quite a lot.

4.11 Conclusion

To conclude, a total of 1233 anaesthesia related events have been reported in 60546 paediatric anaesthesia cases, an overall incidence of 2%. These events including 11 serious complications reported from 637 patients' records. The most common intraoperative complications were cardiovascular, whereas respiratory and cardiovascular events were noted highest in post anaesthesia period. Mean fasting time is 4 to 6 hours, but the longest fasting times were more than 8 hours. Additionally, almost 70% of all complication events cases were performed by young anaesthesiologists.

CHAPTER 5

DISCUSSION AND FUTURE DIRECTIONS

5.1 Introduction

"*Primum non nocere* - first do no harm" is Hippocrates' statement that remains an essential rule in medicine and patient care. In many regions worldwide, anaesthesiologists' leadership led to the adoption of monitoring and other care standards in high-income countries during the 1980s, even though anaesthesia related mortality and morbidity incidences were higher in low- and middle-income countries (W. W. M. Adrian W. Gelb, Walter Johnson, Alan F. Merry, 2018).

In 2008, "Safe surgery Saves lives' ' initiatives by the World Health Organizations (WHO) updated first published standards published by the World Federation of Societies of Anaesthesiologists in 1992 (W. W. M. Adrian W. Gelb, Walter Johnson, Alan F. Merry, 2018). Since then, despite developing anaesthesia standards including guidelines, usage of equipment and medications, anaesthesia related complications, mortality and morbidities have occurred with varying numbers of incidents in different countries.

The primary aim of this thesis was to investigate incidences of mortality, morbidity and associated complications of paediatric anaesthesia, while clarifying what common type of anaesthesia events occurred in recent years in Mongolia. These events were reported by anaesthesiologists including anaesthesia trainees and anaesthetist nurses in anaesthesia related documents such as anaesthesia records and post anaesthesia care unit's documentations between 2018 to 2022.

This body of work is part of larger project aimed at developing anaesthesia related standards and guidelines based on the results of this nation-wide study. This will also be part of the beginning of an academic research pathway in Mongolian paediatric anaesthesia field.

In this last chapter of the thesis, the current Mongolian paediatric anaesthesia situation will be discussed, compared with other countries, and what we should do to improve our practice. Moreover, factors that may reduce incidences of critical events in paediatric anaesthesia will be discussed.

Limitation of this study will be discussed, together with the potential future direction of paediatric anaesthesia in Mongolia.

5.2 Where are we going?

The history of paediatric anaesthesia begun in the mid 1800's. Circumcisions, correction deformities, and even amputations were operated on children with small doses of pain relief, before ether began to be used in 1846. Herbal mixture named tsu san sen was used as anaesthetic by Gancho Homma for general anaesthesia in 1837 which is right at the beginning of paediatric anaesthesia history (Franklyn P. Cladis Peter J. Davis, 2022).

Due to the increasing demand for paediatric anaesthesia services, it's quality and safety issues are crucial component to be considered. In regards to the history of paediatric anaesthesia safety, the first report of mortality following chloroform anaesthesia was for a 15 years old girl who had undergone toenail surgery in 1848, presumably due to

aspiration and airway compromise. (Franklyn P. Cladis Peter J. Davis, 2022). Since then, over 150 years, safety and excellent outcome of paediatric anaesthesia has been a subject of interest of all anaesthesiologists and scholars around the world.

Therefore, numerous studies towards patient safety in the perioperative period have been performed in the last century. In the paediatric anaesthesia field, an increasing number of studies are aimed to clarify incidences and prevalence of anaesthesia related complication and their cause, and those studies are the essential basis of subsequent research that is important to safety in paediatric anaesthesia. Initially, studies focussed on single centre reports, but in recent years, hospitals have jointly conducted research as multi-centre studies to examine the occurrence of critical events of paediatric anaesthesia.

As mentioned before, in European countries studies that are named NECTARINE (NEonate – Children STudy of Anaesthesia pRactice IN Europe), APRICOT (Anaesthesia PRactice in Children Observational Trial) has been successfully conducted and continues to bring positive results in patient safety. This is a multicentred study which was conducted with 261 participating centres across 33 European countries (Walid Habre, 2017).

In Asian countries, PEACH (PEri-Anesthetic morbidity in CHildren) study is ongoing currently. This research project is welcoming health centres among Asia. Although outcomes from this study have not been published and presented internationally, this study will absolutely bring new ideas and positive results that elevate patient safety in anaesthesia up to the next level.

Wake Up Safe is an organization that was founded by Society of paediatric anaesthesia in America. This organization consistently processes research and quality improvement activities towards patient safety in perioperative period. Main mission of this organization is that learning from past occurred critical events in paediatric anaesthesia to prevent complications in the future (David W. Buck, 2021).

In terms of Mongolia, although Mongolian paediatric anaesthesia field has historical background over more than 60 years, we do not have studies that have been performed to clarify incidence of common morbidities, anaesthesia associated complications and mortality. This study is considered as an initiative of patient safety in paediatric anaesthesia of Mongolia. Then, the question arises, how are the results compared to other studies that are performed internationally. Compared results demonstrated in the below table.

Table 46: Compared results with other studies

	Mongolian data	APRICOT	WakeUpSafe
Respiratory complications	44:1000	31:1000	0.3:1000
Cardiovascular complications	74:1000	19:1000	0.13:1000
Neurological complications	0.02:1000	0.16:1000	0.04:1000
Cardiac arrest	0.1:1000	0.3:1000	0.33:1000
Death	Not reported	0.09:1000	0.09:1000

Internationally, the most common complication in peri operative period is respiratory followed by cardiovascular events based on research outcome of APRICOT (European) and Wake Up Safe (American) studies. Neurological complications, especially brain

damage incidents, are considered rarer complications compared to respiratory and cardiovascular problems related to anaesthesia in paediatric fields. Despite developing anaesthetics, anaesthesia equipment and monitoring systems, cardiac arrest and anaesthesia related death are reported from time to time.

In Mongolia, data reveals that most common anaesthesia related events were cardiovascular followed by respiratory. Although the cardiac arrest incidence in the peri anaesthesia period was reported, it may be unreported compared to the other international studies. It would be based on a limited reporting system that has not been developed well in Mongolia yet. Regarding anaesthesia related mortality, there weren't any death incidents reported related to anaesthesia. More detailed comparison information will be given in the next paragraphs.

Cardiovascular events excluding cardiac arrest incidents were prevalent during the study period with an incidence of 74 per 1000 cases. This is 3.9 to 7.4 times higher than international revealed data. Therefore, hypotension is noted as a common cardiovascular problem during the anaesthesia in Mongolia, which is equivalent with data results that have been reported in multicentre studies performed in European countries and America.

Moreover, regarding respiratory events, 44 respiratory events in 1000 cases occur 1.41 to 1.46 times higher in Mongolia compared to other studies. Laryngospasm is considered as a common respiratory complication, which is the same result of international studies. Neurological complication and cardiac arrest incident numbers are quite a lot lower than international data suggests. We must consider reporting bias to be an issue here, as it is unlikely that our national incidences of these serious complications would be substantially lower than comparative international data.

To conclude, morbidity and associated complication in paediatric anaesthesia in Mongolia has higher incidents compared to other studies which were performed in European countries and America. Hence, there is demand that we must critically improve crucial components such as pre anaesthesia assessment, monitoring, and the complication reporting system urgently. We will discuss possible improvements that are considered as crucial in paediatric anaesthesia in next subchapters.

5.3 Impact of assessment standard, monitoring system and preoperative preparation in paediatric anaesthesia safety and complications prevention

Improvements in the Mongolian health system had not seriously included surgical and anaesthesia care until mid 2010'. Initial acknowledgement and recognition of surgery and anaesthesia health services as a crucial part of Universal Health Cover was on the 68th World Health Assembly (World Health Assembly Resolution 68.16) in 2015. Regarding resolution from this assembly, it encourages enhancement in delivering surgical and anaesthesia services as close to the community as possible (Raymond Price, 2015).

In terms of paediatric anaesthesia, the subject related to service that is close to the patient is significant and multifaceted. It includes key components which play a key role to improve patient safety and excellent outcomes while minimizing risks before and during, as well as after anaesthesia. In the preoperative period, preparing children for anaesthesia and surgery is important, and it should be based on qualified assessment. Therefore, an excellent and standardized monitoring system during and after anaesthesia period can help to prevent complications and recognize events in early periods. In the next subchapter, we will discuss how these key components including

preoperative assessment and preparation, monitoring enhances the quality and safety in paediatric anaesthesia.

5.3.1 Standardisation preoperative assessment

It has been challenging to assess the children in different age groups properly, because they had specific anatomical and physiological differences, age dependent medical histories. Assessing paediatric patients before surgery or procedure requires professional skills and knowledge from anaesthesiologists.

Studies that have been performed in the last decades highlighted age, medical histories including prematurity or gestational age and comorbidities as risk factors. In other word, having identified features including medical history and physical status of every child, it would be possible to achieve the positive outcome without any complication at the end of the anaesthesia. It is strongly related to country specific preoperative assessment which would be standardized and updated by scientific information based on international guidelines and studies.

Holistic approach of preoperative assessment standard would be based on a systematic evaluation tool that can determine children's health status, while identifying risk factors and planning to proper anaesthesia and post anaesthesia care plan by anaesthesiologists with parents.

In Mongolia, a preoperative assessment tool in paediatric anaesthesia is used as an assessment chart which has not been majorly updated in recent decades. Although anaesthesiologists use this chart for routine cases, it is insufficient for complicated cases which are evaluated as ASA physical status 3 and above. Regarding this situation, anaesthesiologists need to write notes by hand on the patient's paper-based history. It takes time to do a comprehensive preoperative assessment which can contribute to evaluation bias.

Compulsory components of paediatric anaesthesia assessment would be reflected in comprehensive preoperative evaluation tools. Physical examination, information of medical history and necessary laboratory test evaluation section must be included. Therefore, possible issues such as allergic history, underlying medical conditions and history of previous surgeries with anaesthesia should be possible to clarify in this tool. Therefore, behavioural and anxiety information would be mentioned, because it is crucial to planning pre and post anaesthesia care. In one word, standardized assessment tools of anaesthesia give holistic information of a particular patient while would be convenient for anaesthesiologists.

Having improved preoperative assessment based on a convenient tool, it would be given a chance to enhance the risk management and anaesthesia planning.(Ireland, 2022), (Fabio Sbaraglia, 2024).

5.3.2 Update in perioperative preparation

Safe paediatric anaesthesia driven by preoperative preparations including evaluating the children, preparing the team and operating room and preparation of patient and carers for anaesthesia. (Matthew Harvey, 2021). Core components of patient preparation can be fasting, preoperative medication management and mental preparation for carers

(parents) and children. Regarding collected data, some recommendations related to the importance of preoperative preparation will be discussed in this subchapter.

Fasting before scheduled general anaesthesia is necessary for paediatric patients. However, hunger, discomfort, headache, dehydration and imbalance of blood sugar would be caused by fasting over 2 hours. (Allan F. Simpao, 2020). Latest data reveals that average fasting time between 4-6 hours, even over 8 hours fasted cases were reported in Mongolia. Regarding this result, hypotension and any other cardiovascular complications were reported most common in paediatric anaesthesia of Mongolia. Although fasting is an excellent way to prevent vomiting and aspiration complications, new data reminds us to review the local fasting guidelines and do updates.

Children who have been diagnosed as sick need to continue use their medication preoperatively (eg: diabetic usage of insulin preoperatively, and anticonvulsant usage in patients with epilepsy). (Fabio Sbaraglia, 2024). This important information has not been noted sufficiently in anaesthesia records that have been examined during the research period. Therefore, data of preoperative preparation related to medication illustrates most common treatment was antibiotics whether cases are indicated to antibiotics or not. In terms of this situation, there is an urgent demand to review preoperative assessment and preparation that are related to antibiotics and other medications.

Surgery is a stressful and unforgettable experience in children' life. It can affect their mental condition, treatment and recovery, and affect their future handling of anaesthesia and surgery. (Gunilla Lööf, 2021). Paediatric anaesthesiologists meet parents and carers with their children before the anaesthesia to explain what will happen in the operating room, because hospitals in Mongolia do not allow parents and carers to the operating and premedication rooms. Therefore, time to discuss the detailed process of anaesthesia is always too short under rushed circumstances due to the workload that is waiting for attending doctors. Regarding this situation, it is time to discuss extending the chance to talk with children and their family while preparing them mentally before anaesthesia, because it is important to relieve anxiety of neither carers nor children and the outcome will be strongly related with their future behavioural consequences.

To conclude, it is time to review all preoperative preparation guidelines and standards that currently anaesthesiologists follow to do updates. Therefore, local guidelines should be reflected in the mental preparation standards and guidelines that are used as internationally recognised towards children and their families.

5.3.3 Monitoring system

Mortality, morbidity and anaesthesia associated complication incidents still exist in paediatric anaesthesia, even though preparation guidelines before anaesthesia and medications have been upgraded. Crucial factors that would alter occurrences of perioperative anaesthesia complications are consumption of the standardized monitoring and safety devices. (Marinella Astuto, 2016). This subchapter will be given brief information about what a monitoring system is, how it is important and prospective technological development of monitoring in paediatric anaesthesia.

Almost hundred years after first successful paediatric anaesthesia case, Dr. Robert. Smith who was an alumni of a Harvard Medical School introduced the precordial stethoscope and routine temperature monitoring when he was working at the Children's Hospital Boston in 1946. Precordial stethoscope was a popular perioperative monitoring

device until the 1980s which is considered the beginning of a new era of important developments in paediatric anaesthesia. Important technologies including pulse oximetry, blood pressure monitoring with invasive and non- invasive approaches and electrocardiography have been introduced since the 1980s. Therefore, alarm systems to detect hypotension and disconnection have been brought into use by paediatric anaesthesia pioneers during this period (Christine L. Mai, 2012). Having introduced these devices, children's safety in anaesthesia has been enhanced up to advanced levels.

Current monitoring system guidelines and standards have been changed and updated during the last decades. Since the first standard for Safe Practice of Anaesthesia was published by the World Federation of Society of Anaesthesiologists (WFSA) in 1992, monitoring standards became more practical and convenient to follow. This standard has been reviewed and revised as a part of Safe Surgery Saves Lives initiative by the World Health Organization (WHO) since 2008 and it is intended to be the International Standard 2018. In terms of this standard, it defines perioperative monitors as highly recommended which are emphasising to prevent serious complication including cardiovascular and respiratory etc peri anaesthesia period (stethoscope, pulse oximeter, carbon dioxide detector and non-invasive blood pressure monitor with proper sized cuff), recommended (electrocardiogram, temperature and neuromuscular transmission monitor) and suggested (inhalation agent concentration monitor, invasive blood pressure and continuous temperature monitor) (W. W. M. Adrian W. Gelb, Walter Johnson, Alan F. Merry, on behalf of the International Standards for a Safe Practice of Anesthesia Workgroup, 2018). Although this is the international safety standard of anaesthesia, anaesthesiologists can work by their own perioperative safety guidelines, if it is available in a particular area.

All these advancements in paediatric anaesthesia monitoring systems have been implemented to improve the main outcomes of patient's safety during its development period. In other words, having enhanced accuracy of measuring vital signs in all parts of anaesthesia, patient's safety would improve while complication incidents have been decreased. Therefore, accuracy of vital sign measurements could lead to improvements of response time against the critical events. In result, obvious reduction of critical incidents of anaesthesia would be seen in practice. For example, in a Uganda study, all anaesthesiologists who attended pulse oximeter training indicated in questionnaires done after the training that patient safety and early warning action during critical events significantly improved. (L. C. Finch, 2014).

In Mongolia, there is no local standard for perioperative anaesthesia monitoring, and it is reasonable to suggest that adopting current international standards be the best way forward, whilst local practice evolve. Although adequacy of anaesthesia monitoring systems has been improved compared to before 2000's, shortage and limited consumption of monitoring equipment still occur in the main and provincial hospitals. Our data reveals that only 30% of cases with described complications in Mongolia has all recommended monitoring applied during their care.

To conclude, monitoring that meets basic requirement proper access can save lives, having improved patient safety during anaesthesia. Regarding this, there is an urgent need to develop local standards based on international on demand. Although a monitoring equipment shortage exists in all levels of hospitals, anaesthesiologists should use equipment that is available at their hospital as much as they can in every single case.

5.4 Does decentralisation improve patient safety in Mongolian paediatric anaesthesia?

In the present, global healthcare systems are suffering common problems that are not only human resource paucity, but also systems have repeatedly been unable to determine considerations, essential concepts of universality, equality, opportunity, and responsibility in health and wellbeing. In terms of this situation, a reform which is named decentralization has been begun in some nations since the 1990s. Decentralization in health care is the consideration of government policy that is related to system structure and allocation of responsibilities and authority (Regmi, 2014).

In Mongolia, decentralization issues have been discussed within the health developments policy while obvious implementations have been seen in health sectors in recent decades. Therefore, it has been considered as a leading subject of government in the next 5 years. Having implemented decentralization, health care will be more accessible and equally delivered to the public in their local area (Parliament, 2020 оны 08 сарын 28 өдөр). Although some health care services which are centralized in the capital city have been deconcentrated to peripherals, the flow of paediatric surgery and anaesthesia services are still towards central and tertiary hospitals.

In this subchapter, the current centralized situation of Mongolian paediatric anaesthesia, possible benefits and risks will be discussed while some recommendation and discussion will be given at the end.

The National Centre for Maternal and Child Health (NCMCH) is a centre that has been considered as the only specialized tertiary hospital for paediatric and women's health in Mongolia, even though there are other hospitals established in the last decade. The paediatric surgery caseload at the NCMCH is three to five times higher compared to other hospitals and paediatric surgery caseload is particularly low in district and private hospitals since the beginning of the 2000's. It has been discussed as a demand of collecting information and doing research of the cause of centralization of paediatric surgery and anaesthesia services for years, because there would be enough accessible or sufficient information about it. Practically, human resource shortage in paediatric anaesthesia has been considered as the main possible reason for many years. In other words, the number of trained paediatric surgeons and anaesthesiologists increased in recent years, these are insufficient for the growing demand of particular services. Therefore, some local areas still needed trained surgeons or anaesthesiologists paediatric specialised services. For example, hospitals that have paediatric anaesthesiologists are not available paediatric surgeons, whereas some hospitals are converted.

Table 47: Paediatric anaesthesiologists and surgeons by location in 2022

		Paediatric anaesthesiologists (n)	Paediatric surgeons (n)
Ulaanbaatar (Capital)	The National Centre for Maternal and Child Health	12	35
	The First State Central Hospital	-	-
	The Second State Central Hospital	-	-
	The Third State Central Hospital	4	4
	District hospital (Songinokhairkhan district)	1	-
	District hospital (Bayangol district)	1	1
	District hospital (Nalaikh district)	1	1
	Private hospital (Intermed)	1	1
	Private hospital (Songodo)	1	1
Provinces	Arkhangai province	-	1
	Bayan-Ulgii province	2	1
	Bayankhongor province	1	1
	Bulgan province	-	1
	Darkhan-Uul province	-	1
	Dornod province	1	1
	Dornogovi province	-	1
	Dundgove province	-	1
	Govi-Altai province	1	1
	Govisumber province	-	-
	Khentii province	1	1
	Khovd province	-	1
	Khuvsgul province	-	-
	Umnugovi province	1	1
	Orkhon province	1	1
	Uvurkhangai province	1	1
	Selenge province	-	1
	Sukhbaatat province	-	1
	Tuv province	-	1
	Uvs province	2	1
	Zavkhan province	-	1

Human resource paucity is playing a leading role to increase the workload of paediatric anaesthesiologists in Mongolia. Regarding the work force map by World Federation Society of Anaesthesiologists (WFSA), the density of attending anaesthesiologists is 8.05 in the 100,000 population., which is higher than minimum density <5 anaesthesiologist per 100.000 population (Anaesthesiologists, 2022-2024). However, this density is quite lower in Mongolian paediatric anaesthesia. As of 2022, there are 2.4 paediatric anaesthesiologists per 100.000 children in Mongolia. Moreover, there is a large difference between the number of cases that were allocated to one paediatric anaesthesiologist in tertiary and provincial hospitals reported in the research period. In other words, anaesthesiologist who belongs to a tertiary hospital performed an average 673 cases in a year, whereas 321 cases have been done by an anaesthesiologist in a provincial hospital. Physician anaesthesia providers are still needed in Mongolia to improve patient safety in paediatric anaesthesiology practice, because workload imbalance combined with physicians' shortage would play the main role to increase the mortality and morbidity in this field.

Having spread out centralized health care service from the tertiary to secondary level hospitals, it would be beneficial for economic and management systems in health care (Adenanterad Wicaksono, 2018). Furthermore, patient's safety would be enhanced in clinical practice, because, regarding the Lancet commission, having increased number physicians in surgery, anaesthesiologists and obstetrics, mortality rate will be decreased significantly (John G Meara & Johanna N Riesel, 2015). Conversely, reduced number of cases for per anaesthesiologists can physician's performance, in a result complication rate can be decreased. There is a tension between excessive clinical loads in the central specialist paediatric hospitals, resulting in burnout and potential complications, and too low a caseload per anaesthesiologist in another non-tertiary environment. Balancing these issues in a very sparsely populated country is a substantial challenge.

5.5 Impact of training system update in safety improvement in paediatric anaesthesia

Young age, ASA physical status and surgical procedures are considered as common factors when we are discussing the serious events of paediatric anaesthesia. These are factors that are related to patients. However, anaesthesiologists'' experience and training pathway can play a vital role in patient safety during the anaesthesia. In other words, an experienced anaesthesia team could lower incidence of complications and enhance outcomes. Regarding this, anaesthesia training standard would be a crucial factor to reduce occurrence of serious events including cardiac arrest paediatric anaesthesia (Andreas Hohn, 2019).

Internationally, most countries are reported that the minimum duration of anaesthesia training including paediatric anaesthesia rotation is 4 to 5 years. Between one year to 3 years is an acceptable duration to be able to provide the anaesthesia to patients as physician anaesthesia providers in many countries (James Matthew Kynes, 2019). After anaesthesia residency training, 1 year paediatric anaesthesia fellowship training is accepted as an official training for anaesthesiologists who are enthusiastic for this speciality. Other subspecialty training such as paediatric regional anaesthesia, paediatric cardiac anaesthesia and paediatric neuro anaesthesia training are required 0.5 to 2 years training after fellowship. Anaesthesiologist who wants to be a qualified paediatric anaesthesiologist need to be trained for an average 5 to 6 years including fellowship training.

In Mongolia, anaesthesia training program has been updated since it was established. The 2 years program is officially considered as anaesthesia residency training. It includes 12 weeks of paediatric anaesthesia rotation. Fellowship training with a 6 month duration is available for anaesthesiologists. There is not any subspecialty training such as paediatric neuro and regional anaesthesia after fellowship training. All these training programs are more practice based, even though lectures are provided.

In terms of improving patient safety in paediatric anaesthesia, one of the important aspects can be involved with training curriculum and qualification. Although the duration of paediatric anaesthesia rotation during residency program and fellowship training is shorter than internationally recognized programs, it would need time and more attention from policymakers. However, organizations that are responsible for qualification of residency and fellowship training programmes should work more closely with anaesthesia physicians to make improvements in training programs while updating it.

Training curriculum updates would include more effective activities which can bring positive outcomes in a practice. For example, simulation training, adverse events analysis and involvement in process improvement are officially considered as part of qualified international anaesthesia programs. During these activities, trainee will have

chance to involve critical events and discuss the how to solve those problems, what is the reason and mistakes that have been occurred in out of clinical environment. Therefore, although essential knowledge of anaesthesia practice is provided as lectures by senior anaesthesiologists, it should be updated every year and discussion with audit would be performed by academic supervisory team as frequently as possible.

To conclude, qualification of training efforts to patient safety which is a multi factored subject in perioperative medicine. Improving standardization of paediatric anaesthesia training programs is not only patient safety, but also related to enhancing the anaesthesiologist performance and hospital level management system which play an important role of safety in the clinical environment at the end of last point.

5.6 Strengths

The strengths of this study are a large number of patients and participating hospitals that are able to represent the current situation of paediatric anaesthesia service in Mongolia. Our data that were collected from tertiary and secondary level hospitals represent mortality, morbidity and associated complication in Mongolian paediatric anaesthesia. Our results can be motivational benefits to other anaesthesiologists who want to do more detailed studies in this field.

5.7 Limitations

Several potential limitations were taken in this thesis's studies. For clarity, each limitation that belongs to the individual chapters will be discussed chapter by chapter in this subchapter.

Chapter 1: There were insufficient academic resources about Mongolian paediatric anaesthesia in English and Mongolian language either. It leads to citation and reference limitations that have been taken in Chapter 1.

Chapter 2: Definitions of anaesthesia related mortality, morbidity and associated complications were none specified in most of the studies. Regarding this issue, some research that included crucial information may have been missed during the duplication process of this chapter.

Some studies failed to provide information about results and outcomes after anaesthesia complication. Therefore, it was challenging to conclude confounding factors such as age, comorbidity status etc, because analysing methods were quite different in each study.

Chapter 3: Time frame was the main limitation of this part of study. It has not given the opportunity to collect information from detailed documentation such as outside hospital anaesthesia or sedation records. Therefore, light sedation records that have been performed in the ward are not included due to insufficient recording systems at the hospitals.

Chapter 4: Overlapped information that might be given unclear information would be included in this chapter. This is a limitation of the analysing process of this study. Although data analysed by a clearly defined method, it would be given an unclear situation for readers.

Chapter 5: Information from Mongolian side was limited. There was insufficient and accessible information of standard guidelines of perioperative preparation and

monitoring etc. In other words, this chapter has been written based on practical information that may lead to the limitation.

To conclude, limitations of this thesis's study are strongly related with insufficient and non-accessible local information in English and Mongolian language either. However, the study went well and concluded at this point.

5.8 Future direction

The primary finding of this study is that common morbidity and anaesthesia associated complications were cardiovascular followed by respiratory events. Although it is good to find the results that cardiac arrest and anaesthesia related mortality were not reported, these might be due to under reporting. In terms of these results, some future direction as a recommendation have been given to improve paediatric patients' safety during anaesthesia.

Foremost, developing a reporting system and frequent discussion about common problems related to anaesthesia will be important in Mongolia. Having developed these activities, it would be more convenient to gather information about critical events, while creating the standard guidelines toward patient safety.

Future advanced studies that are important to clarify common factors and reasons of respiratory and cardiovascular complication can be performed in Mongolian paediatric anaesthesia field. It is important to explain common factors that trigger the anaesthesia events and give the chance to prevent those complications.

Concluding prevalence and incidence number of mortality, morbidity and associated complication in paediatric anaesthesia is valuable to improve patient safety. Moreover, it gives the opportunity to future study ideas that will be beneficial to not only safety improvement, but also bringing advancement in anaesthesia techniques and clinical management systems in Mongolia.

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