

RESEARCH ARTICLE

Anaesthesia delivery systems in low and lower-middle-income Asian countries: A scoping review of capacity and effectiveness

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Abstract

Literature on anaesthesia systems in low and lower middle-income countries is limited, focused on the Africa region, and provides minimal data on anaesthesia or associated disciplines within intensive care, pain management and emergency medicine. We thus conducted a scoping review of primary and secondary research literature on capacity and effectiveness of anaesthesia delivery in low and lower middle-income countries in the Asia region from 2000–2021, to clarify existing knowledge, important gaps, and possible subsequent steps. We applied Arksey and O'Malley's scoping literature review method to search five databases (i.e. EMBASE, CINAHL, Medline, Scopus, Web of Science), screen, extract, and synthesise data under three themes: (i) availability and type of anaesthesia workforce; (ii) anaesthesia system infrastructure, equipment, and supplies; and (iii) effectiveness of anaesthesia provision. We included 25 eligible sources of 603 identified. Only ten (40%) were published in the last 5 years and Asian lower-income countries were primarily represented in 15 multi-country sources. Fifteen (60%) sources used quantitative methods and provided limited information on data collection, e.g. sampling criteria or geographic areas included. No sources included countrywide data, despite anaesthesia delivery and resources differing significantly sub-nationally (e.g. central versus rural/remote, or insecure areas). Data on anaesthesiology delivery were limited, with findings including insufficiencies in workforce, supplies, training, and skills-building of anaesthesia personnel, along with the lack of consistent strategies for overcoming maldistribution of resources and improving anaesthesia delivery systems in the region. This review, a first attempt to synthesise existing data on anaesthesia delivery systems in low and lower-middle-income Asian countries, shows the anaesthesia literature is still limited. Findings highlight the urgent need for additional research and collaboration nationally and regionally to strengthen anaesthesia delivery and surgical facilities in resource-constrained settings.

OPEN ACCESS

Citation: Shahbaz S, Howard N (2024) Anaesthesia delivery systems in low and lower-middle-income Asian countries: A scoping review of capacity and effectiveness. *PLOS Glob Public Health* 4(3): e0001953. <https://doi.org/10.1371/journal.pgph.0001953>

Editor: Anat Rosenthal, Ben-Gurion University of the Negev, ISRAEL

Received: May 13, 2023

Accepted: February 18, 2024

Published: March 18, 2024

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Data Availability Statement: As this is a literature review, we only include data in our analysis from 24 published sources, all of which are cited in [Table 4](#).

Funding: The authors received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist.

Introduction

Anaesthesia provision that is timely and of good quality can significantly reduce surgical mortality and morbidity, yet almost 90% of populations in low and middle-income countries (LMICs) have difficulties accessing surgical care [1] due to insufficient availability of quality anaesthesia, making it a major limitation globally in achieving comprehensive surgical care needs. This can cause delayed or no surgical treatment for many common and treatable conditions, such as appendicitis or obstructed labour, resulting in higher mortality rates [2]. Additionally, many people in LMICs receive anaesthesia from untrained or unskilled anaesthesia providers, resulting in higher mortality rates than in high-income countries [3].

It is challenging to follow improvements in accessing quality anaesthesia services over time in LMICs [4], especially because of the lack of research in the Asia region, migration of skilled personnel, maldistribution of resources, and protracted or unanticipated conflict and occupation (e.g. Afghanistan, Syria, Palestinian territories). International anaesthesiology research and funding for LMICs is focused primarily and understandably on resource-depleted settings in the Africa region, with most documentation of anaesthesia capacity and effectiveness over time conducted in African countries. Despite less documentation, anaesthesia provision needs also exist in the Asia region, requiring efforts to improve numbers of trained anaesthesia personnel, equipment, and medication [5]. Many lower-income Asian countries have insufficiently resourced systems, with as few as 9 anaesthetists for a population of 32 million in Afghanistan [6].

We contend that existing knowledge on anaesthesia provision needs in lower-income Asian countries requires synthesis to highlight potential knowledge and practice gaps that could be addressed through additional research and funding. Unsafe anaesthesia delivery can lead to unsafe surgery, resulting in increased morbidity and mortality and worsened disease burden for already constrained health systems [6]. Given the insufficient international prioritisation of research data, we aimed to review existing literature on the capacity and effectiveness of anaesthesia delivery systems in lower-income Asian countries, examining infrastructure, workforce, and services. This review can provide a starting point for advancement in this important yet neglected area of medicine in LMICs.

Methods

Study design and definitions

We conducted a scoping literature review using Arksey and O'Malley's method and later refinements [7–11]. We chose a scoping method given the breadth of our research question and anticipated heterogeneity of the literature [9], because it can legitimately be conducted by a single investigator, and because it does not restrict data through formal quality assessment [10, 11].

Table 1 shows our definitions. We used Tranquilli and Thurmon's 2013 anaesthesia definition, as it broadly defines the term and, although anaesthesia is no longer limited to surgical procedures, it is still largely limited to intraoperative procedures in LMICs. Similarly, our chosen definition for anaesthesia delivery system refers to its intraoperative use [12]. We chose the standard WHO health system definition for its familiarity. For lower-income Asian countries, we chose 24 identified by the Organisation for Economic Co-operation and Development (OECD) list for 2022–2023 as low-income or lower-middle-income (i.e. below US\$4045 annual GNI) among the 48 Asian countries recognised by the United Nations.

Table 1. Research definitions.

Anaesthesia	Anaesthesia is categorized as insensitivity to pain, particularly by induction of synthetically-prepared gases or inoculation of drugs prior to surgical procedures [13].
Anaesthesia delivery system	The anaesthesia delivery system comprises the anaesthesia provider, anaesthesia machine, anaesthesia vaporizers, ventilator, breathing circuit, and waste gas scavenging system [12].
Health system	Consists of all organizations, people and actions whose primary intent is to promote, restore or maintain health, including efforts to influence determinants of health as well as more direct health-improving activities [14].
Lower-income Asian countries	Include low-income countries, with a per capita gross national income (GNI) of less than US\$1045 annually, and lower-middle-income countries with a GNI per capita of US\$1046–4096 annually as determined by OECD for 2022. In the Asia region, these are Afghanistan, Bangladesh, Bhutan, Cambodia, India, Indonesia, Iran, Kyrgyzstan, Laos, Mongolia, Myanmar, Nepal, North Korea (DPRK), Pakistan, Palestine, Papua New Guinea (PNG), Philippines, Sri Lanka, Syria, Tajikistan, Timor-Leste, Uzbekistan, Vanuatu, Viet Nam, and Yemen [World Bank].

<https://doi.org/10.1371/journal.pgph.0001953.t001>

Research question

Our research question was: ‘What is the scope (i.e. extent, nature, distribution) and main capacity and effectiveness findings of the existing literature on anaesthesia delivery within healthcare in Asian low and lower-middle-income countries?’

Identifying relevant sources

To ensure breadth and comprehensiveness, we searched five electronic databases systematically (i.e. EMBASE, CINAHL, Medline, Scopus, Web of Science) between February 2022 and January 2023, using the terms and related terminology for ‘anaesthesia’ AND ‘delivery system’ AND ‘LMICs’ AND ‘Asia’ adapted to the subject headings for each database. [Table 2](#) provides an example in Medline.

Table 2. Search syntax and keywords for Medline.

Key word	Medline
Anaesthesia	1. "Anesthesiology"[Mesh] 2. "Anesthesia"[Mesh] 3. anesthesiology OR anaesthesiology OR 4. anesthesia OR anaesthesia 5. 1 OR 2 OR 3 OR 4
Health system	6. Delivery of Health Care / methods 7. Delivery of Health Care / standards* 8. Public Health / methods OR Public Health / standards 9. Quality of Health Care / standards* 10. 6 OR 7 OR 8 OR 9
Asian LMICs	11. Low- and Middle-Income Countries 12. Developing Countr* OR Developing Nation* OR Less-Developed Nation* 13. Least Developed Countr* OR Less-Developed Countr* OR Under-Developed Nation* OR Under-Developed Countr* OR 14. Third-World Nation* OR Third-World Countr* OR 15. 11 or 12 or 13 or 14 16. Afghanistan OR Cambodia OR Azerbaijan OR Bangladesh OR Bhutan OR India OR Indonesia OR Iran OR Democratic people's republic of Korea OR DPRK OR Mongolia OR Myanmar OR Nepal OR Pakistan OR Palestine OR West Bank and Gaza OR Papua New Guinea OR Kyrgyzstan OR Lao* OR Philippines OR Sri Lanka OR Syria OR Tajikistan OR Timor-Leste OR East Timor OR Uzbekistan OR Viet Nam OR Vietnam OR Yemen 17. 5 AND 10 AND 15 AND 16

<https://doi.org/10.1371/journal.pgph.0001953.t002>

Selecting sources

[Table 3](#) provides eligibility criteria, determined via an iterative process. Context was restricted to Asian LMICs to help inform anaesthesiology in the region. Topic was restricted to anaesthesia delivery system as defined in [Table 1](#). Outcomes were restricted to capacity and effectiveness measures. Source type was restricted to primary and secondary research literature. Time-period was restricted to 2000 and after, as before this anaesthesia practices, equipment, and medications were sufficiently different to affect research findings. All languages, study designs, and participants were considered.

First, we downloaded all sources identified across the five databases into EndNote reference manager and deleted all duplicates. Second, we screened titles and abstracts against eligibility criteria and eliminated obviously ineligible sources using Rayyan software. Third, we screened full texts against eligibility criteria and eliminated ineligible sources. Finally, we screened reference lists of included sources to identify any additional eligible sources. This provided our total number of sources included.

Extracting (charting) data

We extracted data from eligible sources to an Excel sheet using the following iterative headings: (i) source identifiers, i.e. publication year, lead author, source type (e.g. article, conference abstract, report), language; (ii) source characteristics, i.e. country/ies, study design, participant characteristics, methods; (iii) findings, i.e. capacity (workforce, infrastructure), efficacy, and effectiveness.

Table 3. Eligibility criteria.

Criteria	Included	Excluded
1. Context	<ul style="list-style-type: none"> Low and lower-middle-income countries in Asia (i.e. Afghanistan, Bangladesh, Bhutan, Cambodia, India, Indonesia, Iran, Kyrgyzstan, Laos, Mongolia, Myanmar, Nepal, North Korea/DPRK, Pakistan, Palestine, Papua New Guinea, Philippines, Sri Lanka, Syria, Tajikistan, Timor-Leste, Uzbekistan, Viet Nam, Yemen) 	<ul style="list-style-type: none"> Other settings
2. Topic	<ul style="list-style-type: none"> Anaesthesia delivery system within health systems (Table 1) 	<ul style="list-style-type: none"> Unrelated to anaesthesia delivery within health systems.
3. Outcomes	<ul style="list-style-type: none"> Capacity, efficacy, or effectiveness. 	<ul style="list-style-type: none"> Other outcomes.
4. Source type	<ul style="list-style-type: none"> Primary research articles. Secondary research articles (e.g. literature reviews). Commentaries/editorials that include primary or secondary research. Conference abstracts that include primary or secondary research. Book chapters that include primary or secondary research. 	<ul style="list-style-type: none"> Not primary or secondary research literature. Conference abstracts covering the same material as an available publication. Audio/video reports. Social media, blogs, media articles. Guidance/legal documents.
5. Time-period	<ul style="list-style-type: none"> Published 2000–2021. Data collected from 2000 onward. 	<ul style="list-style-type: none"> Published or data collected before 2000
6. Language	<ul style="list-style-type: none"> All for which an English abstract is available. 	<ul style="list-style-type: none"> Sources for which no English abstract is accessible.
7. Study design	<ul style="list-style-type: none"> Any 	<ul style="list-style-type: none"> NA
8. Participants	<ul style="list-style-type: none"> Any 	<ul style="list-style-type: none"> NA

<https://doi.org/10.1371/journal.pgph.0001953.t003>

Synthesising and reporting results

First, we summarised the extent (i.e. numbers, publication year, type - article, conference abstract, book, report), distribution (i.e. publication language, countries included), and nature (i.e. study design, participants, outcomes) of sources. Second, we synthesised findings thematically, guided by Braun & Clarke's approach, under three deductive themes: (i) availability and type of anaesthesia workforce; (ii) anaesthesia infrastructure, equipment, and supplies, (iii) effectiveness of anaesthesia provision [15].

Results

Scope of the literature

Extent. We included 25 eligible sources of 603 identified in databases and reference lists (Fig 1). Most were from EMBASE (195) and Medline (185), 209 and 84 records were removed by title/abstract and full-text screening respectively, while 6 were added from purposively searching reference lists of included sources.

Fig 2 shows no sources were published prior to 2006, or in 2008 and 2011, while the maximum number per year never exceeded 3 (e.g. in 2010, 2015, 2017, and 2020 respectively). Overall, no clear trend emerged.

Most sources (21/25; 84%) were research articles, while 2 (8%) were technical reports and (8%) were commentaries.

Distribution. All 25 sources were published in English. Data from all 24 lower-income Asian countries (100%) were included, though detail was limited for most. Ten (40%) were conducted in individual countries while 15 (60%) were conducted in LMICs globally and included one or more lower-income Asian country. Multi-country sources included data from 5 to 24 countries. Fig 3 shows that Afghanistan was most represented (1 single, 7 multi-country sources); followed by India (3 single, 3 multi-country); Bangladesh (2 single, 4 multi-country); Pakistan and Sri Lanka (1 single and 4 multi-country each); Viet Nam (4 multi-country); Papua New Guinea (1 single, 2 multi-country); Bhutan, Cambodia, Indonesia, Iran, and Nepal (3 multi-country each); and Syria (1 single, 1 multi-country). Myanmar, North Korea, and the Philippines were in 2 multi-country sources, while Kyrgyzstan, Laos, Mongolia, Palestine, Tajikistan, Timor-Leste, Yemen, and Uzbekistan were represented in only one multi-country sources. India had the most single-country sources, with 3 conducted in separate states.

Nature. Most used WHO or World Federation of Societies of Anaesthesiologists (WFSA) approved survey tools and participants were primarily facility-based anaesthesia personnel who described available resources and practices. Most sources (n = 14; 56%) used quantitative methods, primarily cross-sectional multicentre or observational surveys; 6 (24%) were literature reviews; 2 (8%) primarily used qualitative methods, including semi-structured interviews and observations; while 3 (12%) did not describe methods. A few sources detailed their sampling strategy, while most provided minimal explanation. Random and purposive samplings were the preferred sampling methods.

Synthesised findings

Table 4 shows coverage of our three deductive themes by sources. Most (21) included more than one theme, and 13 included all three, though depth and rigour varied considerably. We intentionally avoided describing specific health systems, as this information is readily available elsewhere and most countries were included as part of multi-country studies with limited specificity on socio-political context or health system configuration. Despite this, many of the issues described were similar (e.g. insufficient anaesthesia personal, capacity-building and

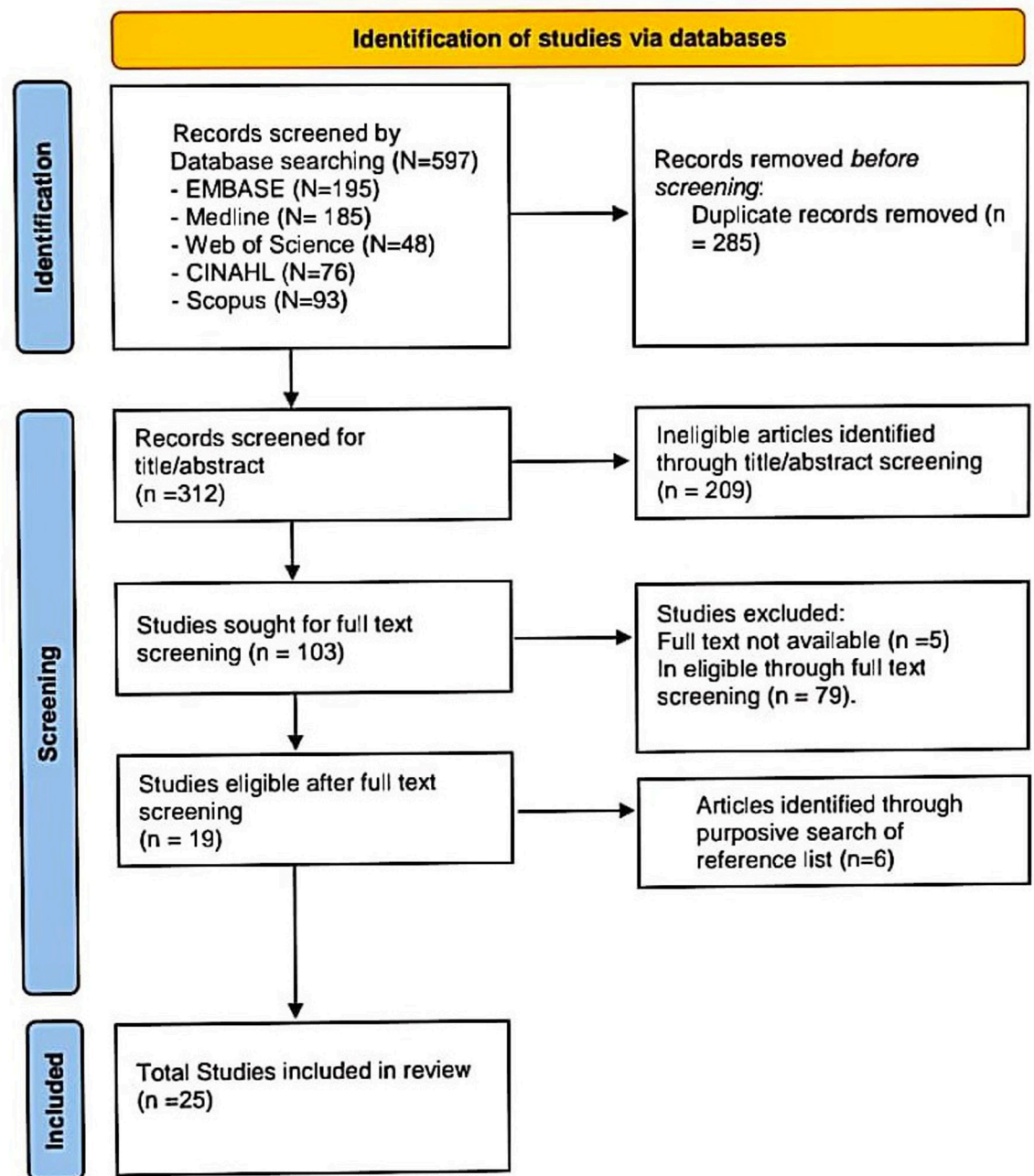


Fig 1. PRISMA flow diagram.

<https://doi.org/10.1371/journal.pgph.0001953.g001>

operational challenges). Therefore, to avoid prioritising specific countries, we synthesised these similar findings to provide a ‘snapshot’ of key issues in the region.

Availability and type of workforce

Twenty sources (80%) included data on this theme, all indicating a lack of sufficient trained anaesthesia personnel. Anaesthesia workforce shortages were acknowledged repeatedly as a

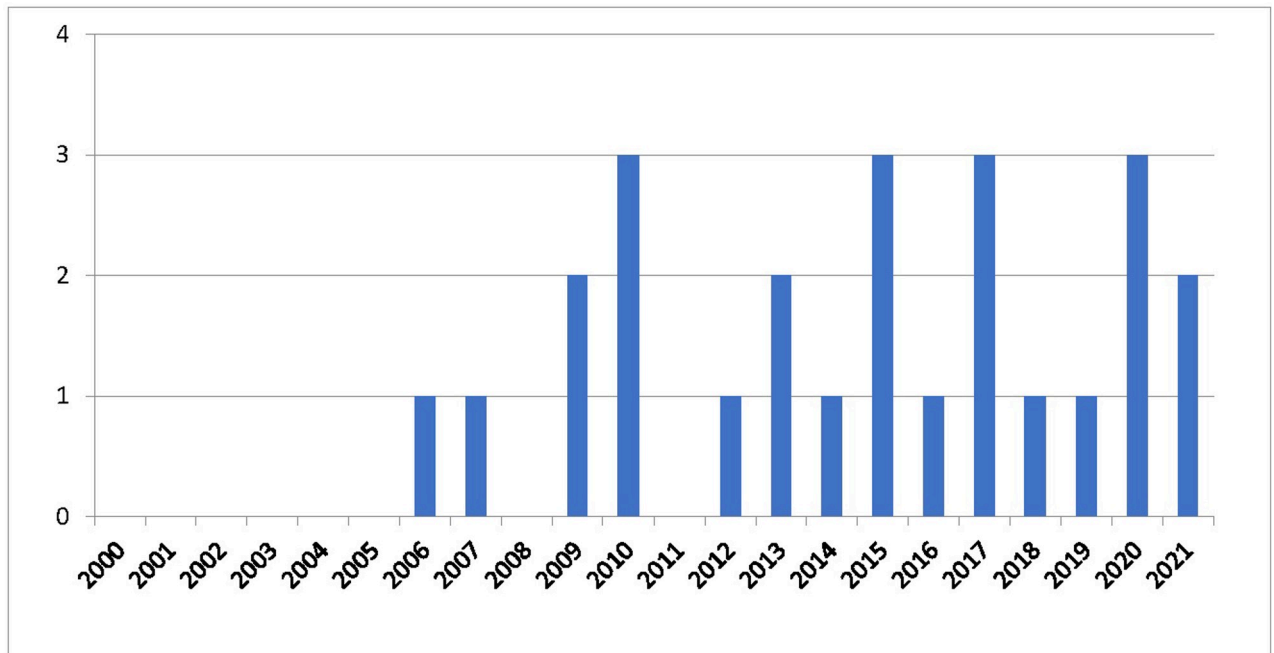


Fig 2. Publication numbers by year.

<https://doi.org/10.1371/journal.pgph.0001953.g002>

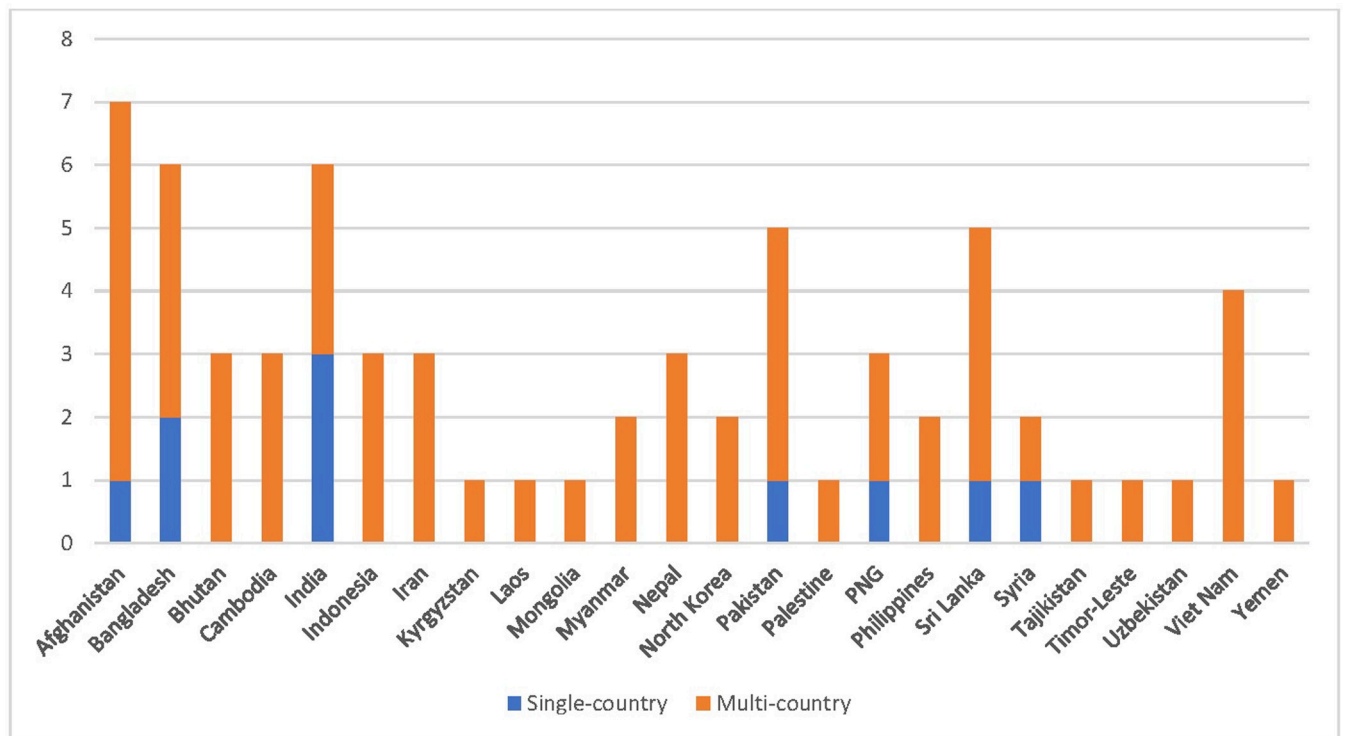


Fig 3. Publications numbers by country.

<https://doi.org/10.1371/journal.pgph.0001953.g003>

Table 4. Coverage of themes by 25 eligible sources.

Lead author, year	Availability and type of workforce	Infrastructure, equipment, supplies	Effectiveness of provision
Bhatia, 2021	✓	✓	✓
Contini, 2010	✓	✓	✓
Dubowitz, 2010	✓		
Froese, 2007	✓	✓	
Hadler, 2016	✓	✓	✓
Kempthorne, 2017	✓		
Khan & Merry, 2018	✓	✓	✓
Khatib, 2017			✓
Kudsk-Iversen, 2018	✓		✓
Kushner, 2010		✓	✓
Lee, 2020	✓	✓	✓
Loughnan, 2021	✓		✓
Loveday, 2017		✓	✓
Marchbein, 2013	✓	✓	
McQueen, 2015	✓	✓	✓
Meadows, 2020	✓	✓	✓
Pieczynski, 2013	✓	✓	✓
Santhirapala, 2020	✓	✓	✓
Sarkar, 2016			✓
Shahbaz, 2021	✓	✓	✓
Steffner, 2014	✓	✓	✓
Suzuki & Asai, 2006	✓	✓	✓
Taira, 2010	✓	✓	
Vo, 2012	✓	✓	✓
Walker, 2009		✓	✓

<https://doi.org/10.1371/journal.pgph.0001953.t004>

key obstacle in achieving safe surgical care. Dubowitz and colleagues reported anaesthesia workforce numbers as low as 0.07 per 100,000 population in Yemen, including physician and non-physician anaesthetists [16]. Similarly, Steffner et al noted the absence of even mid-level anaesthesia providers (i.e. dedicated anaesthesia nurses or technicians) in many hospitals surveyed, leading to anaesthesia provision by physicians and non-physicians without any formal anaesthesia training, and increased perioperative death rates [17]. Contini et al found only 5 of 17 health facilities assessed in Afghanistan had trained physician-anaesthetists, while a few had nurse anaesthetists, but most had no anaesthesia personnel [18]. In 22 LMICs reviewed by Hadler et al, only 56% of hospitals had capacity to perform general anaesthesia because of a lack of trained anaesthetists [19].

Vo and others found anaesthesia provider numbers increased according to hospital bed numbers rather than need or population served, so a 300-bed hospital could have almost 4 anaesthetists compared to 100-bed or smaller hospitals with less than 1 fulltime or no anaesthetist to provide services to a larger population [20]. Bhatia et al reported 1 anaesthetist in a Haryana sub-district hospital for a population of 500,000, which not only showed the lack of anaesthesia workforce but also delayed surgeries due to insufficient appropriate anaesthesia personnel in parts of India [21]. Likewise, Loveday et al described 952 anaesthetists for a population of 163.05 million in Bangladesh (i.e. averaging 0.58 anaesthetists per 100,000 people), a minor increase from 0.52 per 100,000 in 2012 [22]. In most LMICs, non-physician anaesthetists were not routinely trained to help support the system. However, Papua New Guinea,

which has only 0.25 physician-anaesthetists per 100,000 populations, trained non-physician anaesthetists to meet 90% of total anaesthesia demand [23]. Meara and others thus recommend task sharing with non-physician anaesthetists, who are cheaper and quicker to train to fill the gaps in LMICs until minimum essential standards have been attained [2, 24, 25].

No sources covered any country fully and consultants in most countries were concentrated in city centres [26]. Thus, the situation was likely worse in rural, hard-to-reach, and insecure or conflict-affected areas [6]. Moreover, many skilled anaesthetists reportedly left the speciality or their country because of high workloads, burnout, insecurity, or feeling undervalued/under-remunerated [25].

Infrastructure, equipment, and supplies

Eighteen sources (72%) included data on this theme, with none reporting 100% availability of uninterrupted water, oxygen, or electricity in the health facilities examined [18, 27]. Access to fully functional anaesthesia equipment was limited to half of surveyed facilities in most countries [17, 20]. Likewise, Walker et al found availability of pulse oximeters was limited to approximately half of health facilities in Viet Nam and the Philippines [28]. A volunteer anaesthetist in India mentioned his concerns about losing his patient given the lack of basic monitoring equipment [29].

Sources found most facilities relying on Ketamine because of constrained resources, or only using regional anaesthesia as emergency intubation equipment was lacking [18, 19]. Moreover, Contini et al found paediatric intubation sets were not available in half of health facilities examined in Afghanistan [18]. Availability of blood banks and invasive monitoring was restricted to tertiary care facilities in Pakistan and other resource-constrained countries [24, 26]. Face masks, bags, ECG monitoring, and medication were reported as absent in most health facilities studied in Bangladesh [22]. Infrastructure, supplies, and medications availability were reportedly worst in primary and secondary hospitals in almost all sources with only teaching and tertiary hospitals having necessary anaesthesia supplies available, though still often in limited quantities [30].

Effectiveness of anaesthesia provision and future interventions

Nineteen sources (76%) included data on this theme. Despite insufficiencies in workforce and supplies described, consistent strategies for improving anaesthesia delivery in lower-income countries in the region appeared to be lacking. This lack of strategic direction was particularly noticeable in the absence of anaesthesia monitoring and evaluation data collected or analysed, insufficient training and skills building of anaesthesia personnel, frequent maldistribution of anaesthesia resources, and the added health system burden of armed conflict and insecurity.

Contini et al found subnational difference in performance data and outcomes in Afghanistan and other countries, showing the urgent need for nationwide anaesthesia data collection and analysis in each country [18, 20]. Steffner et al noted that any improvement in the anaesthesia system is impossible until comprehensive data analysis on clinical outcomes, cost-effectiveness, mortality, and morbidity is available, while reporting the absence of appropriate indicators on anaesthesia access and outcomes in countries studied [17]. Some sources suggested the perioperative mortality rate could be the WHO-recommended health indicator to monitor and compare perioperative infrastructure across health systems [25].

The presence of anaesthesia personnel did not automatically determine the provision of quality anaesthesia services, as theoretical knowledge and skills could be outdated or insufficient [25], leadership could be lacking, and essential equipment and supplies could be unavailable. Some sources focused on the importance of improving anaesthesia training, along with

capacity improvements [19]. Nurses/technicians delivered most anaesthesia in non-central areas in these countries, or junior doctors with variable training, who also trained other personnel in anaesthesia delivery despite their own limited skills. Thus, if anaesthesia providers' training and capacity are considered, the dearth of anaesthesia effectiveness is even greater. Combining this limited knowledge with limited resources could contribute greatly towards perioperative and intraoperative mortality rates. One source described the positive aspects of involving anaesthesia volunteers from high-income settings in building capacity in LMICs, as not only improving patient care but also training LMIC anaesthesia professionals to continue the same standard of care in their own countries [29].

One of the most important aspects mentioned in sources was the maldistribution of anaesthesia resources that made remote and secondary health facilities unsafe for anaesthesia provision [22, 27, 30]. Several sources reported better facilities and concentrations of qualified anaesthetists in teaching and tertiary level hospitals, while health facilities in remote areas were left without meaningful guidance or support [22, 27, 30]. Moreover, many Asian countries did not allow employment of non-physician anaesthetists, which not only promoted unsafe practices but also burnout among the limited available physician-anaesthetists. With growing focus on the global surgery agenda, anaesthesia could likely become a rate-limiting step to increasing surgery capacity in many LMICs in Asia [22].

Contini and others described how decades of war in some Asian LMICs further degraded the anaesthesia delivery system, with either no data available on surgery and anaesthesia or data going unreported or being misplaced or destroyed [18]. Marchbein et al also reported that workable pre-conflict anaesthesia delivery systems were often destroyed or evacuated during conflict. For example, security concerns in Syria meant health-workers were unwilling to share data as this could make them targets for treating opposition fighters [31].

Discussion

Key findings

This review is the first to our knowledge to synthesise the scope and main findings of the literature on capacity and effectiveness of anaesthesia delivery systems in lower-income Asian countries. Eligible sources were limited, as most anaesthesia delivery literature only discussed clinical aspects, but highlighted important delivery weaknesses that contributed to preventing the region from achieving international criteria for minimum essential anaesthesia staffing, equipment, and medication. The relatively limited literature indicates the need for further research on this topic in Asia. However, most sources from different countries discussed common trends and issues, which enabled thematic synthesis. The review thus provides a starting point for future research and analysis on anaesthesia delivery systems in lower-income economies in the region.

Availability of oxygen, water, and electricity are minimum standards for facilities providing surgery and anaesthesia, but no country included in our review provided this 100% of the time in all facilities [32]. This lack of infrastructure aligned with several studies in the Africa region, showing 50–75% of hospitals assessed were without basic facilities such as pulse oximeters or monitors [33–35]. In Asian LMICs, 50–75% of hospitals studied had these facilities except those experiencing ongoing conflict [26]. Most teaching and tertiary-level hospitals in our review met WFSA mandatory standards for safe practices including availability of opioid analgesics [36], while secondary and primary health facilities generally lacked these as also noted in LMICs in the Americas and Africa regions [34, 37–39]. As found in many LMICs, ketamine was extensively used [40]. This emphasises the importance of ketamine in resource-

constrained settings - until international criteria of minimum essential equipment and medications are met, as it provides anaesthetic effects without compromising patients' airways [41].

WFSA recommends a minimum of 5 physician-anaesthetists per 100,000 population [6]. Unfortunately, even after including non-physician anaesthetists, none of the countries in this review achieved this target. In most, non-physician anaesthetists were not allowed to practice or given formal training to overcome this gap, as compared to some African countries in which anaesthesia officers and nurse-anaesthetists work effectively to bridge the gap in qualified personnel [42–44]. Poor employment conditions, security, burnout, and limited professional acknowledgment are noteworthy obstacles to recruitment and retention of the anaesthesia workforce in Asian LMICs [45]. Stress, high workloads, insufficient remuneration, and security issues associated with anaesthesiology reduces the number of medical students joining this speciality, while migration of skilled anaesthesia professionals to high-income countries replicates the health-worker 'brain-drain' found in many health specialisations [46, 47].

Implications

Two major lacunae are identifiable from our data: (i) inadequate reporting on the availability and effectiveness of existing systems; and (ii) inadequate anaesthesia delivery systems, including staffing and infrastructure. The implications of both are very different, but inter-related. Without proper reporting, shortcomings cannot be assessed or addressed during resource planning (e.g. required numbers and placement of staff, equipment, or medication) and gaps/inadequate provision are likely to continue. Without proper staffing and infrastructure, patient health and surgical outcomes will certainly suffer. However, while this appears logical, literature on post-operative anaesthesia-related morbidity and mortality in LMICs remain limited. We identified a few studies in the Asia and Africa regions that correlated poor surgical outcomes and anaesthetic death with insufficient trained anaesthesia personal or equipment and supplies [48–52]. For example, Jasper's 7-year review of operating table deaths in a Nigerian general hospital found 10 deaths of 1,187 surgeries, all of which may have related to anaesthesia or the anaesthetist [48]. Khan & Khan's 11-year review in a 'developing country' university hospital found 35 deaths of 111,289 surgeries, in 4 and 8 of which anaesthesia was solely and partially responsible respectively [50]. Blaise Pascal et al's 5-year review of general anaesthesia-related mortality in two DRC hospitals found 38 anaesthesia-related deaths of 921 surgeries, with improper infrastructure, drugs, equipment, and training noted as limiting safe anaesthesia [51].

Key implications for policymakers and practitioners are the urgent need to achieve minimum anaesthesia standards for infrastructure and staff in the Asia region. First steps in improving these anaesthesia systems would be strengthening adherence to WHO guidance on data recording and reporting, and then assessing and planning how to fund and standardise capacities in numbers, training, and experience of physician and non-physician anaesthetists in accordance with WHO-WFSA 'highly recommended' standards of quality anaesthesia services for surgical support [53]. Operational challenges in accessing remote and disputed or conflict-affected settings must be addressed, requiring collaboration among national and international organisations able to improve anaesthesia and surgical facilities in the region. Retention of trained anaesthesia personnel is a key problem, and effective nationally relevant policies are urgently needed to reduce 'brain drain.'

It should be noted that several eligible countries and territories, i.e. Kyrgyzstan, Mongolia, Palestine, Tajikistan, and Uzbekistan were not included in any sources regarding anaesthesia capacity (i.e. equipment and medication) or effectiveness, which could threaten achievement of the global plan of surgical and anaesthetic safety [54]. Thus, a key role for researchers would be to support efforts to fill data gaps, particularly for these countries. Additional operational

and implementation research is needed to determine feasible and cost-effective approaches to training, recruitment, and retention of anaesthesia personnel and provision of good-quality essential equipment and supplies.

Limitations

Several limitations should be considered. First, literature was heterogeneous, with substantial differences in methodologies, data collection tools, and study samples. Second, no source represented an entire country, despite the acknowledgement of significant subnational differences in anaesthesia resources and capacities, particularly between capital and rural or remote regions. Third, study quality assessment was not conducted as it is not required for scoping reviews and could have further reduced the number of eligible sources. Fourth, individual country-based data from only 7 countries were available, indicating further data collection is required in all countries to better understand the situation in the region. However, several patterns were clear despite data gaps, including the lack of electricity, oxygen, and pulse oximeters, insufficient quantity and quality of anaesthesia staff, and challenging work environments. Fifth, all assessments were conducted and reported by different research teams, which may have resulted in discrepancies in reporting. However, most tools were validated for multi-country use by WFSA or WHO. Finally, to ensure manageability we restricted eligibility criteria to anaesthesia delivery system capacity and effectiveness and may thus have excluded some reporting of clinical outcomes. Future research could focus on aggregating clinical outcomes of surgical and anaesthesia provision in the literature.

Conclusions

This is a first attempt to synthesise existing research data on anaesthesia delivery systems in Asian lower-income countries, which have often been overlooked given more extreme health disparities in other regions. This review clearly highlights the urgent need for additional research and improved anaesthesia services quality in this region. Governments and partner organisations must mobilise additional resources to improve data collection, training, and provisioning of anaesthesia delivery, particularly in resource constrained and conflict-affected areas. Only this way can we prevent anaesthesia from being a rate-limiting step in surgery provision in Asia.

Author Contributions

Conceptualization: Sumbal Shahbaz, Natasha Howard.

Data curation: Sumbal Shahbaz.

Formal analysis: Sumbal Shahbaz, Natasha Howard.

Funding acquisition: Natasha Howard.

Methodology: Natasha Howard.

Project administration: Sumbal Shahbaz.

Supervision: Natasha Howard.

Writing – original draft: Sumbal Shahbaz.

Writing – review & editing: Natasha Howard.

References

1. Chang CY, Abujaber S, Reynolds TA, Camargo CA, Obermeyer Z. Burden of emergency conditions and emergency care usage: new estimates from 40 countries. *Emergency Medicine Journal*. 2016; 33(11):794. <https://doi.org/10.1136/emmermed-2016-205709> PMID: 27334758
2. Meara JG, Leather AJM, Hagander L, Alkire BC, Alonso N, Arneh EA, et al. Global Surgery 2030: Evidence and solutions for achieving health, welfare, and economic development. *Lancet*. 2015; 386(9993):569–624. [https://doi.org/10.1016/S0140-6736\(15\)60160-X](https://doi.org/10.1016/S0140-6736(15)60160-X) PMID: 25924834
3. Ozgediz D, Jamison D, Cherian M, McQueen K. The burden of surgical conditions and access to surgical care in low- And middle-income countries. *Bulletin of the World Health Organization*. 2008; 86(8):646–7. <https://doi.org/10.2471/blt.07.050435> PMID: 18797625
4. Hendel S, Coonan T, Thomas S, McQueen K. The rate-limiting step: the provision of safe anesthesia in low-income countries. *World J Surg*. 2015; 39(4):833–41. <https://doi.org/10.1007/s00268-014-2775-9> PMID: 25201470
5. Beringer RM, Eltringham RJ. The Glostavent: evolution of an anaesthetic machine for developing countries. *Anaesth Intensive Care*. 2008; 36(3):442–8. <https://doi.org/10.1177/0310057X0803600317> PMID: 18564808
6. Kempthorne P, Morriss WW, Mellin-Olsen J, Gore-Booth J. The WFSA Global Anesthesia Workforce Survey. *Anesthesia and Analgesia*. 2017; 125(3):981–90. <https://doi.org/10.1213/ANE.0000000000002258> PMID: 28753173
7. Woodward A, Howard N, Wolffers I. Health and access to care for undocumented migrants living in the European Union: a scoping review. *Health Policy Plan*. 2014; 29(7):818–30. <https://doi.org/10.1093/heapol/czt061> PMID: 23955607
8. Khalil H, Peters M, Godfrey CM, McInerney P, Soares CB, Parker D. An Evidence-Based Approach to Scoping Reviews. *Worldviews Evid Based Nurs*. 2016; 13(2):118–23. <https://doi.org/10.1111/wvn.12144> PMID: 26821833
9. Peters MD, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. *Int J Evid Based Healthc*. 2015; 13(3):141–6. <https://doi.org/10.1097/XEB.0000000000000050> PMID: 26134548
10. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *International journal of social research methodology*. 2005; 8(1):19–32.
11. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. *Implementation science*. 2010; 5(1):69. <https://doi.org/10.1186/1748-5908-5-69> PMID: 20854677
12. Eisenkraft JB, Jaffe MB. Hazards of the anesthesia delivery system. *Anesthesia equipment*: Elsevier; 2021. p. 489–525.
13. Tranquilli WJ, Thurmon JC, Grimm KA. *Lumb and Jones' veterinary anesthesia and analgesia*: John Wiley & Sons; 2013.
14. WHO. *Everybody's business—strengthening health systems to improve health outcomes: WHO's framework for action*. 2007.
15. Braun V, Clarke V. Using thematic analysis in psychology. *Qualitative Research in Psychology*. 2006; 3(2):77–101.
16. Dubowitz G, Detlefs S, McQueen KA. Global anesthesia workforce crisis: a preliminary survey revealing shortages contributing to undesirable outcomes and unsafe practices. *World J Surg*. 2010; 34(3):438–44. <https://doi.org/10.1007/s00268-009-0229-6> PMID: 19795163
17. Steffner KR, McQueen KA, Gelb AW. Patient safety challenges in low-income and middle-income countries. *Curr Opin Anaesthesiol*. 2014; 27(6):623–9. <https://doi.org/10.1097/ACO.0000000000000121> PMID: 25225826
18. Contini S, Taqdeer A, Cherian M, Shokohmand AS, Gosselin R, Graaff P, et al. Emergency and essential surgical services in Afghanistan: still a missing challenge. *World J Surg*. 2010; 34(3):473–9. <https://doi.org/10.1007/s00268-010-0406-7> PMID: 20087587
19. Hadler RA, Chawla S, Stewart BT, McCunn MC, Kushner AL. Anesthesia Care Capacity at Health Facilities in 22 Low- and Middle-Income Countries. *World J Surg*. 2016; 40(5):1025–33. <https://doi.org/10.1007/s00268-016-3430-4> PMID: 26822158
20. Vo D, Cherian M, Bianchi S, Noël L, Lundeg G, Taqdeer A, et al. Anesthesia capacity in 22 low and middle income countries. *J Anesth Clin Res*. 2012; 3(4):207.
21. Bhatia MB, Mohan SC, Blair KJ, Boeck MA, Bhalla A, Sharma S, et al. Surgical and trauma capacity assessment in Rural Haryana, India. *Ann of Global Health*. 2021; 87(1):1–11. <https://doi.org/10.5334/aogh.3173> PMID: 33614421

22. Loveday J, Sachdev SP, Cherian MN, Katayama F, Akhtaruzzaman AKM, Thomas J, et al. Survey of Emergency and Essential Surgical, Obstetric and Anaesthetic Services Available in Bangladeshi Government Health Facilities. *World J Surg.* 2017; 41(7):1743–51. <https://doi.org/10.1007/s00268-017-3918-6> PMID: 28275833
23. Loughnan TE, Cooper MG, Wake PB, Aigeeleng H. History of non-physician anaesthesia providers in Papua New Guinea: from heil tultuls to Anaesthetic Scientific Officers. *Anaesth Intensive Care.* 2021; 49(1_suppl):29–40. <https://doi.org/10.1177/0310057X211027872> PMID: 34558991
24. Lee S, Onye A, Latif A. Emergency Anesthesia in Resource-Limited Areas. *Advances in Anesthesia.* 2020; 38:209–27. <https://doi.org/10.1016/j.aan.2020.09.005> PMID: 34106835
25. Kudsk-Iversen S, Shamambo N, Bould MD. Strengthening the anesthesia workforce in low- and middle-income countries. *Anesthesia and Analgesia.* 2018; 126(4):1291–7. <https://doi.org/10.1213/ANE.0000000000002722> PMID: 29547423
26. Shahbaz S, Zakar R, Fischer F. Anesthesia Health System Capacities in Public Hospitals of Punjab, Pakistan. *Inquiry.* 2021; 58:469580211059740. <https://doi.org/10.1177/00469580211059740> PMID: 34894837
27. Kushner AL, Cherian MN, Noel L, Spiegel DA, Groth S, Etienne C. Addressing the Millennium Development Goals from a surgical perspective: essential surgery and anesthesia in 8 low- and middle-income countries. *Arch Surg.* 2010; 145(2):154–9. <https://doi.org/10.1001/archsurg.2009.263> PMID: 20157083
28. Walker IA, Merry AF, Wilson IH, McHugh GA, O'Sullivan E, Thoms GM, et al. Global oximetry: an international anaesthesia quality improvement project. *Anaesthesia.* 2009; 64(10):1051–60. <https://doi.org/10.1111/j.1365-2044.2009.06067.x> PMID: 19735394
29. Pieczynski LM, Laudanski K, Speck RM, McCunn M. Analysis of field reports from anaesthesia volunteers in low- to middle-income countries. *Medical Education.* 2013; 47(10):1029–36. <https://doi.org/10.1111/medu.12262> PMID: 24016173
30. Taira BR, Cherian MN, Yakandawala H, Kesavan R, Samarage SM, DeSilva M. Survey of Emergency and Surgical Capacity in the Conflict-Affected Regions of Sri Lanka. *World J Surg.* 2010; 34(3):428–32. <https://doi.org/10.1007/s00268-009-0254-5> PMID: 19847480
31. Marchbein D. Humanitarian surgery: a call to action for anesthesiologists. *Anesthesiology.* 2013; 119(5):1001–2. <https://doi.org/10.1097/ALN.0b013e3182a950fb> PMID: 24037317
32. Gelb AW, Morriss WW, Johnson W, Merry AF. World Health Organization-World Federation of Societies of Anaesthesiologists (WHO-WFSA) international standards for a safe practice of anesthesia. *Canadian Journal of Anesthesia/Journal canadien d'anesthésie.* 2018; 65(6):698–708.
33. Hsia RY, Mbembati NA, Macfarlane S, Kruk ME. Access to emergency and surgical care in sub-Saharan Africa: the infrastructure gap. *Health Policy Plann.* 2012; 27(3):234–44. <https://doi.org/10.1093/heapol/czr023> PMID: 21441566
34. Odinkemelu DS, Sonah AK, Nsereko ET, Dahn BT, Martin MH, Moon TD, et al. An assessment of anesthesia capacity in Liberia: opportunities for rebuilding post-ebola. *Anesthesia & Analgesia.* 2021; 132(6):1727–37. <https://doi.org/10.1213/ANE.0000000000005456> PMID: 33844659
35. Roth R, Frost EA, Gevirtz C, Atcheson CL. *The role of anesthesiology in global health: A comprehensive guide*; Springer; 2014.
36. Merry AF, Cooper JB, Soyannwo O, Wilson IH, Eichhorn JH. International standards for a safe practice of anesthesia 2010. *Canadian Journal of Anesthesia/Journal canadien d'anesthésie.* 2010; 57(11):1027–34. <https://doi.org/10.1007/s12630-010-9381-6> PMID: 20857254
37. Baxter LS, Ravelojaona VA, Rakotoarison HN, Herbert A, Bruno E, Close KL, et al. An observational assessment of anesthesia capacity in Madagascar as a prerequisite to the development of a national surgical plan. *Anesthesia & Analgesia.* 2017; 124(6):2001–7.
38. Hodges SC. Anaesthesia and global health initiatives for children in a low-resource environment. *Current Opinion in Anesthesiology.* 2016; 29(3):367–71. <https://doi.org/10.1097/ACO.0000000000000319> PMID: 26905873
39. Walker IA, Obua AD, Mouton F, Ttendo S, Wilson IH. Paediatric surgery and anaesthesia in south-western Uganda: a cross-sectional survey. *Bulletin of the World Health Organization.* 2010; 88:897–906. <https://doi.org/10.2471/BLT.10.076703> PMID: 21124714
40. Hodges S, Mijumbi C, Okello M, McCormick B, Walker I, Wilson IH. Anaesthesia services in developing countries: defining the problems. *Anaesthesia.* 2007; 62(1):4–11. <https://doi.org/10.1111/j.1365-2044.2006.04907.x> PMID: 17156220
41. McQueen K, Coonan T, Ottaway A, Hendel S, Bagutifils PR, Froese A, et al. The Bare Minimum: The Reality of Global Anaesthesia and Patient Safety. *World J Surg.* 2015; 39(9):2153–60. <https://doi.org/10.1007/s00268-015-3101-x> PMID: 26067632

42. Bickler SW, Telfer ML, Sanno-Duanda B. Need for paediatric surgery care in an urban area of The Gambia. *Tropical doctor*. 2003; 33(2):91–4. <https://doi.org/10.1177/004947550303300212> PMID: [12680542](https://pubmed.ncbi.nlm.nih.gov/12680542/)
43. Jochberger S, Ismailova F, Lederer W, Mayr VD, Luckner G, Wenzel V, et al. Anesthesia and its allied disciplines in the developing world: a nationwide survey of the Republic of Zambia. *Anesthesia & Analgesia*. 2008; 106(3):942–8. <https://doi.org/10.1213/ane.0b013e318166ecb8> PMID: [18292444](https://pubmed.ncbi.nlm.nih.gov/18292444/)
44. Hansen D, Gausi S, Merikebu M. Anaesthesia in Malawi: complications and deaths. *Tropical doctor*. 2000; 30(3):146–9. <https://doi.org/10.1177/004947550003000311> PMID: [10902471](https://pubmed.ncbi.nlm.nih.gov/10902471/)
45. Rama-Maceiras P, Jokinen J, Kranke P. Stress and burnout in anaesthesia: a real world problem? *Current Opinion in Anesthesiology*. 2015; 28(2):151–8. <https://doi.org/10.1097/ACO.0000000000000169> PMID: [25695803](https://pubmed.ncbi.nlm.nih.gov/25695803/)
46. Chan DM, Wong R, Runnels S, Muhizi E, McClain CD. Factors influencing the choice of anesthesia as a career by undergraduates of the University of Rwanda. *Anesthesia & Analgesia*. 2016; 123(2):481–7. <https://doi.org/10.1213/ANE.0000000000001433> PMID: [27308955](https://pubmed.ncbi.nlm.nih.gov/27308955/)
47. Bhattacharyya S, Issac A, Rajbangshi P, Srivastava A, Avan BI. “Neither we are satisfied nor they”- users and provider’s perspective: a qualitative study of maternity care in secondary level public health facilities, Uttar Pradesh, India. *BMC Health Serv Res*. 2015; 15(1):1–13. <https://doi.org/10.1186/s12913-015-1077-8> PMID: [26409876](https://pubmed.ncbi.nlm.nih.gov/26409876/)
48. Jasper AO (2011). Death on the operating table: Nightmare of the anaesthetist. Seven years review in a Nigerian General hospital. *Continental Journal of Medical Research*, 5(1), 14.
49. Bharati SJ, Chowdhury T, Gupta N., Schaller B., Cappellani R. B., & Maguire D. (2014). Anaesthesia in underdeveloped world: present scenario and future challenges. *Nigerian medical journal: journal of the Nigeria Medical Association*, 55(1), 1 <https://doi.org/10.4103/0300-1652.128146> PMID: [24970961](https://pubmed.ncbi.nlm.nih.gov/24970961/)
50. Khan M., & Khan F. A. (2007). Anesthetic deaths in a developing country. *Middle East journal of anaesthesiology*, 19(1), 159. PMID: [17511190](https://pubmed.ncbi.nlm.nih.gov/17511190/)
51. Blaise Pascal F. N., Malisawa A., Barratt-Due A., Namboya F., & Pollach G. (2021). General anaesthesia related mortality in a limited resource settings region: a retrospective study in two teaching hospitals of Butembo. *BMC anesthesiology*, 21, 1–13.
52. Sobhy S., Zamora J., Dharmarajah K., Arroyo-Manzano D., Wilson M., Navaratnarajah R., et al. (2016). Anaesthesia-related maternal mortality in low-income and middle-income countries: a systematic review and meta-analysis. *The Lancet Global Health*, 4(5), e320–e327. [https://doi.org/10.1016/S2214-109X\(16\)30003-1](https://doi.org/10.1016/S2214-109X(16)30003-1) PMID: [27102195](https://pubmed.ncbi.nlm.nih.gov/27102195/)
53. Weiser TG, Makary MA, Haynes AB, Dziekan G, Berry WR, Gawande AA. Standardised metrics for global surgical surveillance. *Lancet*. 2009; 374(9695):1113–7. [https://doi.org/10.1016/S0140-6736\(09\)61161-2](https://doi.org/10.1016/S0140-6736(09)61161-2) PMID: [19782877](https://pubmed.ncbi.nlm.nih.gov/19782877/)
54. Cooper MG, Wake PB, Morriss WW, Cargill PD, McDougall RJ. Global safe anaesthesia and surgery initiatives: implications for anaesthesia in the Pacific region. *Anaesth Intensive Care*. 2016; 44(3):420–4. <https://doi.org/10.1177/0310057X1604400318> PMID: [27246944](https://pubmed.ncbi.nlm.nih.gov/27246944/)