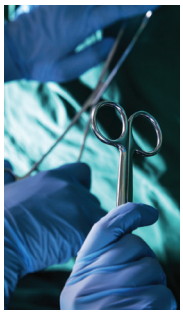

Chapter 15

Anesthesia and Perioperative Care

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INTRODUCTION

In the not-so-distant past, the impact of safe anesthesia on surgical outcomes often went unrecognized. Beginning in the 1950s, as surgical techniques advanced, strategies to improve patient safety and surgical outcomes were emphasized; physician anesthesia providers were recognized as essential members of surgical teams in high-income countries (HICs). Most low- and middle-income countries (LMICs), which have the greatest unmet surgical need, have not been able to apply the anesthesia advances in patient care and monitoring that have proven so successful in HICs. The availability of anesthesia providers is limited in LMICs, and many lack requisite training and supervision.

Although many of the advances that improved outcomes in anesthesia and surgery are technology based and expensive, several early interventions are feasible in all settings. As surgical intervention expands in LMICs to fill the growing and largely unmet treatment needs, an anesthesia crisis looms.

This chapter reviews the historical, remote, and recent global data that reveal the contributions of anesthesia to surgical and perioperative outcomes, as well as the anesthesia-associated morbidity and mortality rates, where available. It emphasizes the role of outcomes analysis and quality improvement, and it discusses the global cost and cost-effectiveness data, as well as the limited data from LMICs on human resources, education, and outcomes. Finally, this chapter proposes effective and responsible policy and funding solutions for the anesthesia crisis in most of these countries.

ANESTHESIA AND THE GLOBAL BURDEN OF DISEASE

Global Burden of Disease Averted by Safe Anesthesia for Surgical Interventions

The anesthesia crisis significantly affects the global gap between the surgical burden of disease and access to surgical services. The World Health Organization's (WHO's) Global Health Estimates documented substantial premature death and disability from trauma, cancer, and pregnancy and childbirth worldwide (WHO 2013a) and the inadequate surgical resources to meet these burgeoning surgical needs (Notrica and others 2011; Penoyar and others 2012). The unmet anesthesia and patient safety needs are generally correlated with the level of a country's development, with the greatest needs in South Asia and Sub-Saharan Africa (map 15.1).

Noncommunicable diseases are eclipsing infectious diseases as the leading global health issue and are projected to be the most important cause of mortality by 2020. Many of these conditions are potentially amenable to surgical treatment. Although providing adequate

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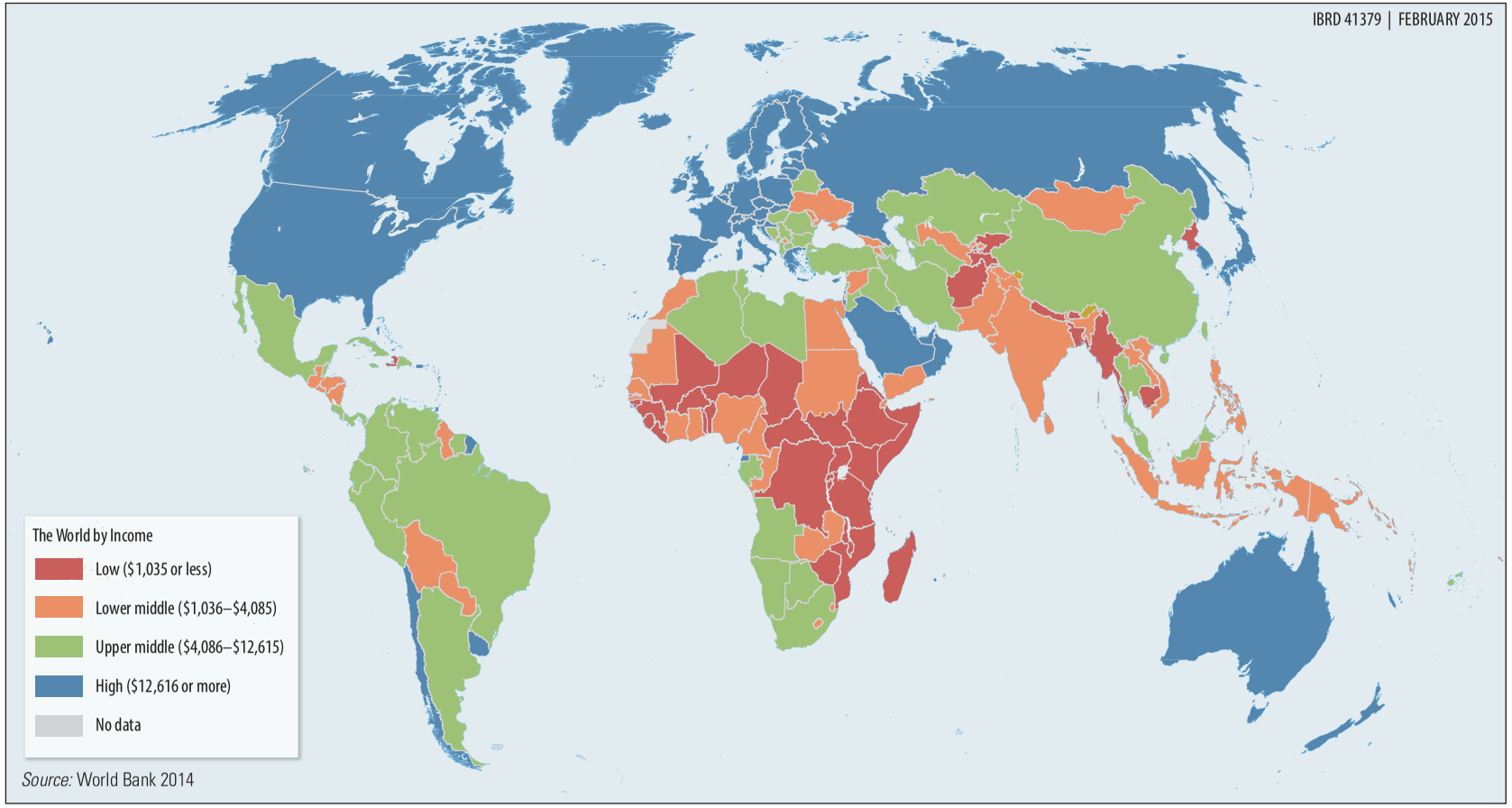
Map 15.1 Global Development and Surgical Need



Source: World Bank 2014

GSDPM Map Design Unit

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resources is a daunting task, it is no more impossible than addressing the HIV/AIDS crisis in the past 25 years. Cost-effective and attainable surgical solutions exist (WHO 2008) but will only be valuable if safe anesthesia is simultaneously supported. The contribution of anesthesia to the burden of surgical disease is difficult to measure, but it is integral to surgery and an equal contributor to disability and death. Without safe anesthesia, current anesthesia practice will contribute to additional disability and death, even when surgery is provided.

Definitions essential to understanding the contributions that anesthesia makes to patient safety and outcomes include the following:

- **Anesthesia machine**: A machine specifically designed for the delivery of anesthesia that includes the ability to provide oxygen and ventilation.
- **Patient safety**: A phrase that describes processes in place in hospitals and operating rooms to ensure the best possible outcomes for patients; these processes include policies and monitors that focus on preventing adverse outcomes and on alerting personnel to situations requiring urgent attention.
- **Precordial stethoscope**: A modified stethoscope for the purpose of listening to heart and breath sounds; it may be modified to become an esophageal stethoscope that amplifies sounds.
- **Perioperative period**: The days and weeks immediately preceding and following a surgical intervention. In this period, optimization of the patient's health may occur preoperatively, and complications are observed. In HICs, the postoperative period at 24 hours and at 30 days is specifically noted for critical events, including death.
- **Perioperative Mortality Rates (POMRs)**: The mortality rates in the operating room or within 24 hours of a surgical intervention and anesthesia. In HICs, these rates are reported and followed as indicators of safety.
- **Vigilance**: The continuous presence of and monitoring by providers, without distraction or time lapses.

Global Anesthesia Crisis

In LMICs, poor perioperative care has several causes: few trained providers; unreliable access to essential medications, including oxygen; limited safety monitoring; and limited options for postoperative care, including pain management.

In these truly austere situations, most anesthetics are administered with intravenous or intramuscular ketamine, with no safety monitoring and no oxygen, by attendants with limited training. Airway protection with a tracheal tube is often not an option, even during general anesthesia, because of a lack of provider skills and the absence of a laryngoscope required for intubation. Equipment is antiquated, broken, or absent. Frequently there are no pressurized gasses, no anesthesia circuitry or other requisite disposables, and no medications for hemodynamic rescue.

Causes of the Crisis. Many factors contribute to the crisis (McQueen 2010). Inadequate numbers of trained anesthesiologists and the brain drain to other specialties or higher resource countries are important contributors.[1] Understandably, available resources—human, capital, and pharmaceutical—were diverted away from surgically treatable diseases and toward HIV/AIDS.

A correlation exists between surgical access, anesthesia capacity, and patient safety on the one hand and mortality on the other hand. Few studies speak directly to this correlation. Several studies strikingly reveal specific risks of anesthesia in LMICs. Anesthesia-related mortality is unacceptably high in these countries and is amplified in the maternal and pediatric populations (Bosenberg 2007; Fenton, Whitty, and Reynolds 2003; Hodges and Hodges 2000; Hodges and others 2007; Jochberger and others 2008; Kushner and others 2010; Walker and Wilson 2008; Walker and others 2010). Globally, 2 billion people lack access to surgical treatment (Funk and others 2010), and 85 percent of children in LMICs are likely to require treatment for a surgical condition by age 15 years (Bickler, Telfer, and Sanno-Duanda 2003). In Uganda in 2010, 17 percent of anesthesia providers had no formal training (Walker and others 2010). The absence of trained providers for children is a matter of particular concern.

Barriers to Safe Anesthesia Services. The greatest barriers to access to safe anesthesia are the lack of adequate training and supervision for providers, safety monitoring capacity, sustainable organizational structure, and a modern system of quality review. The state of the crisis has been largely underestimated as a result of the lack of outcomes measurement, including perioperative mortality, and the overall absence of patient follow-up. Assessments of anesthesia-related mortality rates, when available, are indicative of poor patient care and safety (Bosenberg 2007; Fenton, Whitty, and Reynolds 2003; Hodges and Hodges 2000; Hodges and others 2007; Jochberger and others 2008; Kushner and others 2010; Walker and Wilson 2008; Walker and others 2010).

The shortage in the number of anesthesiologists is exacerbated by the fact that the available anesthesia providers spend only 60 percent of their time in

clinical care. The remainder is spent dealing with broken equipment and the bureaucracy necessary to improve conditions for providers and patients (Dubowitz, Detlefs, and McQueen 2010).

SAFE ANESTHESIA FOR SURGICAL INTERVENTIONS

Patient Safety

Successful initiatives directed at patient safety and improved outcomes include airway management, cardiac outcomes, and perioperative care.

Airway Management. Safe anesthesia requires the skills to maintain an open airway and to provide breathing and oxygenation. The lack of such skills is at the core of patient safety issues in LMICs.

Pulse oximetry and continuous capnography have undoubtedly improved results in HICs, although ethical practice has forestalled a true scientific study comparing anesthesia safety with and without these monitors. Pulse oximetry, a noninvasive monitoring of oxygen saturation, has been in use since 1981. Capnography is the monitoring of carbon dioxide in the respiratory gases. Anesthesia-related mortality rates declined in HICs with the mandatory use of both of these monitors. Both pulse oximetry and capnography require the continuous vigilance of an anesthesia provider with appropriate skills to respond to deviations. Such providers are more important than the monitors (Beecher and Todd 1954; Merry and others 2010; Pedersen and others 2014).

The contributory role of neuromuscular blocking agents administered to facilitate intubation or surgery in poor outcomes related to airway management is well known. In a seminal examination of perioperative mortality in a cohort of American hospitals, Beecher and Todd (1954) document a twofold increase in death when these agents were used. Neuromuscular blocking agents are included in the *WHO Model List of Essential Medicines* (WHO 2013b) but are often unavailable in LMICs, which is perhaps fortunate for patient safety. However, as surgical interventions become increasingly available and surgical techniques advance, these medications have the potential to contribute to poor outcomes.

Cardiac Perturbations. Myocardial depression is a common side effect of anesthesia medications and can prove lethal in patients with underlying disease or those with hemorrhage or hemodynamic instability. The older anesthetics still commonly in use in most LMICs, including halothane, cause more myocardial depression than more modern agents. Unfortunately, in these same settings, standard rescue medications, including epinephrine, are not routinely available to treat these predictable side effects.

One major study found that in HICs approximately 5 percent of patients have perioperative myocardial infarctions following major noncardiac surgery (Devereaux and others 2011). This event was associated with a fivefold increase in 30-day mortality. Evidence suggests that changes in the perioperative management initiated by anesthetists at the time of surgery can significantly reduce mortality related to these anticipated cardiac events (Canty and others 2012).

Perioperative Care. The perioperative period—extending from the initial preoperative evaluation of the patient's general health and comorbidities to 30 days postoperatively—is an important window for patient evaluation and significantly affects patient outcomes. Perioperative evaluation provides valuable information to providers planning optimal anesthesia management. An inexpensive screening test, such as hemoglobin measurement, contributes to improved outcomes.

Comorbidities. Ideally, the perioperative period should be used to alter or improve comorbidities and to improve perioperative health status. The current situation in most LMICs does not often allow for this advance preparation; as surgical systems evolve, planning for perioperative evaluation will become necessary.

Pain Management. Pain management is not only basic to the right to health (MacIntyre and Scott 2010; Morriss and Goucke 2011; Size, Soyannwo, and Justins 2007), but inadequately treated pain contributes to morbidity and, in some rare cases, to mortality. Uncontrolled acute pain also increases the incidence of chronic pain (MacIntyre and Scott 2010), potentially imposing a degree of suffering and disability that may last for years. The tragic reality in LMICs is that pain medicines, opioids, or nonsteroidal anti-inflammatory medications are often unavailable, even though they are included on the *WHO Model List of Essential Medicines* (WHO 2013b) and are inexpensive and effective.

In HICs, the initial postoperative care of patients is provided by anesthesia providers and thereafter by surgeons and other physicians; this approach has improved outcomes. In LMICs, postoperative care is often administered by family members, even in the immediate postoperative period. Although the impact of the absence

of professional care in the postoperative period is unknown, it is likely to be associated with increased POMRs.

Perioperative- and Anesthesia-Related Mortality

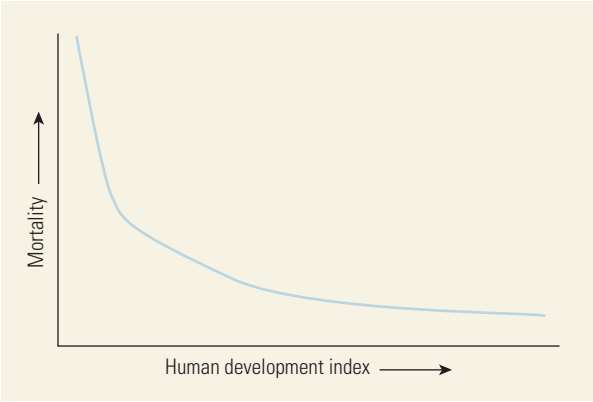
Systematic review of perioperative and anesthesia-related mortality demonstrates global improvements in outcomes during the past five decades, primarily in HICs (Bainbridge and others 2012). Overall mortality from anesthesia fell from 357 per million before the 1970s to 34 per million during 1990–2010, despite the growing number of patients with increased anesthetic risks. Analysis demonstrated not only an increased risk of anesthesia in higher-risk patients but also a correlation between anesthesia risk, mortality, and the human development index (HDI), an index related to life expectancy, education, and income (Bainbridge and others 2012). In countries with high HDIs, anesthesia mortality has fallen from 357 per million to 25 per million. In low-HDI countries, no figure from before the 1970s is available; in recent decades, the estimate of 141 per million has been reported (Bainbridge and others 2012).

Studies of perioperative mortality are difficult to conduct and infrequent in LMICs. However, a series of small anesthesia outcome studies in Sub-Saharan Africa from the 1980s to the 2000s has reported consistent and shocking rates of mortality in otherwise healthy patients in countries with similar HDIs. In 1988, a study from a hospital in Zambia reported an anesthesia mortality rate of 1 in 1,925; in Malawi in 2000, a rate of 1 in 504; in Zimbabwe in 2005, a rate of 1 in 482; in Togo in 2005, a rate of 1 in 133; in Nigeria in 2006, a rate of 1 in 387 in mothers undergoing cesarean section; and in Benin in 2010, a rate of 1 in 97 in pediatric anesthesia patients (Enohuman and Imarengiaye 2006; Glenshaw and Madzimbamuto 2005; Hansen, Gausi, and Merikebu 2000; Heywood, Wilson, and Sinclair 1989; Ouro-Bang'na Maman and others 2005; Zoumenou and others 2010). In comparison, the perioperative mortality in the United States in the 1950s was 1 in 1,500 (Beecher and Todd 1954). In each study, deaths from anesthesia were most commonly due to undetected hypoxia or hypovolemia. Inadequate equipment, training and supervision, and safety monitoring—particularly pulse oximetry—were cited as contributors to these poor outcomes. Several of these studies shared a similar methodology; despite being relatively small, they are important because of the consistently high rates of mortality reported.

During the past 30 years, anesthesia mortality and morbidity have decreased significantly, primarily in HICs, as a result of aggressive implementation of clinical adjuvants, monitoring capacity, and the imprint of a culture of safety (Eichorn 1989; Merry and others 2010). For example, 50 years of intense commitment in Australia has reduced avoidable anesthesia-related mortality from 1 in 5,000 to 1 in 100,000—and 1 in 180,000 in cases in which anesthesia is the sole cause of mortality and morbidity (Mackay and Cousins 2006). Unfortunately, LMICs lag far behind; mortality rates solely related to anesthesia are 100 to 1,000 times higher than in HICs, especially in obstetric and pediatric populations (Hansen, Gausi, and Merikebu 2000; Heywood, Wilson, and Sinclair 1989; Kushner and others 2010; McKenzie 1996; Ouro-Bang'na Maman and others 2005; Vasdev and others 2008). Information related to perioperative morbidity is more difficult to obtain because of the lack of postoperative care units and postsurgical patient follow-up. Solutions to this information gap are possible based on HIC models, but the feasibility of these solutions may be decades away.

As the anesthesia and surgical resources of a country improve, gains in absolute perioperative mortality are likely to be reinvested in operating on patients with more serious conditions and comorbidities. Figure 15.1 provides a graphic representation of this hypothesis. Low-HDI countries with high POMRs today might be expected to make rapid progress in the short term, perhaps based on a few highly cost-effective interventions. In time, however, the improvements in mortality will plateau. Further gains will require exponentially greater investments, and progress might be more apparent in the increased acuity of patients taken to the operating room rather than in improved overall survival.

Figure 15.1 Perioperative Mortality versus National Resources



Reporting POMRs and benchmarking outcomes will be essential to improving patient safety and to better anesthesia and surgical outcomes in LMICs. Preventable, anesthesia-specific mortality rates will only be affected when common inciting events are documented and stratified using the American Society of Anesthesiologists (ASA) physical status, age, and the social determinants of health related to living in LMICs (Doorley and others 2013).

COST, EFFECTIVENESS, AND COST-EFFECTIVENESS OF SAFE ANESTHESIA

Improvements in monitoring, and the increased availability of medications and screened blood products, have elevated the effectiveness and safety of anesthesia. These improvements have occurred in the context of a platform of professional education and training, clinical excellence, and professionalism. Safety innovation has not always occurred under circumstances of rigorous validation of efficacy and cost-effectiveness. The pulse oximeter, for instance, was rapidly embraced as mandatory safety technology and included as a required monitor for sedation and anesthesia by organizations and societies throughout the world; to date, however, it has not been evaluated for cost-effectiveness (Pedersen and others 2014). The most compelling argument for the effectiveness of anesthesia safety initiatives is evident in a comparison of the mortality rates over time in HICs (table 15.1), and between countries that commonly use standard safety measures and those that do not (Bainbridge and others 2012; Fenton, Whitty, and Reynolds 2003; Hodges and Hodges 2000; Hodges and others 2007).

Costs of Adequate Resources and Patient Safety

Safety measures since 1970 include the required vigilance of anesthesia providers, improved pharmacology to support hemodynamic stability, and safety monitoring to provide early warning of the common risks of anesthesia—hypoxemia, inadvertent esophageal intubation, and cardiac depression. The mortality rates in table 15.1 suggest that these improvements and interventions have been effective. The determination of cost-effectiveness is more arduous. Even in HICs, cost-effectiveness analyses have not been applied to the standard monitoring of patients undergoing anesthesia.

Table 15.1 Global Perioperative Mortality, per 1 Million Population

	Before 1970	Since 1990
Anesthesia-related mortality	357	34
Perioperative mortality	10,600	1,170

Source: Bainbridge and others 2012.

Absolute Costs. The absolute cost of providing safe anesthesia is a complex equation that varies by country and is affected by market variables such as the required use of medical-grade equipment, nongeneric medications, and changing technology. Every variable, from the cost of training a physician anesthesiologist to providing oxygen, is affected by local access, government, and regional availability of resources. Table 15.2 illustrates the spectrum of costs in HICs for necessary infrastructure and the required safety equipment to provide continuous information on patients' vital functions.

The comprehensive list of medications, solutions, and blood products for anesthesia are included in the *WHO Model List of Essential Medicines* (WHO 2013b); the World Federation of Societies of Anaesthesiologists (WFSA) considers these to be the minimum for the safe administration of anesthesia (Merry and others 2010). The WHO's selection process for essential medicines ensures cost-effectiveness and promotes quality (Manikandan and Gitanjali 2012), but it requires appropriate resourcing and procurement by governments. The medicines for anesthesia and pain management included on the *WHO Model List of Essential Medicines* identifies inexpensive and cost-effective choices, agreed upon by international experts for local, regional, and general anesthesia as well as for acute and chronic pain management (table 15.3).[2]

Efficacy and Cost-Effectiveness

An evolving library of literature is evaluating anesthesia efficacy and cost-effectiveness, applicable mostly to upper-middle-income countries and HICs (Nakada and others 2010; Rando and others 2011). Some of these studies will have applicability for LMICs when trained providers and advanced pharmacology are available and adequate monitoring is in place. Until then, the most compelling analyses are those comparing general, regional, and local anesthesia for specific procedures (Borendal Wodlin and others 2011; Doberneck 1980; Duh and others 1999; Gonano and others 2009; Schuster and others 2005; Shillcutt, Clarke, and Kingsnorth 2010; Shillcutt and others 2013; Song and others 2000; Wilhelm and others 2006). Much of this research was undertaken in HICs, and more research specific to LMICs is needed. Local and regional techniques provide nearly equivalent

Table 15.2 Required Patient Safety Monitors and Medications in High-Resource Settings

Improvement or intervention	Year introduced	Cost (US$)
Professionalism in anesthesiology	1950s	$1,000–$148,000[a]
Sphygmomanometer	1881	Less than $20
Electrocardiogram (three-lead machine)	1901	More than $1,000
Smartphone monitor (AliveCor)		$199 + phone
Precordial stethoscope	1950s	Less than $20
Capnography	1990	$1,600–$2,500
Pulse oximetry	1980	
Durable, portable unit (Lifebox)		$250
Smartphone monitor (Masimo)		$100 + phone
Anesthetic agent monitoring	1980s	$350 to $2,500
Oxygen:	1903	$40/6,000 liters + $100 flowmeter + more than $10,000 per 20 beds
Cylinders		$500–$1,500
Hospital piping system[b]		
Concentrator[c]		
Rescue medicines	1902	Less than $1

a. Estimated training costs per anesthesiologist based on country of training.
b. Initial capital costs for systems and equipment.
c. Electricity must be available and energy costs must be considered for operating a concentrator.

Table 15.3 World Health Organization's List of Essential Medicines for Anesthesia and Pain Management, 2013

Medication class	Specific medication listed
Inhaled gas	Oxygen, halothane, isoflurane, nitrous oxide
Muscle relaxant	Suxamethonium, atracurium
Sedative/hypnotic	Ketamine, propofol or thiopental, midazolam, diazepam
Narcotic	Morphine, codeine
Local anesthetic	Lidocaine, bupivacaine
Anti-inflammatory	Ibuprofen, paracetamol
Antiemetic	Ondansetron
Chronic pain relief	Amitriptyline
Reversal agent	Neostigmine, naloxone
Rescue medicines	Epinephrine, atropine, ephedrine

Source: WHO 2013b.

surgical conditions, hemodynamics, and patient comfort, compared with general anesthesia (Faisy and others 1996). Where providers have limited training and rescue medicines are often unavailable, the safety profile for these approaches is greater (Edomwonyi and others 2000; Fenton, Whitty, and Reynolds 2003; Glenshaw and Madzimbamuto 2005; Hansen, Gausi, and Merikebu 2000; Heywood, Wilson, and Sinclair 1989; McKenzie 1996; Ouro-Bang'na Maman and others 2005; Vasdev and others 2008; Walker and others 2010; Zoumenou and others 2010).

Both local and regional anesthetic techniques are low cost and low technology; they offer achievable proficiency and have a good safety record when basic sterile techniques are employed and key safety steps are observed. Few direct comparisons of local anesthesia versus neuroaxial anesthesia, such as spinal anesthesia, have been performed in LMICs; however, Vaz and others (2010) report no increase in operative time, and significant reductions in recovery room time and immediate postoperative pain, in a group receiving local anesthesia and intravenous sedation for loop colostomy. This technique was cost saving when compared with spinal anesthesia for the same procedure.

Comparisons between local anesthetic classes (amide vs. ester) reveal no difference in efficacy in endodontic treatment and a statistically significant cost savings when the amide lidocaine is used (Li and others 2000; Maniglia-Ferreira and others 2009). The risk profiles of local anesthetics vary significantly, as do the costs of treating toxicity for an accidental intravascular injection of an amide or an ester (Harmatz 2009).

Intralipid, the treatment for intravascular injection of bupivacaine (Mirtallo and others 2010) is approximately US$100–US$300 per dose and not routinely available in LMICs; for this reason alone, lidocaine is cost saving in LMICs.

Literature from HICs compares regional, local, and general anesthesia safety and outcomes; on balance, there is no consensus that regional and local anesthesia are superior to general anesthesia (Lin and others 2013). However, there is no evidence that regional and local anesthesia are inferior. Studies conducted in HICs have consistently shown lower costs and at least equal efficacy with regional anesthesia compared with general anesthesia (Neuman and others 2012).

The situation is quite different in LMICs. Reliable equipment for general anesthesia, including airway equipment and the medications necessary to manage circulatory challenges, is limited and frequently not available. Regional and especially local anesthesia are therefore preferable, when feasible (Schnittger 2007; Wilhelm and others 2006).

The systematic literature review of anesthesia cost-effectiveness revealed no cost-effectiveness analysis of general anesthesia, and no comparisons between general anesthesia and regional anesthesia in LMICs. Logical conclusions can be drawn from the comparative costs of general anesthesia and regional anesthesia, especially when the costs are inclusive of an anesthesia machine specific for this purpose (Beringer and Eltringham 2008; Read and Taylor 2012). Anesthesia machines for general anesthesia deliver anesthetic gases and frequently have a ventilator component, essential to providing oxygenation and ventilation when pharmaceutical paralytics are used for some types of surgical intervention. However, if based only on known mortality rates related to anesthesia in adults, children, and parturients, the cost-effectiveness of local and regional anesthesia exceeds that of general anesthesia (Bosenberg, Jöhr, and Wolf 2011; Fecho and others 2008; Luger and others 2010; Wilhelm and others 2006). General anesthesia is uniquely related to malignant hyperthermia, a genetic condition for which anesthesia gases are the trigger, requiring prompt treatment with dantrolene for survival. Dantrolene is expensive and not available in most LMICs, and this rare but reported event is uniformly fatal in these countries.

Although the general anesthesia medications on the *WHO Model List of Essential Medicines* (WHO 2013b) are cost-effective, the overall costs are substantially affected by the additional supplies, delivery systems, and related complications. When general anesthesia is indicated, it is possible to deliver a cost-responsible option with available medications and other resources. However, in LMICs, the skill of providers and the lack of safety monitors contribute to the overall greater risk for complications. The quality and type of anesthesia provided for the surgical intervention, particularly regional versus general, and the adequacy of postoperative analgesia have a major impact on the incidence of complications, and thereby the overall cost-effectiveness of the technique (Duggan and Kavanagh 2010; MacIntyre and Scott 2010). The relationship between general anesthesia and complication incidence is one reason that ketamine is ubiquitously and uniquely used in LMICs. Ketamine, which can be used alone or as an adjuvant therapy for postoperative or chronic pain management, can be safely used for general anesthesia for many surgical interventions without the additional infrastructure required for general anesthesia secondary to inhaled gases (Green, Clem, and Rothrock 1996).

Developing markets in LMICs are driving the availability of cost-appropriate equipment, anesthesia machines, and safety monitors. The nearly ubiquitous availability of smartphones has encouraged manufacturers to produce pulse oximetry and electrocardiogram (ECG) attachments and apps for use wherever smartphones are functional (Dawson and others 2013).[3] These solutions have yet to be tested and compared with standard monitors, but the trend is encouraging for patient safety in LMICs (McCormick and Eltringham 2007). It is timely that an initiative is underway for the creation of an International Organization for Standardization (ISO) standard for equipment being marketed to LMICs (Walker and others 2010).

The best evidence of the cost-effectiveness of successful interventions is likely to be the prevention of ASA category 1 or 2 perioperative deaths or permanent disability secondary to hypoxemia or sustained hypotension. Modeling has shown that overall risk is reduced by a checklist (WHO 2006) that includes the use of a pulse oximeter and the ability to identify risks related to surgery, anesthesia, and the presence of patient allergies.

Cost of Training Anesthesia Providers

Until trained and credentialed providers are present and vigilant for every surgical intervention, it is unlikely that the addition of technology, machines, or advanced medications will significantly affect outcomes in the short term; even the addition of cost-appropriate monitors and equipment must be carefully balanced with the simultaneous addition of education and training. Investments in training and evaluating existing providers will have the greatest impact on patient safety and outcomes in LMICs. The costs of training vary, and the effectiveness of training

in anesthesia is likely to be revealed by the anesthesia-related mortality rates.

The shortage of physician anesthesiologists has led to task-shifting to nurses and technicians as the most feasible workforce alternative in many LMICs (Hoyler and others 2014; Rosseel and others 2010). This practical measure can mitigate the crisis but does not replace the long-term need for physician anesthesia providers for leadership, oversight, and education. The critical need and dangerous situation require accepting a functional model for the provision of anesthesia that specifically addresses barriers to patient safety and unacceptable outcomes. Building on existing in-country models will facilitate the transition to safe patient care if education and credentialing are provided at all levels.

Comprehensive information on types of and costs of training for anesthesia providers in LMICs is still widely unavailable. Increasingly, however, reports are available from surveys (Hoyler and others 2014) and from several training programs in East Asia and the Pacific and in Sub-Saharan Africa (table 15.4). The training required, costs incurred, and external support received vary considerably across countries and regions; the absence of a related metric or indicator limits comparison of effectiveness and resulting patient safety.

Many countries train their own anesthesia providers, even if only in the form of on-the-job training at the hospital level. Countries that provide training outside of physician training programs usually offer two tiers of training (Cherian, Merry, and Wilson 2007; Collins 2011; Dubowitz, Detlefs, and McQueen 2010; Dubowitz and Evans 2012; Hodges and others 2007; Notrica and others 2011; Rosseel and others 2010). At a basic level, anesthesia officers often originate from a nursing or medical background and train for 6 to 24 months. Graduates of these programs commonly provide basic anesthesia in second- and third-level hospitals, under varying degrees of supervision, and frequently without supervision. Several LMICs offer a higher level of training to medical practitioners for two to four years; these providers function in third-level referral hospitals providing complex anesthesia and supervision of anesthesia officers at all levels (Dubowitz, Detlefs, and McQueen 2010; Dubowitz and Evans 2012; Newton and Bird 2010; Notrica and others 2011).

Anesthesia training in HICs is evidence based and includes theoretical knowledge and clinical, practical experience. At its most basic level, four practical skills are required of anesthesia providers:

- Intravenous cannulation
- Bag-mask ventilation
- Tracheal intubation
- Initiation of neuroaxial (spinal or epidural) or peripheral nerve block anesthesia.

Table 15.4 Training and Education Levels, Time Commitment, and Costs in Selected Countries, 2013

	Physician anesthetists		Anesthesia officers			External support	
Country	Duration of training	Cost of tuition (US$ per year)	Duration of training	Cost of tuition (US$ per year)	Resident salary (per year)	Financial (per year)	Teaching (months per year)
Rwanda	4 years	$0	2 years	—	$8,400	$500,000	18
Zambia	—	—	2 years	—	$9,700	$24,000	—
Uganda	—	$2,000	18–24 months	$400	Variable, may be $0	$2,000+	—
Kenya	4 years	$2,500	18–24 months	$2,500	$0	—	—
Lao PDR	3 years	$0	6–12 months	$0	$0	$2,500	3
Mongolia	2 years	$1,000	—	—	$0	$0	4
Fiji	4 years for a master's	$0	1 year for a diploma	$0	—	—	18
Canada	5 years	$0	—	—	$60,000–$80,000	—	—

Sources: Personal communications with local professionals providing and administering education: Dr. Paulin Ruhato, Rwanda; Dr. Sarah Hodges, Zambia; Dr. Gerald Dubowitz, Uganda; Dr. Mark Newton, Kenya; Dr. Simon Hendle, Fiji, the Lao People's Democratic Republic, and Mongolia; and Dr. Tom Coonan, Canada.
Note: — = not available.

All providers must also understand basic physiology and a few interventions to improve life-threatening alterations in physiology, including hypoxemia and hypotension. An intricate knowledge of patient physiology, pharmacology, and therapeutics is essential, of course, for physicians and nurses with advanced training. Access to leaders with this knowledge is important to the implementation of a system of safe anesthesia care and patient safety.

The costs of theoretical and clinical teaching vary. Ideally, anesthesia education is provided by physicians with years of clinical experience. In some LMICs, such as Kenya and Rwanda, senior nurses and technicians have become effective clinical teachers. However, the importance of physicians in ensuring the quality and accuracy of the information imparted cannot be discounted. Costs are a consideration for the teaching model chosen; any system must be benchmarked and monitored for acceptable patient outcomes, including perioperative mortality.

Administrative costs are incurred when providing educational materials, as well as when examinations or assessment processes are conducted. In LMICs, living expenses are often required to enable trainees to participate in the program; these expenses may include food, accommodation, and travel. The estimated costs of providing safe anesthesia in LMICs must include the investment in training. These specific costs are program and country specific, and are attainable through several models (table 15.4). Similarly the costs of accreditation will vary by country, and this important component of a system of trained providers is unlikely to add significant costs to the required education and training described.

FUTURE DIRECTIONS FOR MITIGATING THE GLOBAL ANESTHESIA CRISIS

Patient Safety

Improving patient safety and access to surgery requires an investment across health care systems, especially outside of the second- and third-level hospitals in urban areas. Strategies for patient safety will need to be tailored and sufficiently flexible to meet diverse training needs. However, the goal of vigilance must be uniform, even where safety monitors vary. This systemic approach has the potential to improve the entire health system through access to appropriate technology and diagnostics required for surgery and safe anesthesia with dual purposes for other disease states.

Education and Training

Investments in education, training, and credentialing for anesthesia providers are essential to improving patient safety and surgical outcomes. Anesthesia-specific education in LMICs will involve the training of future anesthesia providers as well as the ongoing education and support of those already providing services. *Task-shifting or task-sharing* is often applied to the global surgical and anesthesia crises as a means to expand the workforce responsibly and more rapidly than traditional educational tracks allow. This practice is already widespread in LMICs out of necessity (table 15.5). Ensuring that providers at all levels have education, training, and credentials will be important to ensuring patient safety and creating a culture of vigilance and best practice.

Table 15.5 Surgical and Anesthesia Tasks for Task-Sharing

Health workers	Level of care	Procedures performed
Surgeon-anesthesiologist	Third-level hospital	Complex airway procedures, neurosurgery, thoracic and vascular surgery, pediatric surgery, complex orthopedic surgery, reconstruction surgery, endocrine surgery, critical care
General doctor; nonphysician clinician with surgical or anesthesia skills (nurse or technician anesthesia provider)	Second-level hospital	Cesarean section (elective and emergency), emergency airway management, abscess drainage, wound debridement, circumcision, hernia repair, dilation and curettage, exploratory laparotomy—bowel resection, ectopic pregnancy, ovarian torsion, hysterectomy, appendectomy, limb amputation, skin grafts, skeletal traction, acute burn care
Community health worker	First-level hospital	Prehospital transport of trauma patients, basic wound care, resuscitation, emergency cesarean section

Source: Adapted from Chu and others 2009.

The WFSA regards anesthesia as a medical specialty to be provided by medically trained and accredited physicians. Where this is not possible—and it often is not—the WFSA recommends that medically qualified anesthetists supervise nonmedical anesthesia providers (Merry and others 2010). Although the pros and cons of this position have been debated (Dubowitz, Detlefs, and McQueen 2010; Jacob 2009; Walker 2009), the reality remains that medical anesthetists are often rare in LMICs. What is needed is the development of a coordinated anesthesia workforce led by fully trained physician anesthesiologists who train, supervise, and monitor nonphysician anesthesia providers.

There is no central, international classification of anesthesia providers. Many countries, even at the level of the Ministry of Health, have incomplete knowledge of the anesthesia providers functioning in remote settings. Planning for a spectrum of training and credentialing is recommended, and providing practical guidelines for anesthesia safety will empower even the providers functioning with the fewest resources without compromising progress.

A focus on the ongoing education and training of anesthesia providers will generate benefits, including increased surgical capacity within LMICs, improved patient outcomes, respect for the specialty of anesthesia among other health care providers, and the potential for better staff retention. Creating high levels of patient safety and access to quality anesthesia in the context of the current crisis will require a comprehensive approach:

- Developing and implementing national training programs for anesthesia providers at all levels supported by the national health care system and the Ministries of Health
- Credentialing of trained anesthesia providers that allows for the tracking of providers and ensures a minimum qualification level
- Creating national and global professionalism within the anesthesia community through continuing medical education and the support of national societies for representation and growth.

Quality Improvement

Efforts to improve anesthesia and perioperative care will be influenced by measurement of the outcomes in LMICs similar to the influence of quality improvement programs in Europe and the United States. The observation that surgical outcomes are substantially better in the high HDI world, despite a generally older population of patients with greater comorbidity, confirms the pivotal role of the quality process.

One approach is to pursue quality management metrics for perioperative care that are attainable for LMICs as a tiered process. The most fundamental outcomes to pursue would be simple recording of the surgical procedure performed and the short-term survival of the patient in every setting in which surgical procedures are provided. When possible, additional collection of data, including patient demographics such as age, gender, illness, and the acuity of the planned procedure, will augment the value of the quality metric. Additional stratification of the fundamental outcomes, through capture of the ASA Physical Status, is internationally defined and of value in every setting when outcomes are analyzed (box 15.1). The ASA's five-point scale is intended to capture multiple objective and subjective assessments of patients' states of health before surgery and correlates strongly with perioperative mortality.

Perioperative Mortality Rate. A nonspecific indicator of patient safety during anesthesia and surgery amenable to the tiered process and of value to LMICs is the POMR at 24 hours. This rate, defined as unexpected death within 24 hours of surgery, is often captured even in the most austere circumstances for two reasons: the existence of an operative log book, and the fact that most surgical patients in LMICs remain in the hospital for 24 hours. Consistent with the tiered quality-management process described above, the fundamental outcomes are

Box 15.1

American Society of Anesthesiologists' Physical Status

1 = A normal, healthy patient

2 = A patient with a stable chronic disease, for example, diabetes or asthma

3 = A patient with an active disease process, for example, new onset angina or shortness of breath

4 = A patient with a severe medical condition that is life threatening, for example, liver failure

5 = A patient not expected to survive the surgical procedure

Source: American Society of Anesthesiologists (https://www.asahq.org/For-Members/Clinical-Information/ASA-Physical-Status-Classification-System.aspx).

uniformly available for capture. Although the data captured in the first step of the process are minimal, similar to the maternal mortality rate the POMR is a benchmark of surgical and anesthesia safety, and an initial indicator that is easy to track and report (McQueen 2013; Watters and others 2014).

Stratification and Data Capture. As the data collection capabilities of the hospital or nation advance, more information should be collected and reported related to the outcomes of surgery and anesthesia and the population of patients treated. Anesthesia-related disability or morbidity includes the occurrence of any permanent injury, such as renal failure, myocardial infarction, stroke, or peripheral neurologic injury. Also included at this level of data capture should be the occurrence of perioperative events that carry a high risk of death or major morbidity: malignant hyperthermia, anaphylaxis, intraoperative cardiac arrest, major transfusion reaction, and wrong-site or wrong-side surgery. On the preoperative side, more detailed coding of patient comorbidities (for example, the International Classification of Diseases [ICD] codes) and patient physical examination (for example, body mass index and airway) will allow for improved risk adjustment of quality-management results.

Research

Capturing surgical and anesthesia complications and related mortality rates is not yet a global health priority. As noncommunicable diseases increasingly contribute to the global burden of disease, the need for access to surgical services and safe anesthesia will increase. Related mortality rates are important to benchmark progress and document improved patient safety in LMICs. The only perioperative complication currently recorded on a routine basis is intraoperative death; after the event is recorded in the operating theater log book, it is rarely reviewed.

Perioperative mortality in the operating theater and within 24 hours is reemphasized here because of the ease of data collection and existence of an example of similar reporting—the maternal mortality rate, which is required by the WHO and performed by every member nation on an annual basis.

Finding solutions for collecting meaningful data in LMICs is an important prerequisite to addressing the global anesthesia crisis. Acknowledging that finding solutions may be a stepwise process, and agreeing on an initial indicator that is logistically possible and ultimately meaningful, are the first steps. Several independent groups have suggested the POMR as a low-technology option (McQueen 2013; Watters 2014). Initially nonspecific, the POMR at 24 hours could be stratified and expanded to 30 days as the surgical system grows.

CONCLUSIONS

Safe anesthesia is effective, beneficial, and inexpensive when essential medicines are routinely available, appropriate technology is used, and sustained investments are made in training and credentialing.

The scope of global mortality that would be modified by enhanced surgical capacity is staggering. Safe anesthesia is critical to improving access to surgery, achieving acceptable outcomes for the spectrum of surgical interventions, and mitigating the global burden of disease.

The scale of the global burden of surgical disease in LMICs and the critical role of safe anesthesia in averting disability and death through surgical intervention has led to the following recommendations:

- Prioritize patient safety and safe anesthesia to secure a foundation of quality anesthesia and monitor the impact of surgical intervention on the rates of premature death from surgically treatable diseases
- Maintain functional workforces through patient safety education, training, and credentialing for existing and future anesthesia providers, including technicians, nurses, and physicians
- Create a culture committed to vigilance, and provide appropriate safety monitoring
- Ensure that oxygen and rescue medicines are reliably available
- Collect and report POMRs for benchmarking patient safety and quality improvement
- Recommend universal reporting of POMRs by the WHO as part of the initiative for global patient safety.

NOTES

The World Bank classifies countries according to four income groupings. Income is measured using gross national income (GNI) per capita, in U.S. dollars, converted from local currency using the *World Bank Atlas* method. Classifications as of July 2014 are as follows:

- Low-income countries (LICs) = US$1,045 or less in 2013
- Middle-income countries (MICs) are subdivided:
  - Lower-middle-income = US$1,046 to US$4,125
  - Upper-middle-income (UMICs) = US$4,126 to US$12,745
- High-income countries (HICs) = US$12,746 or more.

1. World Federation of Societies of Anaesthesiologists, http://www.wfsahq.org/.
2. The process by which medicines are added to or deleted from the model list, and the related applications, is available at http://www.who.int/features/2013/essential_medicines_list/en/.
3. "Masimo Launches iPhone-Compatible Pulse Oximeter," Damian Garde, December 13, 2012. http://www.fiercemedicaldevices.com/story/masimo-launches-iphone-compatible-pulse-oximeter/2012-12-13.

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