MILLER'S ANESTHESIA

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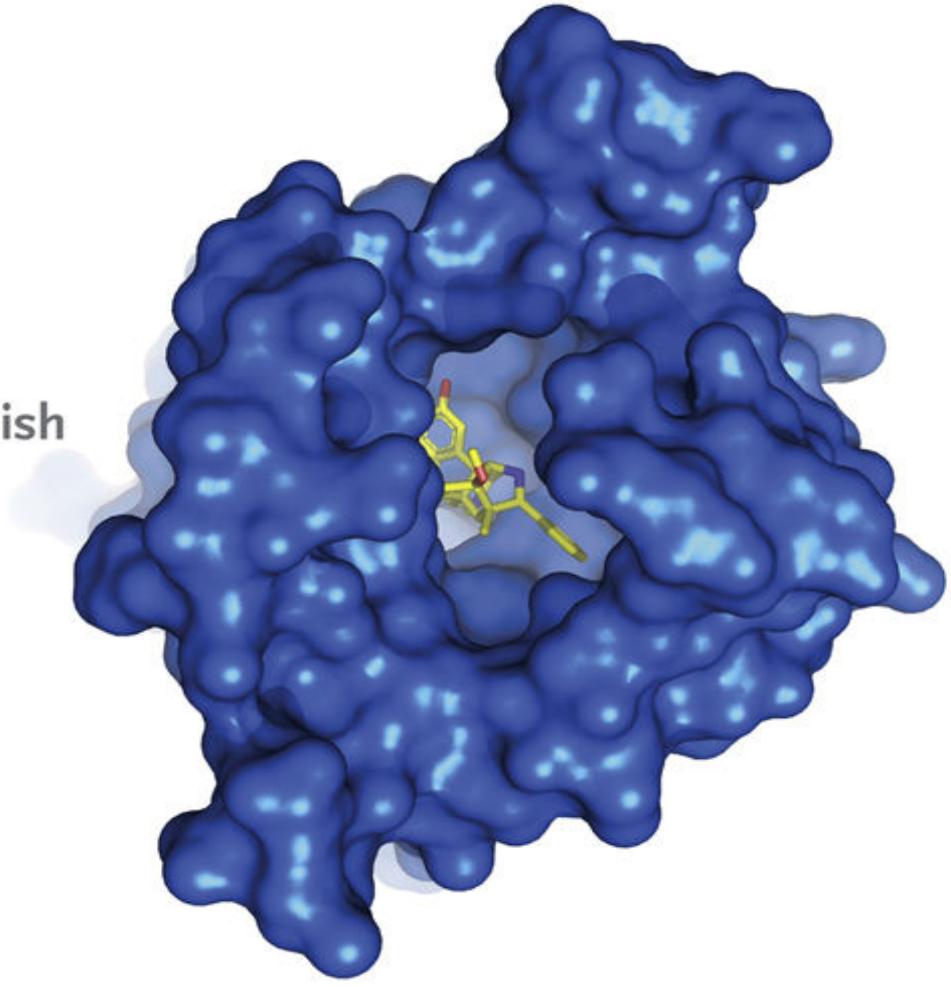

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1 The Scope of Modern Anesthetic Practice

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KEY POINTS

- The scope of modern anesthesia practice includes preoperative evaluation and preparation; intraprocedural care; postoperative care including acute pain management; critical care, resuscitation, and retrieval; chronic pain management; and palliative care. Anesthesia plays a key role in health service delivery and has a significant impact on population health and the burden of disease.
- Global and national forces for change include changing patient populations, locations of care, workforce, costs, quality and safety initiatives, research capability, and the availability of data. These forces have major implications for the delivery of care, evaluation and organization of the anesthesia practice, and education and training of physician anesthesiologists.
- The volume of patients presenting for perioperative and obstetric care continues to grow. Increasingly more patients at extremes of age are requiring anesthesia services. Many of the patients are elderly and have significant comorbidities, including obesity and opioid use disorder. This has important implications for delivery of care and health system issues.
- Anesthesia care is shifting from the traditional surgical suite to other procedural areas, ambulatory sites, office-based facilities, and home environments. As anesthesia care expands, anesthesiologists must focus on maintaining the safety and quality of care in these diverse settings.
- Global and regional deficits in the availability of high-quality anesthesia care must be managed by improving the supply of both physician and non-physician anesthesia providers, by better use of technology, and by limiting demand through health promotion and disease prevention strategies.
- Internationally, the costs of health care continue to escalate; unfortunately the increased spending has not consistently translated into improved health outcomes. Health policy initiatives including alternative approaches to healthcare financing and payment systems are increasingly being implemented to encourage efficient and effective team-based anesthesia care.
- Anesthesiology was among the first medical specialties to focus on improving the safety of patient care. As anesthesia has become safer, attention has intensified on quality improvement, a process designed to improve patient experience and outcomes through systematic change and evaluation.
- Basic, translational, clinical, and implementation research is vital to continuous improvement in outcomes. Opportunities to optimize care are supported by the availability of large datasets generated using electronic health records as well as novel analytic techniques. These changes create new opportunities for anesthesiologists to collaborate with basic and translational scientists to better understand current practices and define better ways to deliver care. As always the provision of resources to support these research initiatives is a challenge.
- The scope of modern anesthetic practice is continually expanding and changing. The changes occurring in health care in the 21st century create opportunities for anesthesiologists to assume a broader role in clinical practice and health policy, providing exciting opportunities for the next generation of physicians in our specialty.

Introduction

Anesthesia is fundamental to the overall practice of medicine worldwide. Hundreds of millions of patients receive anesthesia care each year in association with a wide range of medical, surgical, and obstetric procedures. In addition to direct delivery of anesthesia to patients undergoing a surgical procedure, the scope of anesthesia practice extends beyond the traditional surgical suite to include preoperative evaluation and management of underlying clinical conditions (see Chapter 31); postoperative care including acute pain management (see Chapter 81); critical care, resuscitation, and retrieval (see Chapter 67); chronic pain management (see Chapter 51); and palliative care (see Chapter 52). Anesthesia therefore plays an essential role in health service delivery (see Chapter 3) and has a significant impact on global health and the burden of disease (see Chapter 2). The purpose of *Miller's Anesthesia* is to cover the full scope of

contemporary anesthesia practice, from fundamental principles to advanced subspecialty procedures.

Every edition of this textbook begins with comments about the novel diagnostic and therapeutic procedures that have been developed since the last edition and the increasing complexity of patients presenting for anesthesia and perioperative care, especially those at the extremes of life. Each edition also provides descriptions about advances in anesthesiology that have facilitated patient care, including improved understanding of the processes that underlie disease and injury, the increasing sophistication of the pharmacologic and technical resources available, and the improvements in systems designed to promote safety and quality in health care. The 9th edition is no exception: in the last decade the advances in anesthesia and surgical care, especially for patients receiving complex clinical care, have been truly remarkable.

None of these advances would have been possible without the commitment of anesthesiologists to leadership, teaching, and research. Evidence of their contributions can be found in every chapter of the book, extending from improved understanding of the mechanisms of anesthesia and the processes that regulate organ function and drive organ failure; through new technologies, drugs, and systems of care and education; to improved understanding and acknowledgement of the critical role patients and their families play in decision making about healthcare and end-of-life issues.

The future of anesthesiology is filled with opportunities and challenges. Global and national forces will drive evidence-based, cost-effective perioperative and obstetric care by multiprofessional and multidisciplinary teams. These changes will be supported by integrated electronic medical records and large databases and registries of healthcare outputs and outcomes. Increasingly, anesthesia care has expanded outside the operating room, into preoperative clinics, intervention suites, extended postanesthesia care units, and even into patients' homes. As is true for other medical specialties, anesthesiologists have adopted telehealth strategies to extend the care provided to patients and colleagues beyond face-to-face encounters. Technological advances have and will continue to facilitate less invasive interventions and improved anesthesia delivery and monitoring systems. As a result, seriously ill and injured patients and those at the extremes of age, often with associated comorbidities now have access to care previously not available to them. Care is also becoming more personalized, in large part because of the availability of genetic testing and an improved understanding of the unique needs of each patient based on disease severity and his or her probability of responding to specific treatment modalities. Partially as a result of these improvements in care, the costs of caring for an aging population with progressively sophisticated therapies challenge all nations. These forces will likely have a major effect on the scope of perioperative care in general and anesthesia services in particular. Therefore, anesthesiologists must be involved in health policy decisions about the distribution of resources and the need for high-quality evidence to guide practice. In the rest of this chapter we will deal with some of these forces in detail.

Forces That Will Change Practice (Fig. 1.1)

CHANGING PATIENT POPULATIONS

The volume of patients having surgical procedures each year is large and growing. In 2012, more than 300 million patients had surgery worldwide.[1] This number probably underestimates the overall volume of patients requiring anesthesia services, in large part because much of anesthesia care is now provided outside of traditional surgical suite environments. Global initiatives aimed at delivering universal health coverage and safe and affordable surgery and anesthesia care will result in further increases in the number of patients requiring anesthesia care in coming decades (see Chapter 2).

Increasingly many of the patients requiring anesthesia services will be older and have multiple health problems, including obesity and chronic pain associated with opioid use.

The World Health Organization has estimated that by the year 2050 nearly one-quarter of the world's population will be over 60 years of age.[2] In the United States the number of people aged 65 years and over, and therefore eligible for treatment under Medicare, is expected to exceed 78 million by 2030. In high income countries the increase in the numbers of older patients will result from improved preventative care and management of chronic disease and injury. In low- and middle-income countries this change will result from improvements in maternal and child health and the eradication or control of infectious diseases. Concurrently, improvements in anesthetic and surgical care in many countries are increasing medical care options for older patients, who are now receiving more surgical services—many complicated procedures—than ever before. However, the accessibility of these additional options is presenting new challenges for both patients and providers. Aging is associated with a decline in physiologic reserve and organ function and an increase in the risk of disease, injury, and disability (both physical and cognitive). The aging process is highly variable, with significant influence from genetic, environmental, and societal factors. Aging is also associated with considerable changes in social and economic circumstances. Overall these factors lead the older adult to greater dependence on health and social care and challenges in the provision of safe surgery and anesthesia (see Chapters 65 and 82).

One significant public health issue that is accelerating internationally is obesity. It has emerged as a global health epidemic. In 2016, 39% of adults and 18% of children and adolescents worldwide were overweight.[3] In the United States the prevalence of overweight populations was 67.9% and 41.8% in adults and children, respectively. Although the rate of increase in the number of overweight and obese populations have slowed in some high-income nations, this is not the case in low- and middle-income countries. Poor access to healthy diets and limited exercise contribute to the problem. Obesity is associated with an increased burden of disease and injury, including diabetes and hypertension that result in the need for more interactions with the health system, high costs, and significant challenges in the provision of safe and high-quality surgical and anesthetic care (see Chapter 58).

Fig. 1.1 Changing scope and settings of anesthesia and perioperative medicine. (A) *The Cure of Folly,* by Hieronymus Bosch (c.1450–1516), depicting the removal of stones in the head, thought to be a cure for madness. (B) Friedrich Esmarch amputating with the use of anesthesia and antisepsis. (C) Harvey Cushing performing an operation. The Harvey Cushing Society is observing (1932). (D) Placement of a deep brain stimulator for the treatment of Parkinson disease using a real-time magnetic resonance (MR) imaging technology (MR fluoroscopy). The procedure occurs in the MR suite of the radiology department. The patient is anesthetized and (E) moved into the bore of the magnet. (F) A sterile field is created for intracranial instrumentation, and (G) electrodes are placed using real-time guidance. (A, Museo Nacional del Prado, Madrid. B, Woodcut from Esmarch's *Handbuch Der Kriegschirurgischen Technik* [1877]; Jeremy Norman & Co. C, Photograph by Richard Upjohn Light (Boston Medical Library). D to G, Courtesy Paul Larson, University of California–San Francisco, San Francisco Veterans Administration Medical Center.)

Pain management strategies have also had impact on anesthesia practice and perioperative care. The current opioid epidemic arose from increased prescription of opioid drugs to treat all types of acute and chronic pain, including postoperative pain. This crisis has been exacerbated by diversion of prescribed medication (i.e., diverting a medication from its original licit medical purpose) and use of "street" drugs, including opioids. The consequences are significant for individual patients and society as a whole. Opioid use has resulted in addiction, overdoses, homelessness, excessive emergency room visits, increased infections, and neonatal abstinence syndrome. The Centers for Disease Control and Prevention (CDC) estimated that more than 191 million prescriptions (58.7 prescriptions per 100 persons) were filled in the United States in 2017, with marked regional variation characterized with adverse physical, economic, and social circumstances.[4] Opioids were involved in 42,249 overdose deaths in 2016 (66.4% of all drug overdose deaths). The situation is similar in other nations, with the World Health Organization estimating that 27 million people worldwide suffered opioid use disorder in 2015.[5] Recent government action has been substantial, particularly in the United States. The Department of Health and Human Services has implemented a five-point plan to combat the crisis including: (1) improved access to prevention, treatment, and recovery support services; (2) targeted availability and distribution of overdose-reversing (narcotic antagonist) drugs; (3) strengthened public health data reporting and collection; (4) support for cutting-edge research on addiction and pain; and (5) advances in pain management practice.[6] As experts in the pharmacology and clinical use of opioid drugs (see Chapters 24, 51, and 81), anesthesiologists and pain medicine specialists have and must continue their essential role in resolving this crisis.

CHANGING LOCATIONS OF CARE

Anesthesia practice has expanded to a variety of locations. A number of factors account for this shift in anesthesia and perioperative care (see Chapter 73). The costs of traditional operating room care are high and the services available may be unnecessarily comprehensive and complex for the planned episode of care. With advances in clinical care, the need for inpatient perioperative care is reduced for many surgical procedures. As a result more and more procedures are being performed in hospital outpatient settings, ambulatory surgery centers, and office-based practices. The focus of accrediting bodies and anesthesiology societies has been on maintaining the safety and quality of anesthesia care in outpatient settings, including providing for extended admission and escalation of care when clinically necessary to ensure patient safety.[7] At the same time, the payment models have not necessarily kept pace with these advances in clinical care. In the United States, the growth in

nonhospital-based care has occurred despite curbs in reimbursement for ambulatory surgery by governmental and private payers.

The clinical practice for surgical patients has also changed because of changes in sites of care and inpatient management. For most patients, many aspects of perioperative care have shifted from the hospital or other healthcare facility to outpatient or home settings. As one example, the elimination of preoperative hospital admission to day-of-surgery admission is virtually complete in high-income nations. Hospital lengths of stay are also much shorter. As a result, postoperative care is increasingly undertaken in the home as well, often as part of enhanced recovery after surgery programs.[8] Advances in monitoring technology and pain management techniques create opportunities for anesthesiologists in which to not only participate, but also manage many aspects of postoperative care in the home. Although these changes have been beneficial to many patients with improved outcomes and reduced costs, for some families the transition to short hospital lengths of stay has created significant clinical and social problems. Anesthesiologists must have an understanding of patients perioperative and postoperative support needs and should be actively engaged in determining the most appropriate setting for a procedure and how to manage the transitions of care.[9]

In addition to the changes taking place for surgical patients, anesthesia care is also shifting outside the operating room as a result of the advances in minimally invasive techniques provided by cardiologists, radiologists, endoscopists, and pain medicine specialists (see Chapters 51, 55, 57, and 73). As the volume of these services increases, anesthesiologists may be asked to provide care in procedural areas that were not designed for delivery of anesthesia services, and often not properly equipped to support patient and provider needs. The locations are frequently remote from the operating suite and may lack the usual support available for the care of patients with complex cases and the management of crises. Anesthesiologists therefore must participate in planning for these services and provide leadership in defining and maintaining the same standards of operating room practice to other areas of the hospital.[10,11]

Another example of the advances in clinical care and implications is the remarkable increase in referrals for colonoscopy for colon cancer screening.[12] Although the sedation provider for colonoscopy widely varies internationally and regionally within the United States, anesthesiologists are now more commonly participating in the care of these patients, in part due to medical needs related to comorbidities, but also because of documented complications associated with the use of sedation that have resulted in airway compromise or respiratory failure. These complications have caused providers and payers to reevaluate patient needs, the appropriate training of practitioners delivering procedural sedation, and when to optimize care by having an anesthesia practitioner monitor the patient and administer sedation. American[11,13] and international[14,15] sedation guidelines recognize that for many patients, nonanesthesiologist physicians and independent or semi-independent nonmedical practitioners can provide deep sedation for endoscopy; however, all guidelines emphasize that anesthesiologists should be involved in the care of high-risk patients or those with significant comorbidities.

CHANGES IN THE ANESTHESIA WORKFORCE

As a result of advances in perioperative care and the many other changes that impact the need for anesthesia practitioners, global and regional workforce shortages have been identified in recent years and are expected to increase (see Chapter 2). There are a number of reasons for these deficits including an insufficient number of medical graduates (in some places exacerbated by outward migration and an aging workforce), duty hour restrictions for practicing physicians (due to regulation of work hours, changing lifestyle preferences, and desire for better work-life balance), and increased demand for medical services (due to population growth and on a per capita basis). In addition to the impact of these societal changes, demand for physician care in the United States has increased in part due to the Patient Protection and Affordable Care Act (Affordable Care Act) with more patients having medical insurance and seeking care. To respond to the shortages, many countries within the Organisation for Economic Co-operation and Development (there are 36 member countries, including the United States) have increased medical school admissions in recent years.[16] Unfortunately, even this increase in number of trainees is insufficient to meet future needs. In 2017, the United States produced 7.55 medical graduates per 100,000 population, well below average (12 per 100,000 inhabitants). The Association of American Medical Colleges (AAMC) projects a shortage of up to 121,000 physicians by 2030.[14] At the same time, despite the increases in medical student enrollment, in the United States, most residency positions are funded by the Medicare program. As the medical school intakes have increased, this federal funding for residency positions (including anesthesiology) has not kept pace resulting in a bottleneck in the training pipeline. Along with reconsidering the cap on federally-funded positions, the AAMC has proposed alternative ways to leverage the skills and experience of physicians to advance care with improved use of technology and more interdisciplinary, team-based care as potential solutions.

Team-based care (anesthesia care team model) is already common in anesthesia practice, particularly in the United States. In the United States, the number of physician and nonphysician anesthesia providers are approaching parity, with the number of nurse anesthetists and anesthesia assistants increasing more rapidly than the number of physician anesthesiologists. In 2017, the American Society of Anesthesiologists (ASA) released a statement on the anesthesia care team that enunciated its vision for physician-led teams where anesthesiologists have a particular role in governance, planning, and oversight of anesthesia care, advanced airway management, and resuscitation.[17] This oversight includes defining and monitoring sedation provided in non-operating room locations and other requirements for the credentialing of providers to optimize care of the patient who requires deep sedation. Similar team-based approaches to care associated with physician supervision are commonplace or emerging in other countries around the world.

The number of women in medical schools has increased to over 50% of the student cohort in many countries. At the same time, until recently, United States anesthesiology training programs have recruited a smaller proportion of

women (37%). In academic departments, few women have reached the rank of professor, or become department chairs, or been elected to leadership positions in representative anesthesia organizations.[18] Programs to improve recruitment and advancement of women in academic medicine and anesthesiology have gained traction in the last decade (e.g., Athena Scientific Women's Academic Network[19]). In addition, all academic programs are paying more attention to diversity in the workforce, particularly among women and underrepresented minorities. With the increased understanding of the inequities, programs can be developed to more effectively address the disparities and broaden the diversity of the anesthesia workforce. It is essential that the anesthesia workforce reflect the diversity of the patient population that is served.

INCREASING COSTS OF CARE

The costs of health care continue to grow internationally, with health care consuming 8% of gross domestic product (GDP) on average in most countries, whereas in the United States the costs are as high as 18% of GDP.[20] Unfortunately the increased healthcare expenditures have not translated into improved health outcomes, particularly for Americans. Despite the Affordable Care Act, the United States continues to have a large uninsured or underinsured population, lapses in quality and safety of care inside and outside the hospital, and high rates of drug abuse, violence, and use of firearms.[21] The National Academy of Medicine concluded that healthcare funding in the United States needs to "reorient competition in the healthcare system around the value of services provided rather than the volume of services provided." This transition from volume to value is creating many new challenges and opportunities for anesthesiologists. As the health system adopts practices that provide documented improved outcomes at reduced costs, anesthesiologists must both understand the implications of these changes in clinical practices and also take a leadership role in identifying opportunities to reengineer care if the specialty is to retain its leadership role in quality and safety (see Chapter 3).

Payment for physician services is being modified to better align health systems, providers, and payers with respect to delivery of high-quality, patient-centered care. Compensation for clinical care continues to have a fee-for-service component, particularly in the United States; however, more compensation is becoming incentive-based to encourage changes in practice that improve efficiency and effectiveness. In contrast to fee-for-service models (which reward inputs), pay-for-performance models reward medical care that is consistent with published evidence and that improves the processes of care (e.g., timely administration of perioperative antibiotics), output (e.g., meeting targets for urgent surgery), or outcome (e.g., fewer central-line associated blood stream infections) measures. In the United States, recent pay-for-performance programs have included the Premier Hospital Quality Incentive Demonstration program of the Centers for Medicare and Medicaid Services (2003–2009) and the national Hospital Value-Based Purchasing Program, adopted after the passage of the Affordable Care Act (2011). This initial attempt to modify anesthesia practice has had limited impact on outcomes, possibly because financial incentives are too small, payment is delayed, and/or the costs associated with implementing the programs is greater.[22] Nonetheless, incentive-based pay-for-performance programs (which are widespread in other nations with high-cost healthcare systems) will continue to expand.[23]

In addition to paying for high-quality performance, in the United States and other high-income nations there has been increasing emphasis on not paying for poor outcomes of errors in care. For example, some payers withhold payment for "never" events (e.g., wrong-sided surgery, pressure ulcers, retained foreign objects, mismatched blood transfusion) unless they are present on admission to the hospital. This approach may be expanded to withhold payment associated with treatment of preventable complications. A number of anesthesia-specific activities have been identified that impact outcomes and, if these are not provided, the consequence could be either no payment or penalties. For example, monitoring and maintaining body temperature during surgery as promoted by the Surgical Care Improvement Project is but one example of an anesthesia metric that affects outcomes and costs of care.[24] At the same time, identification of some of the interventions or monitoring techniques that impact outcome is challenging. As a result, it is critically important for anesthesiologists to continue to evaluate practices and do additional research to both optimize care and reduce costs.

Other changes in payment for clinical care have and will continue to have significant impact on compensation for anesthesia services. Some payers are providing "bundled" payments to compensate providers for episodes of care. This approach to payment is an integral part of the reforms introduced under the Affordable Care Act, although some of the incentives may be redefined by subsequent legislation. The Bundled Payments for Care Improvement initiative introduced by the Centers for Medicare and Medicaid Services tested the ability of bundling payments as a method for improving quality and lowering costs. The program has been most successful for selected clinical services such as total joint arthroplasty for which participation by anesthesiologists through the continuum of care can be most significant.[25] The ASA has proposed the Perioperative Surgical Home as an anesthesiologist-managed structure to coordinate perioperative team-based care. This model of coordinated care throughout the perioperative period should be amenable to bundled payments or other new approaches to compensating providers.[26]

INCREASING FOCUS ON SAFETY AND QUALITY

Anesthesiology was among the first medical specialties to focus on improving patient safety.[27] A number of initiatives have had major impact on outcomes of care, including improved monitoring techniques, airway management options, and new improved drugs. Anesthesiologists have been actively assessing clinical care through the use of incident reporting systems, morbidity and mortality conferences, and "near-miss" reports. Incident reporting, which was initiated in the United States more than 50 years ago, has documented a decline in anesthesia-related mortality to less than 1 per 1 million population.[28] In recent years national incident reporting programs have been initiated

by the Anesthesia Quality Institute (Anesthesia Incident Reporting System[29]) and the Society of Pediatric Anesthesia (Wake Up Safe[30]). In addition to helping identify areas in which to improve clinical care, these programs provide legal protection to practitioners under the Patient Safety and Quality Improvement Act (2005). A number of programs have developed based on the experiences identified through these reporting mechanisms. Recognition of the human factors associated with adverse events has spawned a national and international movement directed at improving situational awareness and team functioning through simulation training (see Chapter 6). More recently programs to encourage healthcare providers and consumers to speak up about traditional patient safety concerns (e.g., commencing a wrong-side procedure) and unsafe professional behaviors (e.g., bullying and sexual harassment) have been integrated into workplaces nationwide and internationally.[31]

Anesthesiologists also led the way in the development of practice standards and checklists to improve clinical care. In some cases, the implementation of checklists has become a requirement for accreditation. In the last decade anesthesiologists were pivotal in the development, implementation, and evaluation of the World Health Organization's Surgical Safety Checklist.[32] Although the uptake of the Checklist has been patchy and its effect on outcomes has been inconsistent, the Checklist is widely implemented in the United States and other countries (see Chapter 2) in the belief that it will enable effective communication and a culture of safety.[33]

As anesthesia has become more and more safe, our attention has increasingly been focused on quality improvement, a process designed to improve patient experience and outcomes through systematic change and evaluation. In the United States, the Anesthesia Quality Institute established the National Anesthesia Clinical Outcomes Registry to enable systematic collection of quality information for use in quality improvement processes both nationally and locally.[34] Recently greater emphasis has been placed on longer-term and patient-centered or patient-reported outcomes. Many of these outcome measures have been incorporated into quality improvement programs and publicly reported metrics.[35] Anesthesiologists have identified the importance of assessing outcomes beyond the immediate perioperative period. As anesthesiologists assume a greater role in overall periprocedural care and outcomes, they will undoubtedly continue to advance the safety and quality agenda in large part due to their longstanding history in safety and quality as well as their training and pivotal role in perioperative care.

NEW OPPORTUNITIES AND CHALLENGES IN RESEARCH

Academic anesthesia departments are committed to advancing the scientific underpinning of anesthesiology. Basic, translational, clinical, and implementation research is vital to the continuous improvement in patient and health service outcomes (see Chapter 89). Fortunately, overall funding for biomedical and health services research in the United States more than doubled between 1994 and 2012. Although overall research funding has increased, since 2004 the overall growth of NIH funding for medical research has declined by 1.8%.[36] Private sources of funding have been important to supplement government-sponsored research support. Industry support is valuable and has been critical to the research agenda for academic departments. It also creates both real and perceived conflicts of interest that can be difficult to manage. Over the past decade, there has been a decline in early-stage research in favor of device development and clinical trials, poor mapping of research effort to the global burden of disease, and limited funding for critically important health services research.[36]

The implications of these changes in research support on anesthesia are significant. Academic anesthesia departments in the United States, as well as many other countries, continue to compete for government funding. Most benchmarks suggest that the specialty of anesthesiology in the United States fares poorly in National Institutes of Health funding when compared with other disciplines.[37] As a result, anesthesia departments, particularly in the United States have had to identify other funding sources, including foundations, industry, and philanthropy, particularly for early-career investigators.[38] For example the Foundation for Anesthesia Education and Research (FAER) has awarded more than $40 million in grants since 1986 and has demonstrated the leverage that these grants provide in achieving federal funding ($17 in funding for every $1 investment). Similar programs are funded by the International Anesthesia Research Society and by other anesthesiology organizations and foundations worldwide. At the same time, and in many respects related to the funding challenges and competing clinical needs, research support and peer-reviewed publications, which have increased in other countries, have not kept pace in the United States. As a result, an increasing number of publications in peer-reviewed journals are from authors outside the United States.

Other factors have impact on what resources are available for research. The clinical demands put on the faculty in academic departments make it difficult for clinician scientists to pursue research activities. Associated with the increasing clinical volume, supervised residents cannot provide all of the clinical care without compromising their educational experiences and fulfilling duty hour and other requirements. As a result, the faculty members are delivering a larger percentage of care on their own. At the same time, the complexity of some of the basic and translational research requires significant dedicated time and skills that are difficult to maintain when the investigator is also encumbered with a high clinical demand. Historically, clinically generated income was used to support research in general and young investigators in particular. As labor and other costs increase (including those associated with quality of care initiatives, clinical and research compliance, and other activities), fewer funds are available to support research. As a result of the high cost of developing new drugs with insufficient incentives for the pharmaceutical industry to develop new anesthetic agents, there is a reduced pipeline of anesthesia drugs.[39]

Despite these challenges, basic science, as well as clinical and translational research, is being performed by anesthesiologists and advances in the specialty are taking place. New models for research have contributed to advances in

our understanding of basic concepts of anesthesia care as well as clinical advances. As is true for clinical care, collaboration has always been vital in biomedical research. In recent years anesthesiology research has increasingly been conducted by multiprofessional, multidisciplinary teams including biostatisticians, health informaticians, and health economists. Translation from discovery to practice has been facilitated by partnerships among basic scientists, clinical scientists, and implementation scientists.[40] In addition to collaborations among colleagues within one institution, increasingly clinical trials are being conducted by large, multicenter networks because of the recognition that single-center studies take too long and cannot recruit enough patients to answer the really important questions in anesthesiology.[41-44] Research based on electronic medical records and databases also requires collaboration between institutions, clinicians, and database experts (see later).

One of the primary motivators to support the research agenda for anesthesiology is the need to define reliable and peer-reviewed data upon which to advance the specialty. Although the volume of anesthesiology information and its ease of access have increased exponentially in the last decade, particularly through social media, anesthesiologists are progressively challenged to find reliable information to guide their practice. In addition to the difficulty of assessing the quality of some of the information posted on various web sites, anesthesiology has also been plagued by high-profile cases of research misconduct, including fabrication, falsification, and misleading reporting of research findings.[45] This has damaged the reputation of anesthesiology research and, as a result of unreliable data upon which to make clinical decisions, put patients at risk. Each anesthesiologist must be diligent in selecting a source of information that takes into consideration the standards of peer review of the material and the financial relationships between the authors and publishers.[46]

INCREASING AVAILABILITY OF DATA

One of the areas of opportunity with respect to better understanding our clinical practices and defining ways to improve care is the increasing amount of data that can inform us. The last decade has seen unprecedented growth in the volume and availability of healthcare data. Electronic health record (EHR) systems (see Chapter 4) facilitate complete data capture and integration from multiple sources, including surgical equipment, anesthesia delivery systems, and physiologic monitors. The EHR has greatly facilitated documentation of individual patient care and provided aggregate data for healthcare services and populations. Other sources of routinely-collected data include health service billing systems, government and insurance databases, disease registries, and public health reporting. In addition, data specifically collected for research and quality improvement is increasingly shared, including research databases and biobanks (including genetic databanks). Meta-data related to the use of electronic resources and social media is also available for interrogation. These data require new management and analysis techniques that are beyond the scope of the practicing anesthesiologist or researcher (see Chapter 4). Truly "big" data includes terabytes of information, is generated and analyzed at high speed, and includes data in a wide variety of formats and from a wide variety of sources.[47]

These large data sets are increasingly being used to answer important research questions, to develop evidence-based clinical guidelines, and to assess the safety and quality of anesthesia and perioperative care, within and across different clinical environments and regions. Although technologic resources are not replacing randomized clinical trials, the information gleaned from large databases can be used to address important questions about how to most effectively deliver cost-effective care. At the same time, it is important to acknowledge the limitations of large databases, which may have missing critical elements of care or outcomes, could misclassify data, or in some cases, lack verification.[48]

Conclusions

The scope of modern anesthetic practice is continually changing and expanding. The forces for change include changes in our patient population, locations of care, workforce, costs, quality and safety initiatives, research, and the availability of data. This chapter emphasizes the implications for these forces on the specialty as well as the influence they have on the delivery of health care in general. The changes occurring in health care in the 21st century obviously have implications for the role of anesthesiology in both the practice and delivery of medicine overall, and provide exciting opportunities for the next generation of practitioners and leaders in our specialty.

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2 Anesthesia and Analgesia in the Global Context

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CHAPTER OUTLINE

KEY POINTS

- More than 5 of the world's 7 billion people lack access to safe anesthesia and surgical services. Surgical disease accounts for 30% of global disease burden, yet less than 1% of development assistance for health supports delivery of anesthesia and surgical care. Lack of access to safe, timely, and affordable anesthesia and surgery kills more than 4 times as many as acquired immunodeficiency syndrome (AIDS), tuberculosis (TB), and malaria combined.
- Lack of access to safe anesthesia and surgical services are among the most neglected crises in global health. Anesthesia-related mortality in some low-income countries (LICs) is reported in the 1:100s and is mostly avoidable. The burden of surgical disease is growing and disproportionately affects low- and middle-income countries.
- Pain is one of the top causes of morbidity worldwide, and inadequate access to analgesia is among the most inequitable global public health crises the world faces today. Five and a half billion people have limited or no access to narcotic medications for analgesia. Six high-income countries (HICs) account for 80% of the world's opioid consumption. Key drug control policies, organizations, and politics continue to influence issues of access and abuse, with disproportionately negative impacts for underserved populations.
- Critical shortages and the inequitable distribution of anesthesia providers are significant barriers to increasing access to safe anesthesia and surgical care. The density of surgery, anesthesia, and obstetric providers is 0.7 per 100,000 population for LICs as compared with 57 per 100,000 population for HICs.

KEY POINTS—cont'd

- Modern anesthesia workforce training and practice models vary widely from country to country. Innovative workforce solutions are needed to increase provider numbers while simultaneously ensuring quality and promoting access for underserved populations.
- Anesthesia, analgesia, and surgical services are feasible in resource-constrained settings and are as cost-effective as many other public health interventions (e.g., vaccinations).
- Issues of access, safety, and resource utilization are relevant to all anesthesia providers. Equipping anesthesia providers with knowledge and skills needed to address global challenges in anesthesia will become increasingly important in order to expand access to safe and affordable anesthesia care worldwide.
- Health care providers from multiple disciplines (nursing, surgery, obstetrics, anesthesia, and many more) are needed to effectively provide surgical and perioperative care. Anesthesiologists routinely work across the perioperative disciplines and can play a significant role to improve cohesive advocacy efforts and lead progress in global health equity for surgical disease and analgesia.
- The global anesthesia community is lagging behind other health disciplines in addressing global health challenges and must rapidly expand investment in initiatives to help characterize (research), address (implementation and policy), and support (financing) global anesthesia challenges.
- Developing infrastructure, expanding workforce, improving data to drive policy, providing financial risk protection mechanisms for surgical patients, improving referral and prehospital systems, and providing essential medicines are actions the global anesthesia community must prioritize. The need to act promptly is immense and must be balanced but not overshadowed by research agendas.

Introduction

There have been considerable efforts in recent years to define a global "standard" or "optimal" practice of anesthesia.[1-4] These debates, investigations, and innovations have most often been framed in the context of maximizing patient safety. More recently the focus of these efforts has expanded to also incorporate the important goals of maximizing not only safety, but also accessibility and affordability of anesthesia services.[5]

With scientific advancement and economic development, anesthesia—like much of medicine—has changed dramatically since the first public display of ether anesthesia in October of 1846. However, over the past 150-plus years, advances in anesthesia have been neither uniform nor universal, resulting in vastly heterogeneous anesthesia practice models and massive inequities in access to safe anesthesia care worldwide. The majority of the world's population does not have access to safe, affordable surgical, anesthesia, or pain services, and relatively few resources are being invested by governments, donors, or the global anesthesia community to address this crisis.

In this chapter we build off the work of Dr. Miller and colleagues' to explore not only the evolution and diversity of anesthesia practice models from around the world, but also challenges facing the global anesthesia community. A better understanding of the evolution of modern anesthesia care models, as well as the challenges they face and have overcome, is a key step to improving access and patient safety worldwide.

The first section of this chapter describes the scope and magnitude of the ongoing global surgical, anesthesia, and pain crises. This section also explores reasons why these crises have been relatively neglected by the global public health community, and reviews potential areas for intervention, advocacy, and change.

TABLE 2.1 World Bank Income Classifications by Gross National Income per Capita

	GNI per Capita (US $)
Low income	<1,005
Lower-middle income	1,006-3,955
Upper-middle income	3,956-12,235
High income	>12,235

GNI, Gross national income.
Source: https://blogs.worldbank.org/opendata/new-country-classifications-income-level-2017-2018.

The second section of this chapter presents examples of different anesthesia care models from around the world, including select historical milestones and snapshots of current challenges from regional and country-level perspectives.

The final section of this chapter provides a primer on essential clinical and nonclinical knowledge relevant for anesthesia practice in resource-constrained settings. The chapter concludes by discussing the role of anesthesia providers beyond the confines of the operating room or hospital setting, who increasingly will be called upon for solutions that increase access to safe anesthesia, surgery, and analgesia in the global context.

Section 1: Anesthesia and "Global Health"

The terms anesthesia and global health, when used together, often invoke thoughts of providers from high-income countries (HICs) providing clinical care in low- and middle-income countries (LMICs) as part of humanitarian outreach or "mission trips" (Table 2.1). Although such initiatives comprise a substantial proportion of efforts that

TABLE 2.2 Definitions of Global Health and Global Surgery

	Global Health*	Global Surgery†
Approach	Field of study, research, practice and advocacy. Emphasizes global perspective and a scientific approach to health promotion and disease prevention, including broad determinants of health.	Area for study, research, practice, and advocacy that places priority on improving health outcomes and achieving health equity for all people worldwide who are affected by surgical conditions or have a need for surgical care.
Geography	Focuses on issues that directly or indirectly affect health but that can transcend national boundaries.	Global surgery emphasizes supraterritorial and transnational issues, determinants, and solutions.
Level of cooperation	Development and implementation of solutions often require global cooperation.	Recognizes that the determinants of inadequate or inequitable surgical care are often the result of common and interdependent global structures and processes, and require global cooperation for global solutions.
Individuals or populations	Embraces both prevention in populations and clinical care of individuals.	Encompasses surgical care for underserved populations in all countries with special emphasis on those affected by conflict, displacement, and disaster.
Access to health	Health equity among nations and for all people is a major objective.	Equitable access to safe and affordable anesthesia, analgesia, and surgical care is a major objective.
Range of disciplines	Highly interdisciplinary and multidisciplinary within and beyond health sciences.	Incorporates all surgical specialties including obstetric and gynecological surgery, anesthesia, perioperative care, aspects of emergency medicine, rehabilitation, and palliative care, and nursing and the allied health professions involved in the care of the surgical patient. Engages non-clinical stakeholders including health economists, governments, and policymakers.

*Modified from Koplan JP, Bond TC, Merson MH, et al. Towards a common definition of global health. *Lancet*. 2009;(9679);1993–1995; Fried LP, Bentley ME, Buekens P, et al. Global health is public health. *Lancet*. 2010;375(9714):535–537.
†Modified from Dare AJ, Grimes CE, Gillies R, et al. Global surgery: defining an emerging global heath field. *Lancet*. 2014;384(9961):2245–2247.

aim to increase access to surgical and anesthesia services in resource-constrained settings, they represent only a fraction of the ever-expanding role of the anesthesia community in global health.

In this chapter, the term "global health" refers to a multidisciplinary field of study, research, practice, and advocacy that develops and implements solutions to promote health equity. Global health transcends national boundaries, requires global cooperation, and utilizes both population-level (e.g., injury prevention) and individual-level (e.g., clinical care) strategies (Table 2.2). Although some debate exists over the optimal definition of global health and its distinction, or lack thereof, from public health, it is worth highlighting that global health is not synonymous with international aid (i.e., going abroad from one's own country) or the transfer of technologies or interventions from HICs to LMICs.[6,7] Global health encompasses much more, including local providers working in the local environment (whether that is a low-, middle-, or high-income setting), and increasing emphasis on health equity.[8]

Global health has received unprecedented levels of interest in recent decades, expanding from its infectious disease origins to now incorporate a wider range of diseases, including the social and environmental factors affecting health.[9,10] Despite this expanded scope, surgery and anesthesia have remained relatively forgotten by the global health community.

In June of 1980, then Director-General of the World Health Organization (WHO), Dr. Halfdan Mahler, gave a presentation to the International College of Surgeons in Mexico City entitled "Surgery and Health for All." In this speech, Dr. Mahler stated that "*Surgery clearly has an important role to play in primary health care and in the services supporting it. Yet, the vast majority of the world's population has no access whatsoever to skilled surgical care, and little is being done to find a solution. I beg of you to give serious consideration to this most serious manifestation of social inequity in health care.*"[11]

Despite recognition of the global anesthesia and surgical crises several decades ago, it has been only recently that the global health community has begun to take notice and action.[12–17] In 2004, the WHO created the Emergency and Essential Surgical Care Program (EESC) and in 2005, the WHO Global Initiative for Emergency and Essential Surgical Care (GIEESC) was formed to convene multidisciplinary stakeholders interested in surgical disease. In 2007, the Bellagio Essential Surgery Group and Burden of Surgical Disease Working Group (later renamed the Alliance for Surgery and Anesthesia Presence [ASAP]) formed as two of the earliest concerted efforts to raise international awareness for surgical disease by advocating for the integration of surgery into health systems and the promotion of research and collaboration across disciplines.[18] These efforts followed in the wake of a seminal chapter on surgery in the Second Edition of the Disease Control Priorities in Developing Countries (DCP2) book in 2006.[19] In 2008, the WHO launched the Safe Surgery Saves Lives initiative along with the WHO Safe Surgery Checklist.[20,21] Also in 2008 multiple leaders in global health highlighted surgery as the "neglected stepchild" and as the "other neglected disease" in global health, drawing comparison with the then emerging term, "neglected tropical diseases."[22,23]

Despite these pleas and consistent, albeit limited, data demonstrating the massive scale of the surgical disease crisis, it was not until 2014–15 that greater attention began to be realized. In 2014, the Amsterdam Declaration on Essential Surgical Care was created, and in 2015, the 68th World Health Assembly (WHA) unanimously passed resolution 68.15 (WHA68.15) to strengthen emergency and essential

BOX 2.1 Key Messages From the Disease Control Priorities 3rd Edition

- Provision of essential surgical procedures would avert an estimated 1.5 million deaths a year, or 6%-7% of all avertable deaths in low- and middle-income countries (LMICs).
- Essential surgical procedures rank among the most cost-effective of all health interventions. The surgical platform of first-level hospitals delivers 28 of the 44 essential procedures, making investment in this platform also highly cost-effective.
- Measures to expand access to surgery, such as task-sharing, have been shown to be safe and effective while countries make long-term investments in building surgical and anesthesia workforces.
- Because emergency procedures constitute 23 of the 28 procedures provided at first-level hospitals, such facilities must be widely geographically available.
- Substantial disparities remain in the safety of surgical care, driven by high perioperative mortality rates and anesthesia-related deaths in LMICs. Feasible measures, such as the World Health Organization's (WHO's) Surgical Safety Checklist,[27a] have led to improvements in safety and quality.
- The large burden of surgical conditions, the cost-effectiveness of essential surgery, and the strong public demand for surgical services suggest that universal coverage of essential surgery (UCES) should be financed early on the path to universal health coverage.
- We point to estimates that full coverage of the component of UCES applicable to first-level hospitals would require slightly more than $3 billion annually of additional spending and yield a benefit to cost ratio of better than 10:1. It would efficiently and equitably provide health benefits and financial protection, and it would contribute to stronger health systems.

From Jemison DT, Alwan A, Mock CN, et al: Universal health coverage and intersectoral action for health: key messages from Disease Control Priorities, 3rd edition. The Lancet 391, Issue 10125, 2018:1108–1120.

BOX 2.2 Key Messages From The Lancet Commission on Global Surgery

- 5 billion people do not have access to safe, affordable surgical and anesthesia care when needed. Access is worst in low-income and lower-middle-income countries (LMICs), where 9 of 10 people cannot access basic surgical care. 143 Million additional surgical procedures are needed in LMICs each year to save lives and prevent disability. Of the 313 million procedures undertaken worldwide each year, only 6% occur in the poorest countries, where over a third of the world's population lives. Low operative volumes are associated with high case-fatality rates from common, treatable surgical conditions. Unmet need is greatest in eastern, western, and central sub-Saharan Africa, and South Asia.
- 33 Million individuals face catastrophic health expenditure due to payment for surgery and anesthesia care each year. An additional 48 million cases of catastrophic expenditure are attributable to the nonmedical costs of accessing surgical care. A quarter of people who have a surgical procedure will incur financial catastrophe as a result of seeking care. The burden of catastrophic expenditure for surgery is highest in low-income and lower-middle-income countries and, within any country, lands most heavily on poor people.
- Investing in surgical services in LMICs is affordable, saves lives, and promotes economic growth. To meet present and projected population demands, urgent investment in human and physical resources for surgical and anesthesia care is needed. If LMICs were to scale-up surgical services at rates achieved by the present best-performing LMICs, two thirds of countries would be able to reach a minimum operative volume of 5000 surgical procedures per 100,000 population by 2030. Without urgent and accelerated investment in surgical scale-up, LMICs will continue to have losses in economic productivity, estimated cumulatively at US$12.3 trillion (2010 US$, purchasing power parity) between 2015 and 2030.
- Surgery is an "indivisible, indispensable part of health care."[1] Surgical and anesthesia care should be an integral component of a national health system in countries at all levels of development. Surgical services are a prerequisite for the full attainment of local and global health goals in areas as diverse as cancer, injury, cardiovascular disease, infection, and reproductive, maternal, neonatal, and child health. Universal health coverage and the health aspirations set out in the post-2015 Sustainable Development Goals will be impossible to achieve without ensuring that surgical and anesthesia care is available, accessible, safe, timely, and affordable.

Mock CN, Donkor P, Gawande A, et al: Essential surgery: key messages from Disease Control Priorities, 3rd edition. The Lancet 385, Issue 9983, 2015: 2209–2219.

surgical and anesthesia care as a component of universal health coverage.[24,25] Also in 2015, publication of DCP3 and the Lancet Commission on Global Surgery (LCOGS) "Global Surgery 2030" report significantly expanded the body of data characterizing the global surgical and anesthesia crises, and also outlined strategies for addressing some of these challenges (Boxes 2.1and 2.2).[5,26] During the LCOGS development, Jim Kim, President of the World Bank, echoed the words of Dr. Mahler from 35 years earlier by stating, "…surgery is an indivisible, indispensable part of health care and of progress towards universal health coverage."[27]

These events provided a much needed boost to efforts aimed at improving the accessibility, affordability, and safety of surgical, obstetric, and anesthesia care worldwide. They also helped provide a framework for including surgery and anesthesia as global health priorities by linking surgery and anesthesia care to universal health coverage. Surgery and anesthesia were not included in previous priority-setting efforts, in part, because it was not clear how to incorporate them. Limited data about the scale of the crises, as well as misperceptions around complexity and cost-effectiveness (as discussed in the next section) resulted in surgery and anesthesia care being peripheral to global health priority-setting efforts like the Millennium Development Goals (MDGs). Although surgery and anesthesia are not explicitly a focus of more recent global health priority initiatives like the Global Health 2035 report and the United Nations (UN) Sustainable Development Goals (SDGs), these reports emphasize noncommunicable diseases, injuries, healthcare workforce expansion, and universal health coverage, which incontrovertibly depend on surgery and anesthesia.[28,29]

Milestones like LCOGS, the WHA resolution 68.15, and the Lancet Commission on Palliative Care and Pain Relief have helped call attention to the global anesthesia, analgesia, and surgery crises at hand.[30] Entities like the World Federation of Societies of Anaesthesiologists (WFSA), Association of Anesthetists of Great Britain and Ireland (AAGBI), Canadian Anesthesiologists' Society International Education Foundation (CASIEF), and Lifebox are among the increasing

number of anesthesia organizations working on system-level changes, research, and large-scale education initiatives in LMICs. Many national anesthesia societies, such as the United Kingdom's Royal College of Anaesthetists (RCoA), the Royal College of Anesthesiologists of Thailand, and the Chilean Society of Anesthesiologists are also actively engaged in such activities. The number of these global anesthesia efforts is unprecedented, but still nascent and evolving.

If surgery is described as the neglected step-child of global health, then anesthesia is the forgotten relative. Despite significant interdependence, surgery, anesthesia, and obstetrics have yet to harmonize global health efforts and maximize impact. Global health efforts involving either surgery or anesthesia have become known collectively as "global surgery" (see Table 2.2). In 2014, "global surgery" was defined "…as an area for study, research, practice, and advocacy that places priority on improving health outcomes and achieving health equity for all people worldwide who are affected by surgical conditions or have a need for surgical care. Global surgery incorporates all surgical specialties, including obstetric and gynecologic surgery; anesthesia; perioperative care; aspects of emergency medicine; rehabilitation; palliative care; and nursing and the allied health professions involved in the care of the surgical patient. It encompasses surgical care for underserved populations in all countries and for populations affected by conflict, displacement, and disaster, and promotes access to safe, quality care. Global surgery emphasizes supraterritorial and transnational issues, determinants, and solutions, recognizing that the determinants of inadequate or inequitable surgical care are often the result of common and interdependent global structures and processes, even though they are predominantly experienced within individual countries and communities.[31]" This definition was abbreviated to state "global surgery is an area of study, research, practice, and advocacy that seeks to improve health outcomes and achieve health equity for all people who require surgical care, with a special emphasis on underserved populations and populations in crisis. It uses collaborative, cross-sectoral, and transnational approaches and is a synthesis of population-based strategies with individual surgical care." Although anesthesia is not directly mentioned in this definition, "global surgery" has become a rallying point for anesthesia global health efforts.

SCOPE AND SCALE OF THE GLOBAL ANESTHESIA, SURGERY, AND PAIN CRISES

Global Burden of Surgical Disease

Nearly 30% of global morbidity and mortality is surgically treatable, with tens of millions of lives lost each year due to surgical conditions.[5] This burden of surgical disease predominantly affects LMICs and kills 4 times more people than human immunodeficiency virus (HIV), TB, and malaria combined (Fig. 2.1).[32] In addition to negative impacts on health and well-being, there is also significant economic burden associated with surgical morbidity and mortality. By 2030, morbidity and mortality from surgical conditions could reduce annual gross domestic product (GDP) growth by an estimated 2% in LMICs. In the past, similar calculations were used to successfully generate global investment in malaria, but had estimated much lower (1.3%) decreases in GDP due to malaria.[33] Without significant and immediate intervention, surgical disease will produce economic productivity losses of more than US$12 trillion for LMICs between 2015 and 2030. While it is generally agreed that surgical conditions account for a large proportion of global morbidity and mortality, precise data to support this have been lacking. This challenge has been attributed in part to a lack of resources being invested in such research and also to several inherent difficulties in quantifying surgical diseases.

The term "global burden of disease" (GBD) uses the disability-adjusted-life-year (DALY) as a unit to quantify premature death (years of life lost) and disability (years of life lived in a state of less than full health) (Fig. 2.2). The DALY was originally developed for the seminal GBD 1990 Study to quantify the burden of different diseases around the world and has since become commonly used in public health and health economics.[34,35] Because the DALY is routinely used to inform resource allocation, it has been utilized to describe surgical and pain disease burdens as well. The global health community has moved away from using terms such as third world, developed, or developing when describing countries' level of economic development. Leading causes of DALYs are often reported geographically by World Bank income level (see Table 2.1) or more recently by socio-demographic index (SDI) (Figs. 2.3 and 2.4). The SDI is a composite average of three indicators predictive of health outcomes: income per capita, average educational attainment (for population >15 years old), and total fertility rate.

The 2006 DCP2 publication was one of the first attempts to quantify surgical disease burden and did so by asking 18 surgeons for an educated guess, using convenience sampling and an online survey. Although the reported number

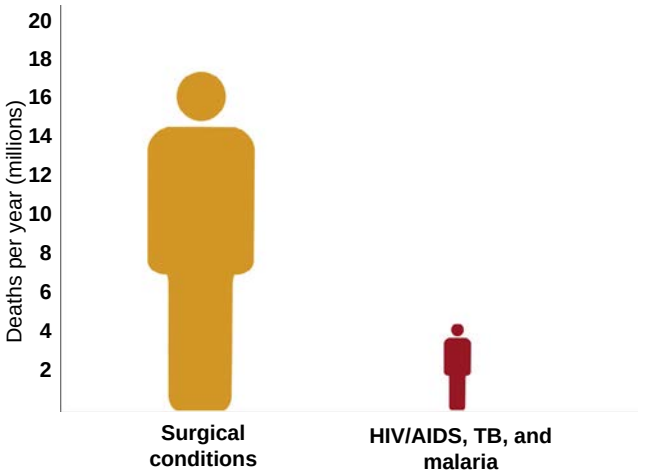

Fig. 2.1 Surgical conditions account for more annual deaths (16.9 million) than HIV/AIDS (1.03 million), TB (1.21 million), and malaria (0.72 million) combined. *AIDS*, Acquired immunodeficiency syndrome; *HIV*, human immune virus, *TB*, tuberculosis. (Data from Shrime MG, Bickler WS, Alkire BC, et al. Global burden of surgical disease: an estimation from the provider perspective. *Lancet Glob Health.* 2015;3:S8–S9; and GBD collaborators 2016. Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet.* 2017;390[10100]:1151–1210.)

Fig. 2.2 The disability-adjusted life year *(DALY)*. (From Wikipedia. https://en.wikipedia.org/wiki/Disabilityadjusted_life_year#/media/File:DALY_disability_affected_life_year_infographic.svg. Creative commons license: CC BY-SA 3.0.)

(11%) was eye-opening and widely quoted, it was likely a significant underestimation.

In 2015, the DCP3 provided another attempt to assess the public health impact of surgical care by estimating morbidity and mortality averted by scaling up basic surgical and anesthesia services in LMICs (i.e., surgical care for appendicitis, paralytic ileus, intestinal obstruction, hernias, gallbladder and bile duct disease, maternal hemorrhage, obstructed labor, abortion and neonatal encephalopathy, trauma resuscitation, surgical airway, peripheral venous access, suturing, laceration and wound management, chest tube or needle decompression, fracture reduction, escharotomy, fasciotomy, skin grafting, and trauma-related laparotomy and amputation). They concluded that an estimated 1.4 million deaths and 77.2 million DALYs could be prevented each year by scaling up basic surgical and anesthesia services in LMICs.[26]

The LCOGS produced another attempt to estimate global morbidity and mortality from surgical disease by asking 173 surgeons, anesthesiologists, internists, nurses, and public health practitioners from around the world, "What proportion of patients with the following conditions would, in an ideal world, require a surgeon for management?" The result of this survey was 28% to 32% of overall GBD requires a surgeon for management. Based on these results, LCOGS estimated that 30% of GBD is surgically treatable with an estimated 17 million lives lost per year due to surgical conditions.[5]

These reports are consistent with the 1990 GBD Study data, which demonstrate that the morbidity and mortality associated with surgical diseases is significantly larger than that of HIV, TB, and malaria combined.[32] Unintentional injuries are the single largest contributor of DALYs worldwide. The majority of deaths that can be prevented with surgical care are due to injuries (77%), maternal-neonatal

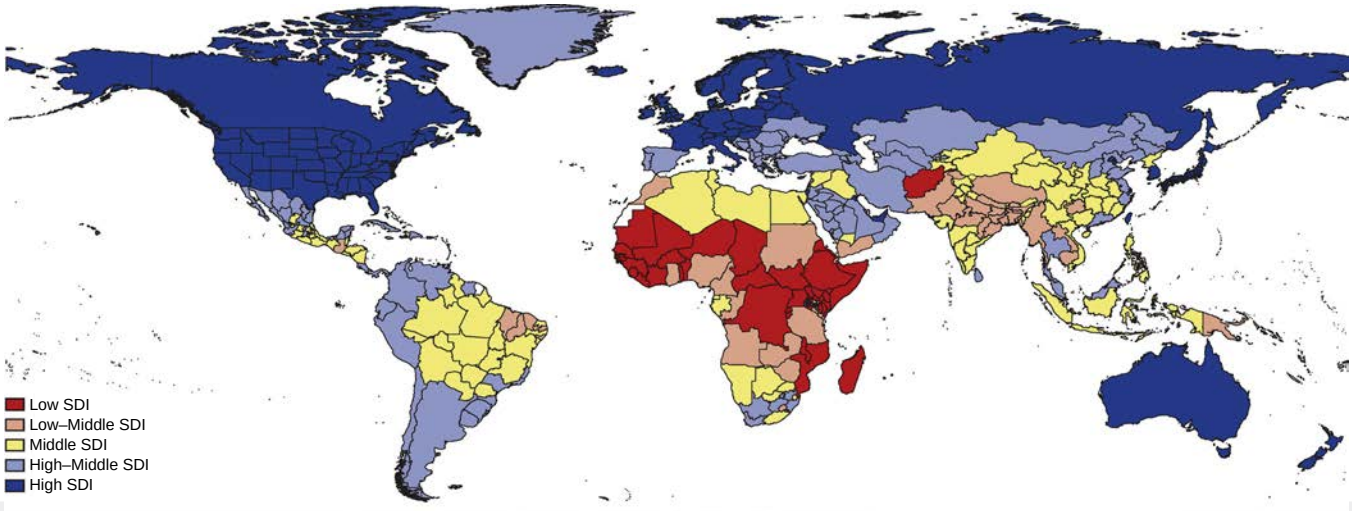

Fig. 2.3 Socio-demographic Index *(SDI)* is calculated for each geography as a function of lag-dependent income per capita, average educational attainment in the population older than age 15 years, and the total fertility rate. SDI units are interpretable; a zero represents the lowest level of income per capita and educational attainment and highest total fertility rate observed during 1980–2015, whereas a one represents the highest income per capita and educational attainment and lowest total fertility rate observed in the same period. Cutoffs on the SDI scale for the quintiles have been selected on the basis of examination of the entire distribution of geographies 1980–2015. *GBD,* Global Burden of Disease. (From GBD 2015 Mortality and Causes of Death Collaborators. Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet*. 2016;388[10053]:1459–1544. Copyright © 2017 The Author[s]. Published by Elsevier Ltd. This is an Open Access article under the CC BY 4.0 license.)

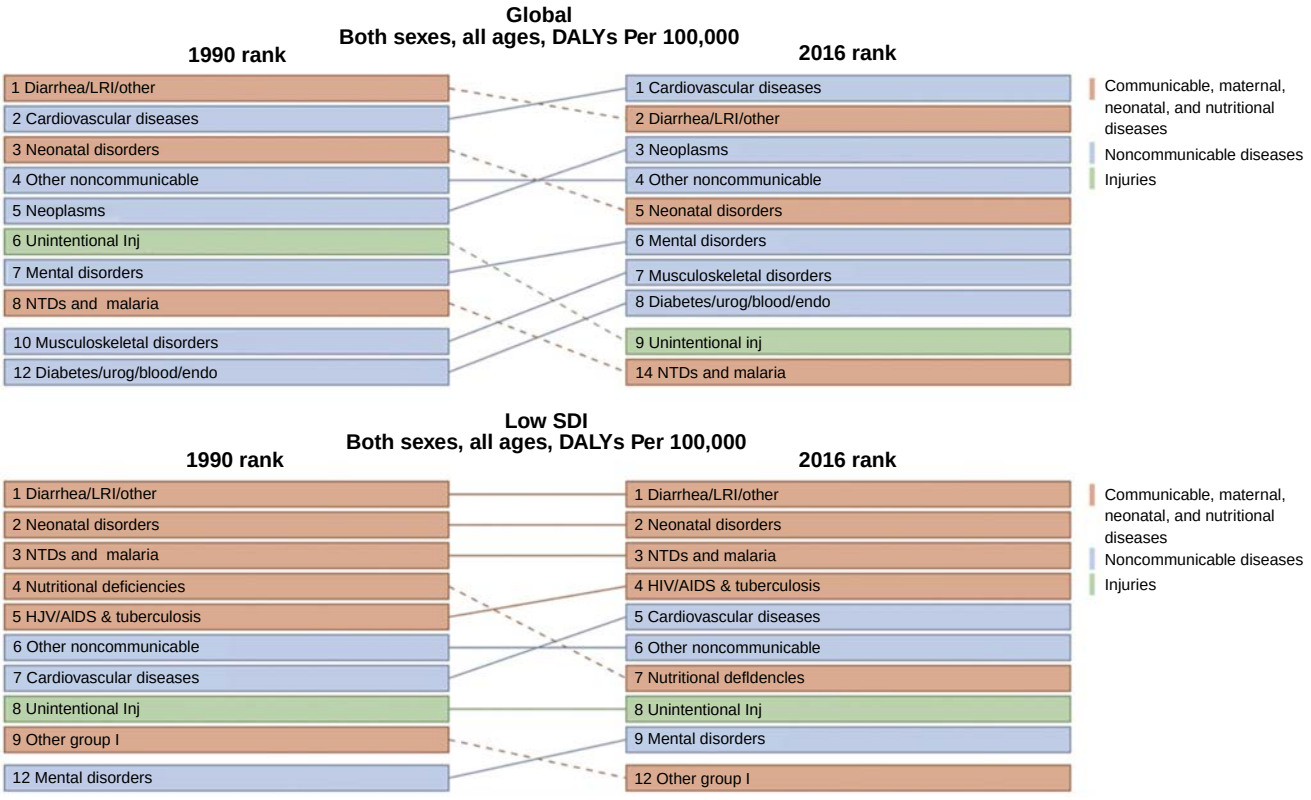

Fig. 2.4 Leading causes of death and disability-adjusted-life-years *(DALYs)*, 1990–2016, global versus low Socio-Demographic Index *(SDI)*. *AIDS*, Acquired immunodeficiency syndrome; *HIV*, human immune virus. (From https://vizhub.healthdata.org/gbd-compare/. Reproduced under Creative Commons Non-Commercial-No Derivatives 4.0 International License.)

conditions (14%), and digestive diseases (9%).[26] Global industrialization and an "epidemiological transition" (i.e., people living longer) in many LMICs have resulted in rising noncommunicable disease and injury burdens (most notably from road traffic crashes) that will likely contribute to increased global surgical disease burden in the coming years.

Each of the methods previously described to estimate surgical disease burden is imperfect. Challenges and limitations include complex methodologies (e.g., Institute for Health Metrics and Evaluation [IHME], GBD Studies), difficulty with measuring and defining surgical diseases (e.g., the same neoplasm in one person may be treated with surgery but in another person may be treated with chemotherapy), and challenges in assigning DALYs to diseases (i.e., disability weighting) and assigning DALYs averted to surgical procedures.[26] To overcome these shortcomings, additional metrics for global surgery and anesthesia have been proposed and include measuring disease prevalence, treatment backlogs for non fatal conditions, morbidity and mortality as a result of delays in care, social benefit, economic benefit, and value of a statistical life (rather than costs per DALY averted).[36]

One significant role for the academic anesthesia community in the global context is working to increase efforts that better quantify the growing surgical disease and pain burdens in order to facilitate appropriate resource allocation and subsequent evaluation of interventions.

Global Burden of Pain

As with surgical disease burden, there is general consensus on the staggering prevalence and incidence of pain worldwide though there are relatively limited data and significant challenges to quantifying pain burden in the global context. Pain is one of the most common reasons for seeking medical attention, is among the top five causes of DALYs worldwide, and directly accounts for four (low back pain, neck pain, musculoskeletal pain, migraine) of the top 10 causes of years lived with disability (YLDs).[32,37] These statistics do not even account for pain secondary to oncology, injury, or postoperative etiologies, which likely increase these numbers substantially. It is estimated that 10% to 25% of the world's population suffer from recurring and chronic pain, with increasing numbers caused by intentional physical harm such as war, violence, and torture.[38] Uncontrolled pain has many potential negative impacts on health, well-being, and economic productivity, including increased risk of myocardial infarction and chronic pain.

The 2017 Lancet Commission on Palliative Care and Pain Relief defined serious health-related suffering (SHS)

as suffering associated with illness or injury that compromises physical, social, or emotional functioning, and cannot be relieved without medical intervention.[30] Approximately half of all deaths worldwide involve SHS and more than 80% of people who die with SHS are from LMICs. It is estimated that 2.5 million children die with SHS each year. Ninety-eight percent of these children live in LMICs, and more than 90% of these deaths are avoidable. Among the top 10 conditions associated with SHS are HIV, malignancy, and injury. Though not as obvious as injury or cancer, HIV/AIDS is a major source of pain and analgesia need.[39] Pain related to HIV is not routinely managed by anesthesiologists when compared to other more common pain etiologies, however, the relevance of HIV as a rallying point to advocate for greater access to analgesics in LMICs is discussed further in this chapter. In many countries, conditions such as diabetes, sickle cell, and leprosy are also responsible for significant pain burdens. With increasing longevity and industrialization, the disease burden for malignancy and injury are expected to increase significantly in LMICs. As providers with often the most experience administering analgesics, anesthesia providers play an expanded and critical role in pain management, especially in resource-constrained settings.

Disparities in Access, Affordability, and Safety

The exact level of disease burden attributable to surgical disease or pain is a focus of ongoing debate and research, yet it is generally accepted that the surgical, anesthesia, and pain crises are massive, largely avoidable, and disproportionately affect LMICs. Of the roughly 300,000 maternal deaths worldwide, 99% occur in low-resource settings (66% in sub-Saharan Africa) and the majority are preventable with relatively basic surgical, anesthesia, and perioperative care.[40] Approximately 70% of global cancer deaths occur in LMICs, with the majority requiring surgical, anesthesia, or analgesia services.[41] Scaling access to basic surgical and anesthesia services in LMICs could avert 77 million DALYs and 1.5 million deaths per year.[26] Injury represents the majority (77%) of this avoidable morbidity and mortality, followed by maternal and neonatal conditions (14%). Approximately 90% of deaths and DALYs that are lost due to road traffic accidents occur in LMICs.

Based solely on the inequitable distribution of operating theatres, more than two billion people have no access to surgical services.[42] When also accounting for timeliness, facility capacity, safety, and affordability, nearly 5 billion people—the majority of the world's population—lack access to surgical and anesthesia care. The Global Initiative for Children's Surgery (GICS) estimates that 1.7 billion children lack access to surgical care.[42a] It is estimated that approximately 143 million additional surgeries are required each year.[5] Of the 234 million major surgical procedures performed annually, only 3% to 6% of them are estimated to occur in LIMCs.[5,43] Disparities in access disproportionally affect lower-income areas like sub-Saharan Africa or South Asia, where more than 95% of the population do not have access to surgical and anesthesia care. In some higher-income areas like North America and Europe, access varies considerably, but generally more than 95% of the population has access (Fig. 2.5).[44] Even in HIC like the United States, access to anesthesia, surgical, and analgesia care can be limited for rural and underserved populations.[45,46] It is estimated that universal access to "essential" surgical procedures (which include treatments for injury, obstetric complications, abdominal emergencies, cataracts, and congenital anomalies) would prevent approximately 1.5 million deaths per year or 6% to 7% of all preventable deaths in LMICs.[26]

Inadequate access to analgesia is among the most neglected and inequitable global public health challenges. The global burden of pain disproportionately affects the world's poor due to the high-burden conditions associated with pain (e.g., HIV, malignancy, and injury) in LMICs, and the general lack of access to analgesics. Although pain is the most common reason for seeking medical attention, and analgesia is considered a basic human right, gaps in access to analgesia are significant and among the most striking global health disparities worldwide.[47–49] Injury and malignancy, two conditions with significant analgesia needs, represent a significant proportion of surgical disease burden in LMICs, yet the vast majority of LMIC populations have limited or nonexistent access to opiate analgesia. Six HICs account for 80% of the world's opiate consumption, and countries that contain 17% of the world's population (Canada, United States, Western Europe, Australia, and New Zealand) are responsible for 92% of the world's opiate consumption (Figs. 2.6 and 2.7).[30,50-52] Pain and palliative care remain relatively neglected by the global health community and disproportionately affect vulnerable populations in LMICs.[30,53] In recent decades, access to opiates has improved in some LMICs, but not all (e.g., consumption in Africa and South Asia has declined).[52] Inequitable access to analgesia is not unique to LMICs and has been repeatedly described in many HICs, including the United States.[54-56] Reasons for the inequitable distribution of analgesia are discussed further in the next section of this chapter.

For the proportion of the world's population that has access to surgical and anesthesia care, they must confront significant disparities in safety. In the last half-century perioperative patient safety has improved by more than 10-fold, though the majority of the gains have been seen in HICs.[57] In the United States during the 21st century, anesthesia-related mortality decreased from 1:1560 around 1950 to less than 1:13,000, and is significantly better than this in healthy patients.[58,59] Worldwide, approximately 32 million people per year receive anesthesia without adequate monitoring, and more than 77,000 operating rooms (19%) worldwide lack pulse oximetry. In some regions, more than 70% of operating rooms lack pulse oximetry.[42] Data on surgical outcomes in LMICs remain limited but have expanded significantly in the early part of the 21st century. Reports of perioperative mortality rates (POMRs) from low-income countries (LICs) have varied widely in both methodology and results, ranging from 0.2% to 6% overall, with significantly higher mortality for emergent procedures (10% overall, 20% for typhoid intestinal perforations).[60–64] One international, prospective, observational cohort study of adults undergoing inpatient surgery in 247 hospitals from 25 African countries reported a 30-day in-hospital mortality rate (2.1%) that was twice the reported global average, despite a significantly younger and lower American Society of Anesthesiologists (ASA) physical classification patient population.[65]

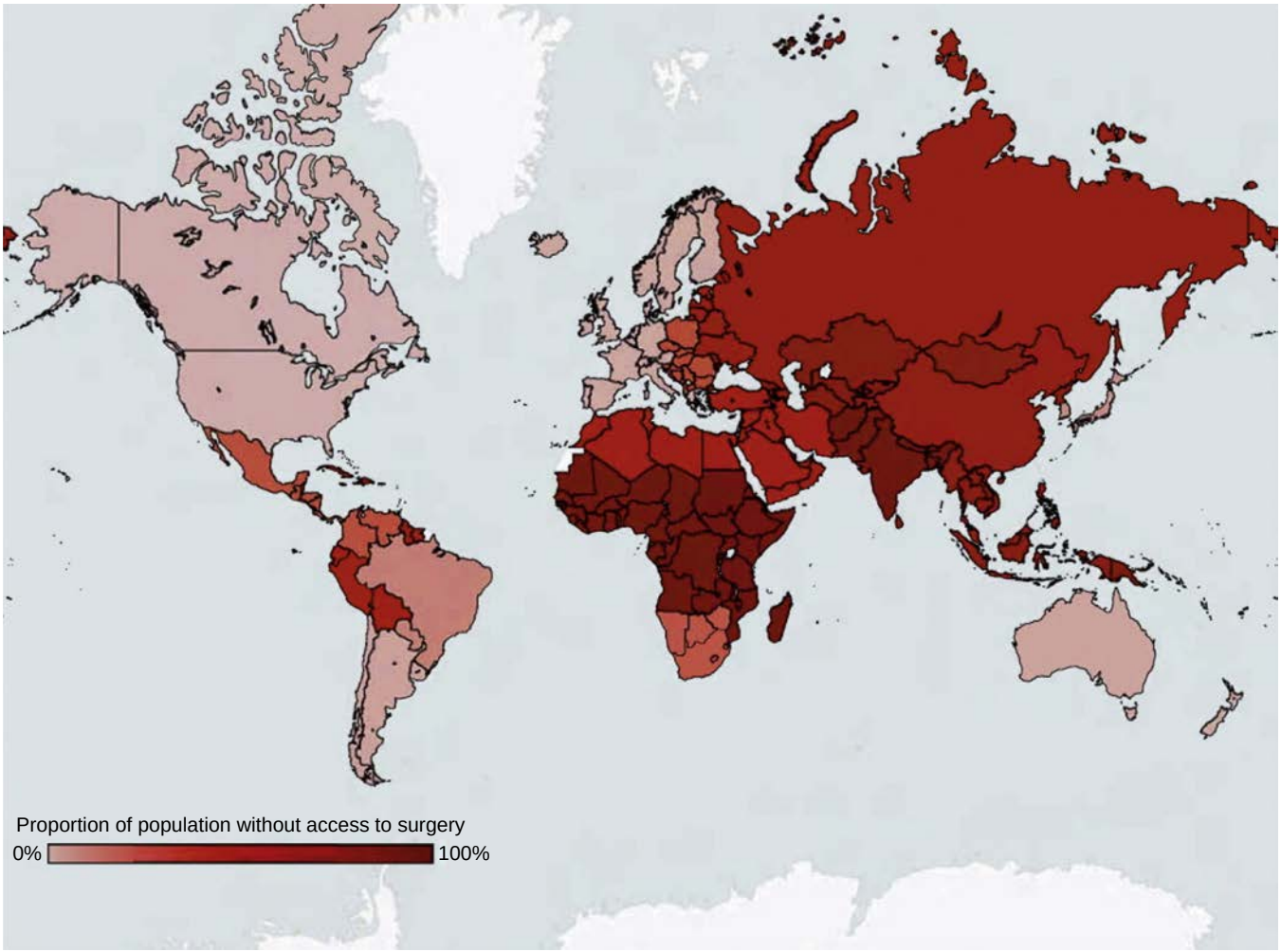

Fig. 2.5 The proportion of population without access to surgery. (From Alkire BC, Raykar NP, Shrime MG, et al. Global access to surgical care: a modelling study. *Lancet Glob Health*. 2015;3:e316–e323. doi: 10.1016/S2214-109X(15)70115-4. Epub 2015 Apr 27. Copyright © 2015 Alkire et al. Open Access article distributed under the terms of CC.)

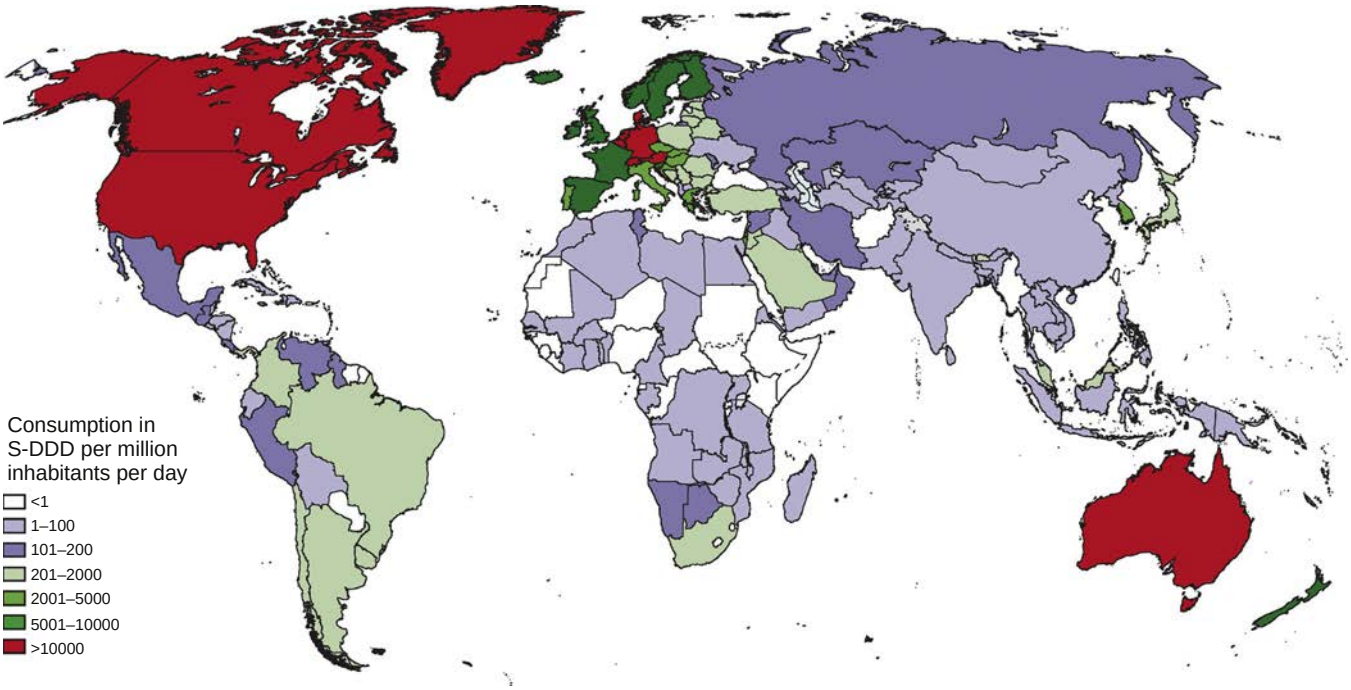

Fig. 2.6 Mean availability of opioids for pain management in 2011–2013. *S-DDD*, Defined daily doses for statistical purposes. (From Berterame S, Erthal J, Thomas J, et al. Use of and barriers to access to opioid analgesics: a worldwide, regional, and national study. *Lancet*. 2016;387:1644–1656. https://doi.org/10.1016/S0140-6736[16]00161-6. Copyright © 2015 Berterame et al. Open Access article distributed under the terms of CC.)

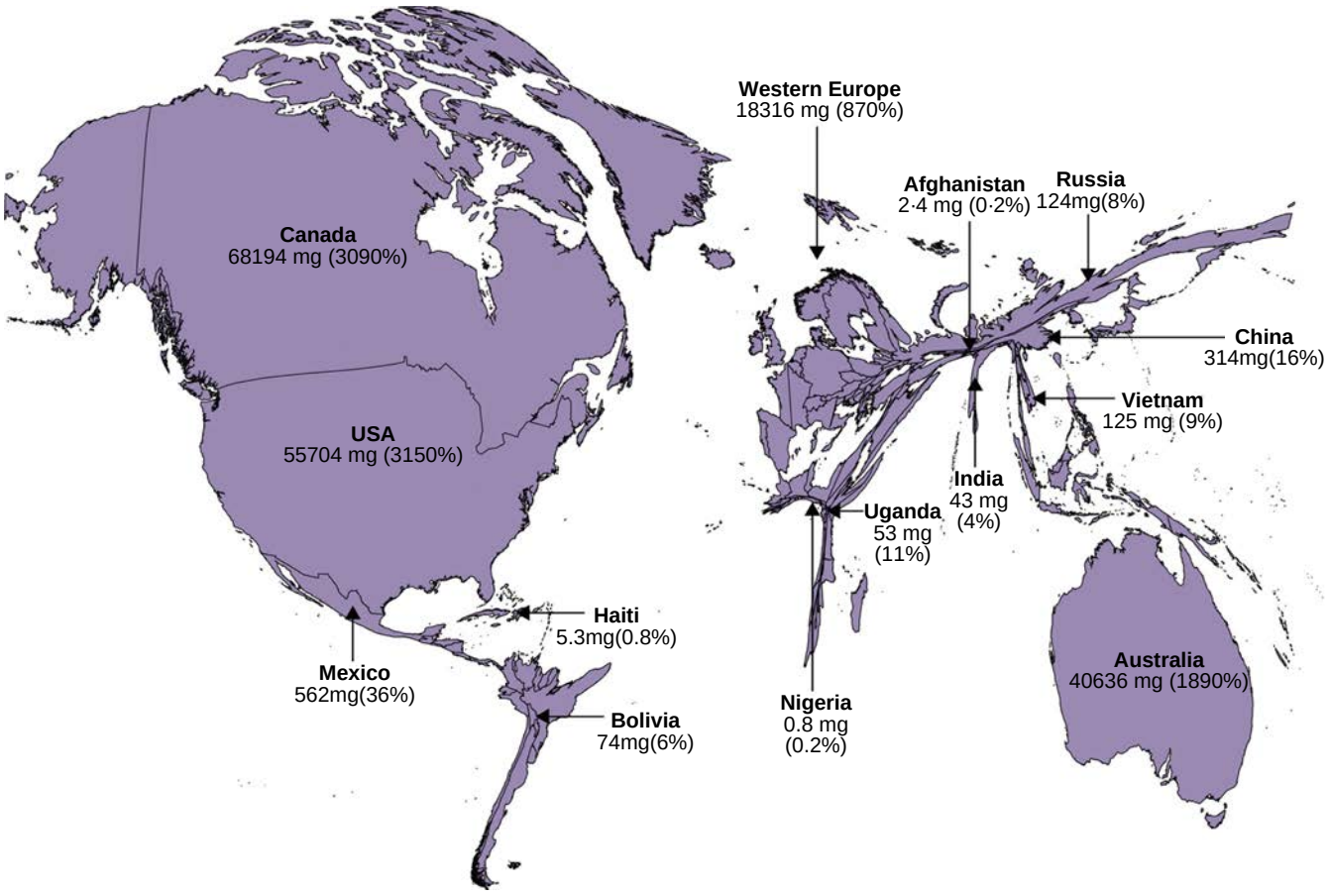

Fig. 2.7 Distributed opioid morphine-equivalent (morphine in mg/patient in need of palliative care, average 2010–2013), and estimated percentage of need that is met for the health conditions most associated with serious health-related suffering. (From Knaul FM, Bhadelia A, Rodriguez NM, et al. The *Lancet* Commission on Palliative Care and Pain Relief—findings, recommendations, and future directions. *Lancet Glob Health*. 2018;6:S5–S6. Copyright © 2018 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY 4.0 license.)

In several African countries, anesthesia-related mortality has been reported to be in the 1:100s (Malawi 1:504; Zimbabwe 1:482; Nigeria 1:387 for C-sections; Togo 1:133 to 1:250).[66–69] In one report of 24-hour surgical outcomes in Togo, 30 deaths occurred (total cases 1464), 22 were deemed avoidable, and 11 were due to avoidable anesthesia complications.[15] Another report from Togo reported a mortality rate of 1:250 and found less than half of the 26 facilities surveyed had pulse oximetry, and none had capnography.[70] In a national report on maternal mortality in South Africa, nearly 2.35% of recorded maternal mortalities were anesthesia related, and the majority (93%) were deemed avoidable. One of the most common causes of anesthesia death in this report was the provision of spinal anesthesia without skills necessary to manage an airway or convert to general anesthesia.[71] Other commonly cited causes of avoidable anesthesia mortality in resource-constrained settings include inadequate staffing, monitoring, and drug overdose. A recent meta-analysis of anesthesia-related maternal mortality in LMICs found the risk of death from anesthesia for women undergoing obstetric procedures to be 1.2 per 1000 (vs. 3.8 per million in the United States), with higher risk reported if general anesthesia was used or if anesthesia was provided by a nonphysician[72]. In this analysis, anesthesia was the cause in 2.8% of maternal deaths in LMICs and 13.8% of all deaths during or after C-section in LMICs. To state this differently, anesthesia-related maternal mortality is 300-fold higher for neuraxial and 900-fold higher for general anesthesia than is reported in the United States.

It is important to note that the relationship between hospital-based perioperative morbidity and mortality and surgical disease morbidity and mortality must be interpreted with caution in settings where patients lack access to hospitals. In other words, in an HIC a patient's chances of dying from a ruptured viscous are roughly the same as the chances of dying from surgery for a ruptured viscous because more than 95% of the population has access to care. However, in an LIC, while the perioperative mortality for a ruptured viscous may be 10%, the majority of patients with this condition never make it to surgery and have mortality rates that are dramatically higher.

Affordability is another significant barrier to accessing surgical and anesthesia services. Each year, approximately 33 million people face catastrophic out-of-pocket expenditure due to payment for surgery and anesthesia (Fig. 2.8) with an additional 48 million people facing catastrophic expenditure related to non medical costs of accessing surgical care (e.g., transportation, lodging, and food).[5,73] Nearly half (3.7 billion) of the world's population is at risk of catastrophic expenditure if they were to have surgical and anesthesia care. The majority of those at risk live in

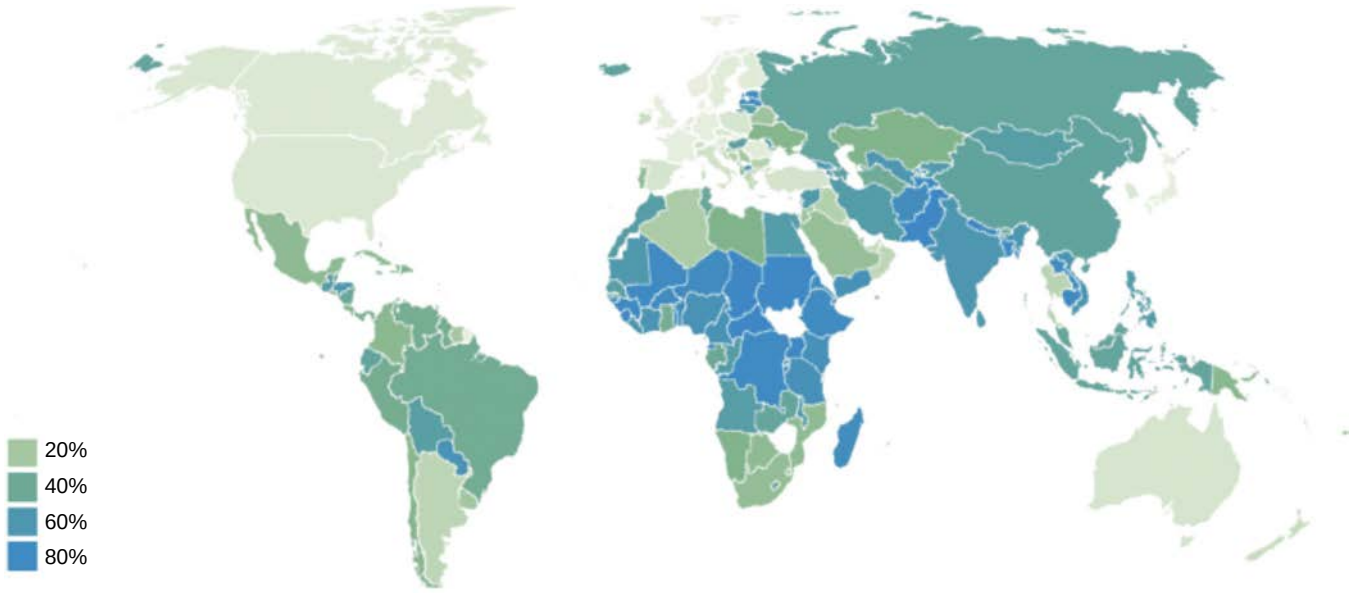

Fig. 2.8 Risk of catastrophic expenditure for surgical care in 2014 (% of people at risk). (Data from http://databank.worldbank.org/data/home.aspx. Originally printed: http://blogs.worldbank.org/opendata/africacan/pt/comment/reply/2341. Copyright © 2018 The World Bank. Reproduced under CC BY 4.0 license.)

sub-Saharan Africa, and South and Southeast Asia. The issue of affordability applies not only to surgery itself but also to components of perioperative care including analgesia and transfusions.[74] For example, in South America, a monthly prescription of opiate for chronic pain may cost 200% of annual income.[57] In India (where nominal gross national income per capita is $1670), a unit of blood often costs up to $247 despite a legal limit of $25.[75,76] Global health and development leaders including the WHO and World Bank prioritize financial risk protection as a key component of achieving universal health coverage goals for all countries. Despite relatively high out-of-pocket costs at the individual level for some procedures, surgery is a highly cost-effective public health intervention as discussed further in the following sections.

GLOBAL ANESTHESIA, SURGERY, AND PAIN CRISES: ORIGINS AND AREAS FOR INTERVENTION

Workforce shortages, inadequate infrastructure, lack of policy and prioritization, and increasing burden of surgical disease are among many factors contributing to current limitations in access, affordability, and safety of anesthesia and surgical services worldwide.[77] As previously discussed, global industrialization and an "epidemiological transition" in many LMICs have resulted in rising noncommunicable disease and injury burdens with lagging investment to address these issues. While these fundamental imbalances between healthcare needs and healthcare resources underlie much of the current global surgery, anesthesia, and pain crises, several additional factors have also contributed.

Misperceptions and Limited Data

Two common misperceptions about surgery and anesthesia have contributed to the delayed recognition of these fields as global public health priorities: (1) the scope and scale of surgical disease and pain burdens were vastly underestimated; and (2) surgical and anesthesia care were erroneously assumed to be too expensive and technology dependent to be done safely or cost-effectively in resource-constrained environments. In this section we discuss reasons why the surgical disease and pain burdens are historically poorly characterized. Misperceptions about cost-effectiveness and feasibility of safe surgery and anesthesia care also have roots in a historical data void, especially from LMICs.

Several innovative service delivery models in the public and private sectors of LMICs (e.g., Indus hospital, Aravind Eye Hospitals, and Narayana Hrudayalaya Heart Hospital) have demonstrated that it is feasible to provide cost-effective, safe, and affordable surgical and anesthesia care in resource-constrained countries.[78–81]

Recent data have consistently demonstrated that surgical services are among the most cost-effective public health interventions (Fig. 2.9). There are several methods to define cost-effectiveness thresholds, each with pros and cons.[82] One of the most commonly cited methods uses GDP-based thresholds. This approach was suggested by the WHO Commission on Macroeconomics and Health and has been defined by authors from the WHO's Choosing Interventions that are Cost–Effective project (WHO-CHOICE) as, "interventions that avert one DALY for less than average per capita income for a given country or region are considered very cost–effective; interventions that cost less than three times average per capita income per DALY averted are still considered cost–effective; and those that exceed this level are considered not cost–effective."[83]

In 2003 in Bangladesh, one of the earliest cost-effectiveness studies on surgical care reported the cost of emergency obstetric care at less than $11 per DALY averted.[16] This was 3 times more cost-effective than the measles vaccine (in 2003 dollars). The DCP2 and DCP3 demonstrated cost-effectiveness of the first-level surgical hospital, with essential surgical services all being highly cost effective and many

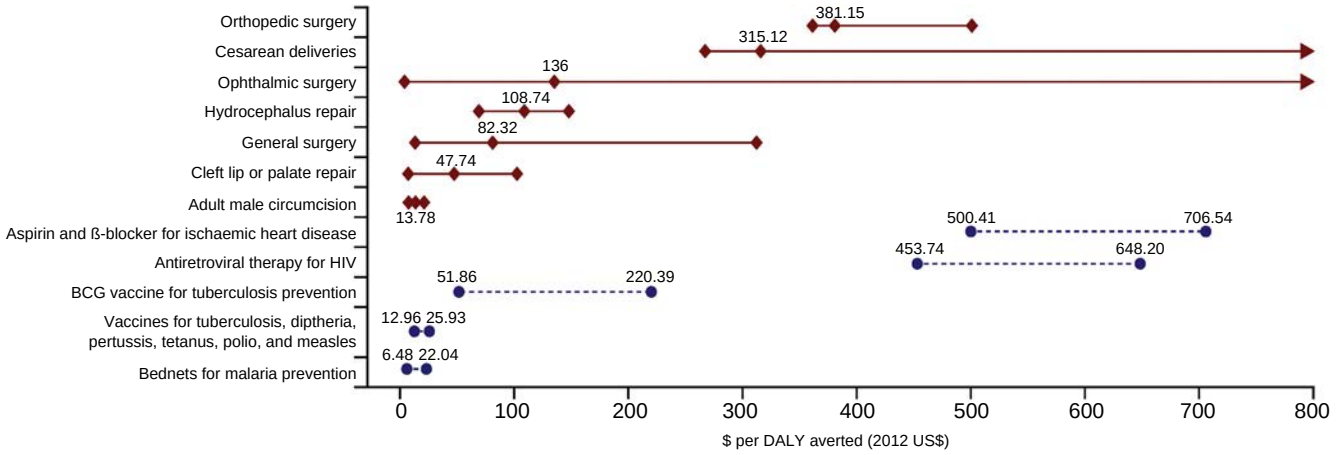

Fig. 2.9 Cost-effectiveness of surgery in low-income and middle-income countries compared with other public health interventions. Data points are medians, error bars show range. Surgical interventions are denoted by the diamonds and solid lines, public health interventions by the circles and dashed lines. *BCG,* Bacillus Calmette–Guérin; *DALY*, disability-adjusted life-year; *HIV*, human immune virus. (Source: Chao TE, Sharma K, Mandigo M, et al. Cost-effectiveness of surgery and its policy implications for global health: a systematic review and analysis. *Lancet Glob Health*. 2014;2:e334–e345. Copyright © 2015 Elsevier Ltd. Creative Commons Attribution License [CC BY].)

costing $10 to $100 per DALY averted. This is comparable to the cost-effectiveness of other public health interventions such as immunizations ($13-$26 per DALY) or bed nets for malaria prevention ($6-$22 per DALY), and much more cost-effective than other high-priority public health interventions such as HIV treatment ($500 per DALY).[84] A recent analysis of the cost-effectiveness of a pediatric operating room in Uganda found a cost of $6.39 per DALY averted and $397.95 per life saved, with a net economic benefit of over US$5 million per year (cost of $41,000 per year).[85]

In a 2012 forum hosted by the Copenhagen Consensus, five leading health economists, including four Nobel laureates, were asked how best to spend US$75 billion over 4 years to "advance global welfare," especially in LMICs. The leading priority identified by the group was the expansion of surgical care capacity (US$3 billion per year).[86]

In the past 5 years the global surgery and anesthesia communities have expanded the volume of data that dispel prior misconceptions and support prioritization of surgical and anesthesia care in the global health agenda. During this timeframe, there has also been an explosion of articles that expand available data on a wide range of global anesthesia and surgical topics. The majority of these articles have been published in the surgical journals though recently anesthesia publications have begun to actively support global anesthesia research. The global anesthesia community must increase research productivity in global health and also invest in advocacy, policy, and implementation sciences in order to ensure impact.

Advocacy and Policy

There are many reasons why surgery, anesthesia, and pain have historically not been prioritized by national health systems, donors, or the broader global health community. Although surgical disease accounts for 30% of global disease burden, less than 1% of development assistance for health supports delivery of anesthesia and surgical care.[87] Imbalance between resource allocation and disease burden is found in many health conditions, though the degree of this disparity for surgical disease and pain is particularly striking.

As discussed previously, lack of disease burden data and misperceptions about safety and cost-effectiveness have significantly hindered advocacy efforts for global anesthesia and surgery. In a qualitative analysis of factors that have hindered political prioritization for global surgery, several additional factors were identified including: fragmentation of the global surgery community, lack of leadership and consensus, and inadequate political strategy (e.g., not capitalizing on opportunities such as the MDGs).[88] In another analysis to determine why certain disease-specific global health networks are relatively more or less effective than others, four common challenges were highlighted, each with relevance to global anesthesia and surgery: (1) defining the problem and how it should be addressed; (2) positioning the issue in a way to inspire action by external audiences; (3) building coalitions that include stakeholders outside the healthcare sector (coalitions are too often dominated by HIC providers); and (4) creating governance institutions that facilitate collective action (Fig. 2.10).[89] Another study that examined factors influencing prioritization of surgery in national health systems concluded that sustained advocacy, effective framing of problems and solutions, robust country-level data, and support from regional and international partners were critical for success but often lacking.[90]

Advocacy efforts for surgery, anesthesia, and pain face a few additional and relatively unique challenges. Unlike infectious diseases such as HIV or Ebola, surgical disease and pain are not pandemic and do not incite similar action by the HIC donor community. Furthermore, most surgical conditions and pain are difficult to advertise and are not disease specific. While select pediatric conditions (e.g., cleft lips) are easily marketable, other conditions like trauma, hernias, and cesarean section are more difficult to compassionately portray in media in attempts to improve public awareness.

The WHA resolution 68.15 emphasized advocacy and resource development in five key focus areas for global surgery (workforce, essential medicines, information management,

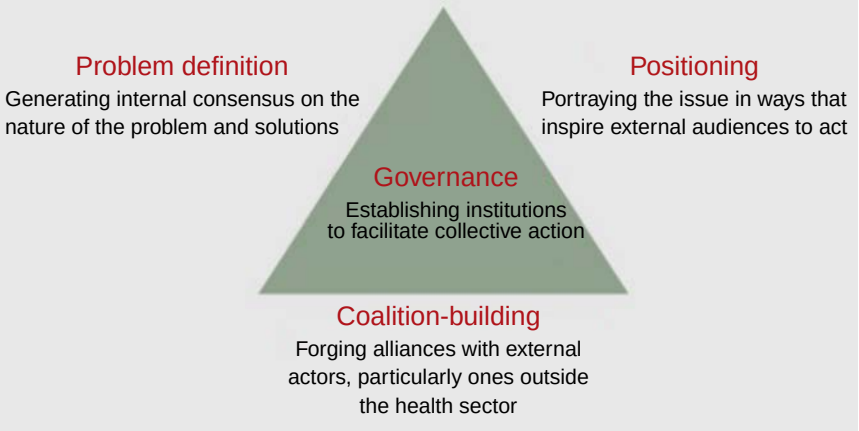

Fig. 2.10 Four challenges that global health networks face. (From Shiffman J. Four challenges that global health networks face. *Int J Health Policy Manag.* 2017;6[4]:183–189. Copyright © 2018 The Author[s]. Published by Kerman University of Medical Sciences. This is an open access article under the CC BY 4.0 license.)

service delivery, and advocacy). The LCOGS provided clear framing of problems (see Box 2.2), outlined priorities for country-level data collection, and helped to provide frameworks for national surgical, obstetric, and anesthesia plans (NSOAPs) in LMICs. As more NSOAPs are produced, they have the potential to serve as key rallying points for national advocacy efforts.

Anesthesia, surgery, and pain need global champions. Only recently has advocacy by leading global organization (e.g., the World Bank, WHO) and select local governments in LMICs focused attention on anesthesia and surgery in the global context. This is in part due to advocacy efforts by several relatively recent initiatives (e.g., LCOGS, The Global Alliance for Surgical, Obstetric, Trauma, and Anaesthesia Care [G4 Alliance], WFSA, GICS, and several more). These multidisciplinary efforts must be expanded and sustained in order to reach the critical mass needed to overcome prior misperceptions and affect change. It is essential that advocacy efforts for surgery, anesthesia, and pain be consistent with the key messages of LCOGS, the Global Health 2035 Report, WHA resolution 68.15, and the SDGs, and emphasize that anesthesia, surgery, and analgesia are indispensable components of "universal health coverage." No longer can surgery be seen as a vertical (i.e., disease-specific) program.

One key objective for advocacy efforts will be to identify new streams of funding from global donors, national budgets, private sectors, and innovative models. Similar to the large-scale funding initiatives to combat HIV/AIDS and other infectious diseases (e.g., the U.S. President's Emergency Plan for AIDS relief, Gavi Vaccine Alliance, The Global Fund), surgery and pain require comparable attention and support. In addition to domestic and international financing mechanisms to support health system scale-up, public-private partnerships and innovative patient-level financial risk protection strategies must be integral components to advocacy efforts.[5]

As leaders in safety, pain, perioperative care, and more, the global anesthesia community must actively engage in policy, research, and innovative global initiatives to expand access to quality care. Academic institutions from all countries can play a significant role in supporting a coordinated research agenda, creating a global voice for advocacy, sharing information, and harmonizing educational standards and opportunities. Anesthesia must follow the lead of other medical disciplines to not only cultivate but also support faculty and trainees with interests in global public health careers. Such advocacy will likely require coordination and partnership with multiple disciplines, including nonphysician provider cadres who perform a significant proportion of anesthesia services, especially in LICs.[91]

Workforce Shortages and Strategies for Expansion

The critical shortage of trained anesthesia providers in resource-constrained settings is one of the most significant barriers to expanding access to safe surgical, anesthesia, and pain services for billions of people worldwide. Although shortages of many key members of the surgical workforce exist (including surgeons, obstetricians, pathologists, radiologists, laboratory technicians, nurses, biomedical engineers, and more), anesthesia provider shortages in LMICs are particularly striking and relatively neglected. Countries like the Central African Republic have no physician anesthesiologists and only 24 nonphysician anesthesia providers (NPAPs) for a population of nearly 5 million. Ethiopia, with a population of over 100 million people, has only 35 physician specialist anesthesiologists. A survey of emergency obstetric care capacity at facilities in Uganda found that lack of staff had the greatest correlation with observed mortality rates.[92] In a survey of 64 public and private hospitals in Uganda, 84% did not have a physician specialist anesthesiologist, and 8% had no trained anesthesia providers at all.[93] In another survey of anesthesia providers from five main referral hospitals in East Africa (Uganda, Kenya, Tanzania, Rwanda, and Burundi), only 7% reported adequate anesthesia staffing.[94] In settings where providers exist but in small numbers, the workforce shortage is compounded by heavy administrative burdens and non-clinical duties.

While the anesthesia workforce shortage is most severe in LICs and particularly pronounced in sub-Saharan Africa, regional workforce shortages also exist in HICs and can significantly limit access to care for rural populations.[95,96] In one survey of rural hospitals in the United States, 36% reported delay or cancellation of surgery due to a lack of anesthesia providers.[97] Data from HICs demonstrate differences in trauma

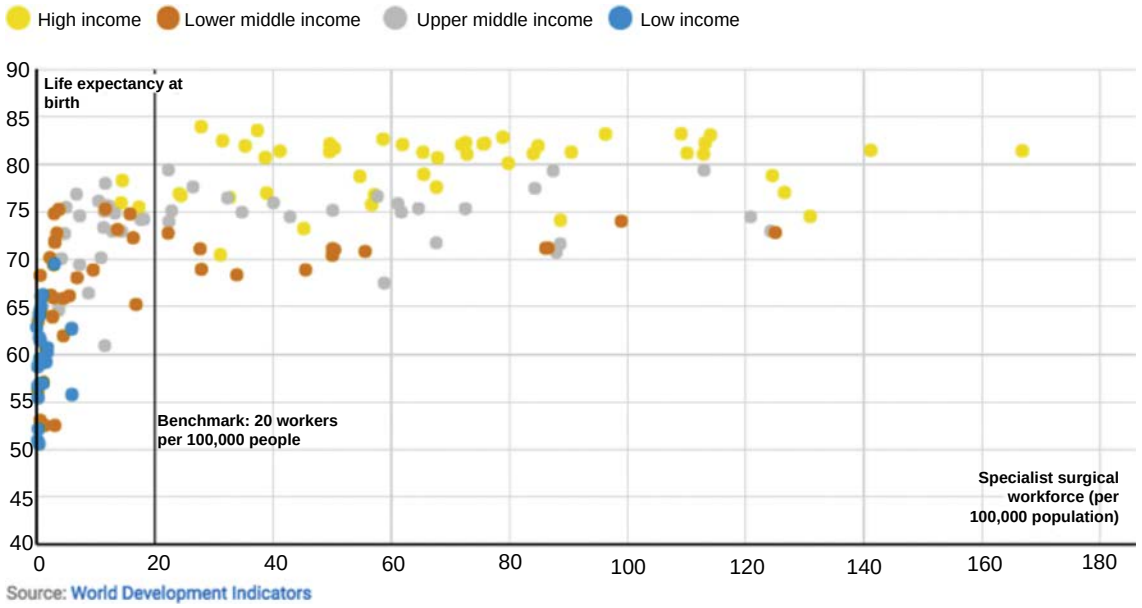

Fig. 2.11 Life expectancy tends to be higher in countries with a surgical workforce larger than 20 workers per 100,000 people. (Data source: http://databank.worldbank.org/data/home.aspx. Originally printed: http://blogs.worldbank.org/opendata/africacan/pt/comment/reply/2341. Copyright © 2018 The World Bank. Reproduced under CC BY 4.0 license.)

mortality are significantly worse starting at five miles from a trauma center in a major urban city.[98] One can only imagine outcome differences in settings where there may be no surgical or anesthesia provider for tens or even hundreds of miles.

The optimal number of specialist surgical, anesthetic, and obstetric workforce (SAO) providers needed to give access to safe surgery is unknown and likely to vary significantly based on local resources and needs. The SAO density correlates with life-expectancy and in one study, as SAO providers increased from 0 to 20 per 100,000 population, maternal mortality decreased by 13.1% for each 10 unit increase in provider density (Fig. 2.11). These benefits were also observed with workforce expansion beyond 20, though with less magnitude beyond 30 and 40 providers per 100,000 (Fig. 2.12).[99] Based on these findings, the LCOGS recommended prioritizing expansion of the SAO workforce to 20 per 100,000 population by 2030, with anesthesia-specific targets of 5 to 10 anesthesia providers per 100,000.[100]

The density of SAO providers has been estimated at 0.7 per 100,000 population for LICs as compared with 56.9 per 100,000 population for HICs.[101] Worldwide, 77 countries report an anesthesia provider density less than 5 per 100,000, with a 90-fold difference between the average physician workforce density in HICs as compared to LICs. The anesthesia workforce crisis is most severe in sub-Saharan Africa, where most countries have approximately 1.0 physician anesthesiologist per 100,000 population as compared to approximately 19 in Europe or 21 per 100,000 in the United States (Fig. 2.13).[100] Twenty-six countries in sub-Saharan Africa reported less than 0.5 physician anesthesia providers (PAPs) per 100,000. In many LICs, NPAPs provide the majority of anesthesia care. When NPAPs are included in calculations of total anesthesia provider density, 16 countries in sub-Saharan Africa still report less than 1 anesthesia provider per 100,000, and worldwide 70 countries still report less than 5 anesthesia providers per 100,000 population. Estimates from the WHO Global Surgical Workforce database demonstrate that 12% of the SAO workforce provides care for approximately a third of the world's population.[101] Worldwide, LICs and LMICs have 48% of the world's population but only 20% of the SAO workforce.

Multiple factors have contributed to the ongoing surgical and anesthesia workforce crises in LMICs, including limited training infrastructure, relatively low professional status, lack of career advancement (especially for NPAPs), perceived limited job opportunities relative to other professions (e.g., infectious disease in LMICs), cost of training, inefficient hiring mechanisms, provider burnout, as well as internal (e.g., private practice in urban settings) and external brain drain (e.g., leaving the country).[102,103] Lack of consensus on anesthesia practice models and polarized views on who should provide anesthesia care (i.e., physician versus nonphysician, supervised versus independent) are additional factors limiting a clear path for rapidly scaling the global anesthesia workforce (Table 2.3).[91] Task-sharing is a prominent and controversial component of many surgical workforce expansion efforts.

Each of the aforementioned challenges must be addressed as part of any national or international effort to expand the anesthesia workforce. The long-term goal of building robust training infrastructures in low-resource settings requires locally led plans for national advocacy, implementation, and evaluation. Such efforts can benefit from international investment and collaboration.[104-108]

Significant heterogeneity in anesthesia care models exists worldwide. Although the varied anesthesia practice and training models have evolved to address different local needs and challenges, excess heterogeneity and lack of consensus on anesthesia workforce strategy may provide an additional challenge to global workforce expansion. For example, within sub-Saharan Africa, formal nonphysician training programs range from 3 to 72 months in duration with widely different entry requirements, no standardized curricula or assessment tools, and different scopes of practice. For countries seeking

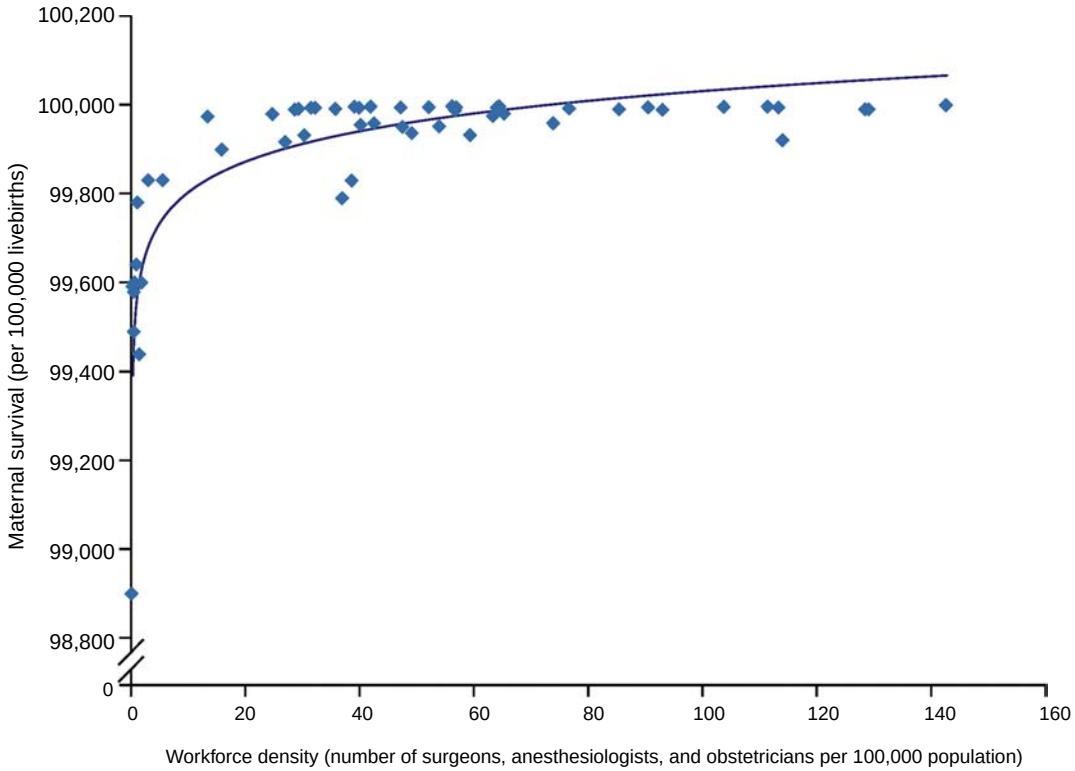

Fig. 2.12 Specialist surgical workforce density and maternal survival. A surgical workforce density of less than 20 per 100,000 specialist surgeons, anesthesiologists, and obstetricians correlates with lower rates of maternal survival. Maternal survival per 100,000 livebirths = 98,292 × ln (workforce density) + 99,579. (From Meara JG, Leather AJ, Hagander L, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet*. 2015;386:569–624. Data from Holmer H, Shrime MG, Riesel JN, et al. Towards closing the gap of the global surgeon, anaesthesiologist and obstetrician workforce: thresholds and projections towards 2030. *Lancet*. 2015;385(suppl 2):S40. Copyright © 2018 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY 4.0 license.)

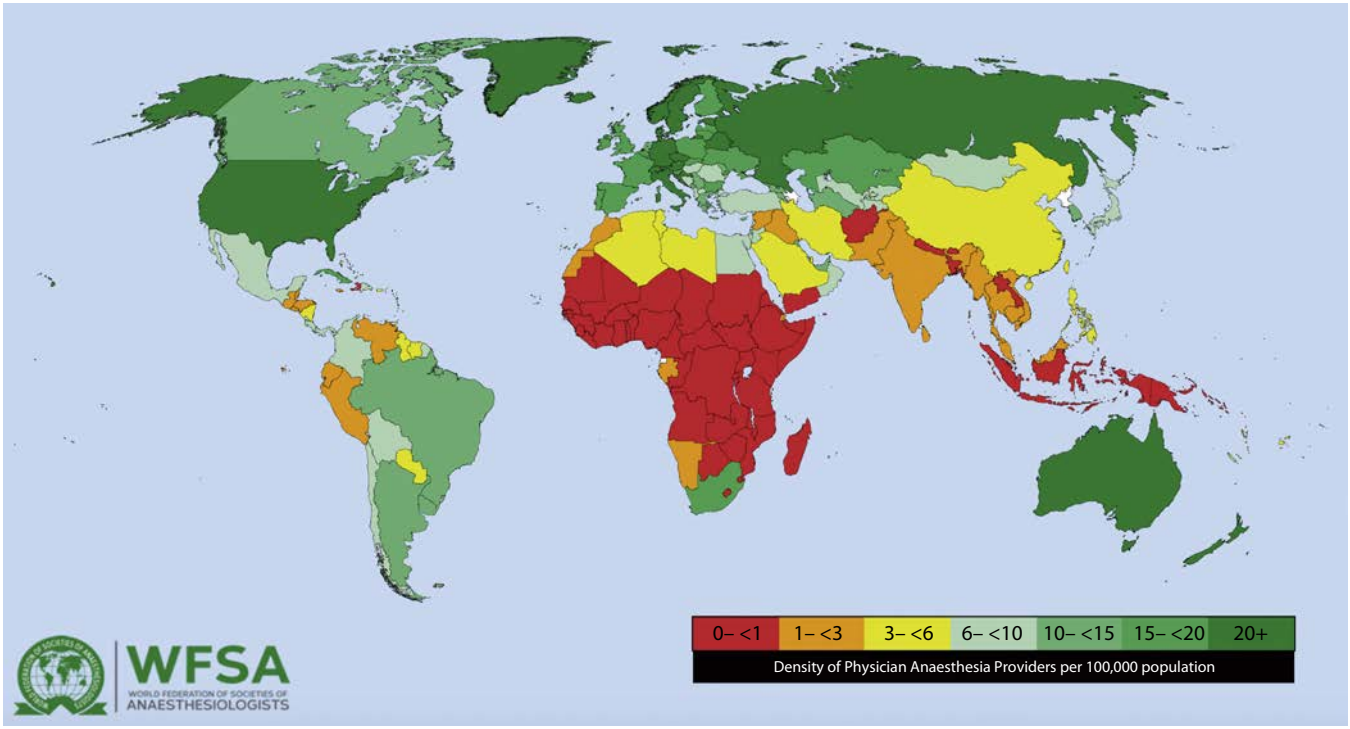

Fig. 2.13 World Federation of Societies of Anaesthesiologists Workforce Map. Image accessed at https://www.wfsahq.org/workforce-map (Data published: Kempthorne P, Morriss WW, Mellin-Olsen J, et al. The WFSA Global Anesthesia Workforce Survey. *Anesth Analg*. 2017;125[3]:981–990. Copyright © 2018 The WFSA. This image is reproduced under the CC BY 4.0 license.)

to increase anesthesia provider numbers, no clear roadmap exists. In most of these countries, task-sharing with NPAPs will likely play a key role in workforce expansion efforts. Collaborative efforts involving stakeholders from different countries and different anesthesia provider cadres can support anesthesia workforce expansion efforts by offering frameworks for anesthesia training, competency assessments, and potential practice models that are feasible with local resources and that meet local needs. Initiatives that ensure quality (e.g., education programs, credentialing bodies, and licensing exams) are as important as those that focus on increasing absolute numbers. The global anesthesia community can play a significant role via advocacy, research, education, and partnership to address many of the challenges that have created the current global anesthesia workforce crisis.

Infrastructure Challenges

The provision of surgical and anesthesia care requires infrastructure that is often lacking in many LMICs. As discussed elsewhere in this chapter, such infrastructure does not necessarily need to be high-cost or based on advanced technologies to provide safe care. In addition to the provider shortages already discussed, additional infrastructure challenges that frequently limit surgical and anesthesia service delivery include: underdeveloped patient referral and prehospital systems, medication and equipment shortages, and inadequate supply chains and facility resources.

In maternal health, and more recently for surgery and anesthesia, a "three delays framework" has been used to describe factors delaying timely access to safe healthcare services.[5] The "first delay" in this model (delay in seeking care) may occur due to financial, cultural, education, or other patient factors. Anecdotally, fear of bad surgical outcomes (whether true or not) and more specifically a fear of anesthesia may also contribute to the "first delay." The second and third delays are more directly linked to infrastructure limitations. The "second delay" (delay in reaching care) occurs when health facilities cannot be reached in a timely manner and may be due to geographic distance or challenges with transportation (e.g., bad road conditions, no access to a car, no money for public transport). Although efforts to improve healthcare infrastructure often focus on facility-based interventions, emphasis on infrastructure that minimizes this "second delay" is underappreciated despite evidence of cost-effectiveness.[109] For example, the lack of prehospital care systems in many LMICs is a significant source of avoidable morbidity and mortality. The DCP3 estimates that 4.7 million deaths in LMICs each year are due to surgical conditions that are potentially addressable through prehospital and emergency care systems. In Uganda, less than 25% of the population lives within 2 hours of a surgical facility, and worldwide approximately 2 billion people lack access due to this second delay.

When discussing infrastructure limitations, most people think of the "third delay" (delay in receiving care), which occurs when patients reach a facility but may not receive adequate care because of limitations in facility resources. Data from 800 first-level health facilities in LICs demonstrate that relatively few first-level hospitals could provide C-sections (64%), laparotomies (58%), or open fracture repairs (40%), and most did not have reliable electricity (31%), running water (22%), oxygen (24%), or Internet access. Without reliable utilities, standard equipment like monitors, ventilators, anesthesia machines, and autoclaves are often not functional, assuming they are even present at all. In recent years, the number of surgical and anesthesia capacity assessment tools increased significantly, although most tools have focused on surgical care with limited ability to assess anesthesia or analgesia capacity.[110–117]

The WHO Surgical Safety Checklist includes requirements for pulse oximetry, anesthesia machine check, and confirmation of instrument sterility, yet these may not currently be feasible in many LMIC health facilities. As the consensus on what constitutes "essential" or "standard" anesthesia and surgical safety equipment is evolving, it is universally agreed that far too many health facilities face routine shortages of even the most basic anesthesia equipment.

Inadequate access to indicator strips, maintenance support, power, and distilled water result in low compliance with the 2016 WHO/Pan American Health Organization (PAHO) standards for cleaning, disinfection, and sterilization in most LMICs.[118,119] In a survey of 28 district hospitals in Zambia, 35% did not have a laryngoscope.[120] A study from Nigeria found that most facilities could not provide general anesthesia (53%); another survey in the Democratic Republic of Congo demonstrated 40% of hospitals lack suction, and in Guatemala only 17% of facilities surveyed had capnography.[121,122] In Uganda, a 2014 survey of health facilities that offer emergency services and surgical care revealed only 22% had pediatric airway equipment, 41% adult airway equipment, and 28% a pulse oximeter.[123] In one survey about obstetric operating room capacity in the five main referral hospitals in East Africa (Uganda, Kenya, Tanzania, Rwanda, and Burundi), only 4% of the providers surveyed reported the presence of electrocardiograph (ECG), pulse oximetry, continuous blood pressure monitoring, capnography, thermometer, stethoscope, difficult airway cart, suction machine, recovery room, and intensive care unit (ICU) facilities.[94] Access to reliable oxygen is a common problem in resource-constrained health systems. In such settings, oxygen is rarely available through central pressurized gas lines and more often provided via tanks or oxygen concentrators, the latter of which has been shown to offer long-term cost savings and increased reliability.[124] (Further discussion of oxygen supply challenges in resource-limited settings is provided in the section, Essentials for Practice in Resource-Constrained Settings of this chapter)

Equipment donations are common in LMICs, however, they often have limited long-term impact and multiple unintended consequences. Donations are frequently made with limited understanding of local needs, lack of communication between donor and recipient, and absence of ongoing technical support or access to consumables. Well-intentioned donors are often unaware of WHO Guidelines for Medical Device Donation, or of the fact that purchase costs account for only 20% of total lifetime costs for a piece of equipment.[125] As a result, up to 30% of donated equipment may only transiently or never become operational, and commonly accumulates in equipment graveyards because of a sense of obligation by recipients to not throw anything away. For example, donations of modern anesthesia machines from HICs is commonly encountered in many LMICs. Without reliable power, pressurized gas supplies, biomedical support, or access to disposables (e.g., carbon

TABLE 2.3 Heterogeneity in Global Anesthesia Workforce

	Australia	Canada	China	Colombia	Fiji	India	Lebanon
Population (millions)	24.1	36.3	1,379	45.5	0.9	1,324	6
GNI per capita (USD)	$54,230	$43,880	$8,250	$6,310	$4,780	$1,670	$7,980
Year formed as a specialty	1952	1910	1989	1963	1970	1964	1954
*Specialist physician anesthesiologists	5,535	3,318	71,698	3,600	18	25,000	500
*Nonphysician anesthetists	0	0	0	0	0	0	70
Anesthesia providers per 100,000 people†	23.0	9.1	5.2	7.9	2.0	1.9	9.5
Years of post-secondary education to qualify as specialist physician anesthesiologist	12	13	11	10	13	8	11
Duration of physician specialist training	5	5	3	3	4	4†	4
Members of anesthesia care team							
Physician specialist	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician non-specialist	Yes	Yes	No	No	No	No	No
Nurse anesthetist	No	No	No	No	No	No	Yes
Non-nurse, nonphysician anesthetist	No	No**	No	No	No	No	Yes
Key national challenges	Rural staffing and training, salaries at risk from governmental defunding	Rural staffing, large rural population	Inconsistent medical training, workforce shortage limiting obstetric and NORA coverage	Rural staffing and inequity, low salaries, high workload	Workforce shortage, few specialist job posts, limited postgraduate funding, limited access to resources	Workforce shortage, rural staffing, polarized views on task-sharing, poverty	Regional instability, limited resources and workforce, large refugee population (~1/3 population)
Subspecialty training programs							
Critical care	Yes	Yes	No	Yes	Yes	Yes	No
Cardiac anesthesia	No	Yes	Yes	Yes	No	Yes	Yes
Pediatric anesthesia	No	Yes	Yes	No	No	Yes	No
Regional anesthesia	No	Yes	Yes	No	No	Yes	No
Obstetric anesthesia	No	Yes	Yes	No	No	Yes	No

GNI, Gross national income.
*In many countries (e.g., South Africa) large numbers of physician non-specialists provide anesthesia, but accurate counts of these cadres are unavailable.
†Physician specialist anesthesia training in India includes 3 years anesthesia training after 1 year as a "house surgeon."
**In Canada, Anesthesia Assistants are trained to perform many of the anesthesia tasks including intubation, extubation, maintenance of anesthesia (including administering drugs) as directed by the anesthesiologist, but are not designated as the primary anesthesia provider for a given case.

Mexico	Norway	Pakistan	Paraguay	Romania	South Africa	Uganda	USA	Vietnam
127.5	5.3	193.2	6.7	19.7	55.9	41.5	325.7	92.7
$9,040	$81,980	$1,500	$4,060	$9,480	$5,480	$630	$56,850	$2,060
1934	1949	1960	1973	1957	1935	1985	1940	1960
13,000	1,138	3,000	258	1,400	1,500	72	50,000	1,000
10	2,000	0	497	0	0	430	50,000	2,000
10.2	59.2	1.6	11.3	7.1	2.7	1.2	30.7	3.2
10	11	10	10	11	13	9	12	11
3	5	4	3	5	4	3	4	5
Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No	Yes	No	No	No	Yes	No	No	No
No	Yes	No	No	No	No	Yes	Yes	Yes
No	No	No	Yes	No	No	Yes	Yes	No
Rural staffing, large rural population, political and civil stability	Inadequate time for non-clinical activities during training	Medication and workforce shortages, geographic distribution and inconsistent quality of care	Inconsistent training standards for non-physicians	Workforce shortages, regional staffing shortages, no standardized nurse curriculum	Workforce shortage, large poor and rural population, inequitable access to care	Workforce shortage, rural staffing, high workload, low remuneration, medication and equipment access, polarized views on task-sharing	Rural access to specialists, high cost of care, polarized views on task-sharing, maternal mortality	Inconsistent medication and equipment access, geographic distribution of workforce
Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Yes	Yes	Yes	No	No	No	No	Yes	No
Yes	Yes	No	No	No	No	No	Yes	Yes
Yes	No	No	No	No	No	No	Yes	Yes
Yes	Yes	No	No	No	No	No	Yes	Yes

BOX 2.3 World Health Organization Essential Medicines List—Anesthesia Medications

General Anesthetics and Oxygen

- Halothane, isoflurane, nitrous oxide
- Oxygen
- Ketamine
- Propofol (or thiopental)
- Bupivacaine
- Lidocaine

Muscle Relaxants

- Atracurium
- Neostigmine
- Suxamethonium
- Vecuronium
- Pyridostigmine*

Preoperative Medication and Sedation for Short-Term Procedures

- Atropine
- Midazolam
- Morphine

Medicines for Pain and Palliative Care

- Acetylsalicylic acid
- Ibuprofen
- Paracetamol
- Codeine
- Fentanyl transdermal (for cancer pain)
- Morphine
- Methadone
- Dexamethasone
- Amitriptyline
- Diazepam
- Haloperidol
- Ondansetron

Additional Medications†

- Epinephrine
- Hydrocortisone
- Naloxone
- Lorazepam
- Enoxaparin
- Heparin
- Tranexamic acid
- Digoxin
- Verapamil
- Amiodarone*
- Hydralazine
- Lasix
- Sodium nitroprusside*
- Dopamine*
- Mannitol
- Insulin
- Glucose
- Ergometrine
- Misoprostol
- Oxytocin
- Misoprostol*

Notable deletions

- Ether (2005)
- Ephedrine (1995)*
- Magnesium sulfate (1988)
- Pethidine (2003)

*Ephedrine is listed in the complementary list of medications in the 2017 20th Edition EML. The complementary list presents essential medicines for priority diseases, for which specialized diagnostic or monitoring facilities, and/or specialist medical care, and/or specialist training are needed.

†Blood products, antiseptics, and antibiotics are included in the EML and not listed here.

Data from http://www.who.int/selection_medicines/committees/DELETIONS.pdf?ua=1.https://www.who.int/medicines/publications/essentialmedicines/20th_EML2017.pdf?ua=1/.

dioxide absorbent, humidity filters, circuit tubing), it is sometimes hard to argue in favor of these machines.

Reliable access to medications and blood are two additional common infrastructure challenges limiting access to safe surgery and anesthesia services worldwide. The WHO Essential Medicines List includes medications to safely perform general anesthesia, monitored anesthesia care (MAC), neuraxial, regional, local anesthesia, as well as acute and chronic pain management (Box 2.3).[126] Despite the existence of the list for more than 40 years, critical shortages of many medications persist. A WHO survey of all health facilities in Uganda examined availability of twelve anesthetic drugs (atracurium, bupivacaine, halothane, isoflurane, desflurane, sevoflurane, ketamine, lidocaine 2%, lidocaine 5% heavy spinal injection, midazolam, nitrous oxide, and suxamethonium) and found that only 2% of the surgical health facilities had all of these medications and only 19% had half.[123] The same WHO survey in the Democratic Republic of Congo found that only 33% of hospitals had bupivacaine, 21% thiopental, and 16% halothane. Factors specifically affecting access to analgesics are discussed further in the next section, though supply chain, cold storage, and cost are common challenges that limit availability for many drugs. Drug quality is also a factor in some LMICs where variable manufacturing quality and fraud (i.e., counterfeiting) are commonly encountered.[127] It is estimated that 1 in 10 medical products (e.g., medications) found in LMICs are substandard or falsified and result in hundreds of thousands of deaths each year.[128,129]

The WHO Essential Medicines List also includes blood products. Despite more than four decades of global advocacy (1975 WHA28.72) for universal access to safe blood, limited transfusion capacity significantly impacts the ability to provide safe surgery and anesthesia care, especially for rural and LMIC populations. Most rural surgical facilities are unable to provide consistent access to safe blood. Patients lack timely access to safe blood as a result of several common challenges including inadequate blood supply, distribution networks, rural blood banking capacity, safety protocols, workforce (e.g., pathologists, laboratory technicians), testing supplies, and policy implementation, as well as high costs of blood and high prevalence of infectious diseases.[75,130,131] The whole blood donation rate is used as an indicator of blood availability. The LCOGS recommends a minimum of 15 blood donations per 1000 people per year, yet this rate is 4.6 per 1000 people per year in LICs (compared with 32.1 per 1000 people per year in HICs).[5,132] Most LMICs cannot maintain adequate supply from voluntary non-remunerated donors (VNRDs) alone (as advocated by WHO), and the use of paid donors or

family donors poses numerous logistic and safety concerns.[75] According to WHO data, 71 countries collect the majority of their blood supply from family or paid donors, 50% lack capacity to separate blood components, and 23.5% of countries have less than 100% screening for at least one of these transfusion-transmissible infections: HIV, hepatitis B, hepatitis C , or syphilis.[132] For many LMICs, investment in transfusion infrastructure, expansion of transfusion research, and advocacy (including rethinking of well-intentioned but context-limited policies such as VNRD-only mandates, requirements for onsite pathologists, and mandatory replacement units) are critical areas for engagement by anesthesia providers in the greater global health community.[75,133]

There is an evolving consensus on global standards for anesthesia equipment, medications, and other infrastructure.[3,117] As a result, most assessments of facility or national capacity capture different data that may over- or underestimate current infrastructure limitations. For example, lack of access to rocuronium, sevoflurane, or propofol does not necessarily indicate inability to safely perform anesthesia if suxamethonium, halothane, isoflurane, or thiopental are available. Currently efforts are underway by the WFSA, GICS, and other organizations to develop anesthesia-specific research tools to assist LMICs in monitoring and evaluation of anesthesia capacity.[116,117] The global anesthesia and surgical communities are likely to benefit from continued collaboration and harmonization of efforts that assess global anesthesia infrastructure.

Inequities in Analgesia

Five billion people worldwide have little or no access to analgesia. As with the surgical disease crisis, inequities in analgesia access are in part a result of the limited availability of data that quantify the problem. Unlike most traditional global health metrics that focus on extending healthy life and productivity, alleviating pain may not always target these same goals (e.g., acute surgical pain relief and palliative care), thus adding to the complexity of quantifying pain burden. Massive inequities in access to analgesia are also attributed to several additional factors including advocacy challenges (pain is not disease specific or easy to associate with a "face"), limited training opportunities for healthcare professions, fear of addiction and diversion, financing, supply chain limitations, cultural attitudes, and regulatory and legal barriers (Box 2.4).[52,53] In the ensuing discussion, we consider some of these barriers and potential areas for intervention by the global anesthesia community.

Limited financial resources and infrastructure hinder the ability of healthcare systems to deliver analgesia (i.e., effective supply chains) and limit the ability of patients to afford such care. Countries with a lower GDP or human development index have less access and use of opiates.[53] Opiate prices in LMICs are often significantly higher relative to GDP. In the recent past in Argentina and Mexico, the monthly cost of an opioid prescription for oncologic pain was reported to be more than 200% the average monthly income.[74,134] In Rwanda, the reported price of injectable morphine is 6 times the lowest cost reported in the International Drug Price Indicator Guide.[30,135] Drivers of these inflated prices include import costs, taxes, licensing fees, storage and sales restrictions, and limited public finance programs. International regulations and misconceptions about pain treatment and addiction form the basis for many of these interventions.

BOX 2.4 Factors Affecting Access to and Availability of Analgesia

Knowledge and Attitudes

- Providers—limited training
- Patients—limited health literacy
- Opiophobia—fear of addiction, diversion, or side effects
- Cultural attitudes and beliefs about pain
- Limited data to estimate pain burden or accurate national analgesia needs
- Challenging advocacy (pain is not disease specific or easy to associate with a "face")

Regulations and Policy

- Prohibitionist bias
- Implementation requires significant resources
- Onerous regulations (e.g., limits on who can prescribe, duration, dose and indication)
- Complex regulations create fear of prosecution among providers
- Limited global advocacy efforts to expand analgesia access

Economics and Financing

- Poverty
- Relatively high analgesic costs in LMICs
- Costs of implementing/enforcing international regulations
- Few mechanisms for financial protection from analgesic costs (e.g., subsidies or UHC)

Health Systems

- Supply chains (timely import, procurement, storage, and distribution)
- Limited analgesic options
- Few providers trained/skilled to provide adequate analgesia
- Inadequate number/distribution of facilities providing analgesia care
- Limited national government capacity

LMIC, Low- and middle-income countries; *UHC*, universal health coverage.
Modified from: Berterame S, Erthal J, Thomas J, et al. Use of and barriers to access to opioid analgesics: a worldwide, regional, and national study. *Lancet.* 2016;387(10028):1644–1656.
Goucke CR, Chaudakshetrin P. Pain: a neglected problem in the low-resource setting. *Anesth Analg.* 2018;126(4):1283–1286.
INCB 2017 report https://www.incb.org/documents/Publications/AnnualReports/AR2017/Annual_Report/E_2017_AR_ebook.pdf.

Misinformation about analgesia has biased knowledge and attitudes among providers, patients, and policymakers, and has resulted in significant undertreatment of pain. Several studies have demonstrated that the risk of addiction associated with appropriate analgesic administration is significantly exaggerated and especially low for acute, oncologic, or end-of-life pain.[136] Nonetheless, widespread and excessive fears over diversion and addiction have resulted in unnecessarily onerous regulatory barriers that often confuse tolerance and dependence, users and addicts, and disproportionately affect poor and marginalized populations.[137] In China, for example, a domestic ketamine abuse problem has led to repeat lobbying of the International Narcotics Control Board (INCB) by the Chinese government to reschedule ketamine as a schedule I drug for all countries. Such regulation would effectively remove the nearly ubiquitous access to ketamine in LMICs, and further exacerbate the ongoing global pain crisis.[138] Ketamine is inexpensive, accessible, and safe, and as a result has become a critical resource for the provision of safe and accessible anesthesia and analgesia services

worldwide. Fortunately, attempts to restrict ketamine have been promptly recognized as heartless and a violation of international regulatory policies.

Tramadol is another analgesic with frequently misunderstood pharmacology that is commonly found in LMICs. Tramadol is not controlled by international regulations, which has led to its widespread availability for analgesia but also to its abuse.[139] Abuse is widely reported in many HICs (e.g., Canada) and LMICs (e.g., many countries in Africa and the Middle East) and is so severe that in countries like Cameroon, it can literally be found in the groundwater as a result of human excretion.[140] Tramadol is not considered an adequate substitute for opiates and is not included in the WHO Essential Medicines List.

Contemporary legal and regulatory/policy frameworks have significantly exacerbated disparities in access to analgesia care. In the wake of several key events in the 1800s that fueled skyrocketing opioid abuse, including the Opium Wars and invention of the hypodermic syringe, the beginning of the 20th century produced several of the first national and international efforts to restrict and regulate narcotics. This included the first international conference on narcotics in 1909 (International Opium Convention in Shanghai) and the first multilateral drug treaty in 1912 (The Hague Opium Convention). One of the most notable regulations of the 20th century is the 1961 UN Single Convention on Narcotic Drugs. The opening sentence of the "Single Convention" recognizes, "…that the medical use of narcotic drugs continues to be indispensable for the relief of pain and suffering and that adequate provision must be made to ensure the availability of narcotic drugs for such purposes…" The Single Convention set out to control the use and trade of plant-based drugs (opium, cannabis, and cocaine) while also assuring availability for medical purposes.[141] This regulation mandated government participation (reporting national estimates of narcotic needs, meticulous record keeping), regulated drug cultivation, restricted trade to authorized international parties, and created the INCB. The INCB was tasked with monitoring UN drug convention implementation and required each country to designate an enforcement office (e.g., the Drug Enforcement Administration [DEA] in the United States). While most countries adopted this onerous regulation, most poor countries did not have the extensive resources needed to enact all of these changes. The Single Convention's "global estimates" system has been particularly difficult for many countries to implement. This system requires all countries to provide an estimate of opiate need (for medical purposes) in order to inform global production goals and limit excess opiate supplies that are at risk for illicit use. Accurate estimates require significant resources, and for many LMICs, inability to provide accurate estimates translates directly to inadequate supply. For example, 2017 opiate estimates for Chad (population 14.5 million) predicted 341 g fentanyl, 249 g morphine, and 105 g codeine. When compared to estimates from Canada (population 36.3 million: 150,000 g fentanyl, 4,750,000 g morphine, 40,020,000 g codeine, and 70 other controlled substances) the disparity and gross underestimation is apparent.[142] By approving such gross underestimates, the INCB effectively is legally prohibiting patients from having access to opiates. In times of humanitarian crisis, the Single Convention impedes the ability to emergently augment local analgesia capacity as became evident in the wake of the 2010 Haiti earthquake.[143]

Global regulations to curb illicit use have dominated efforts to ensure access to analgesics for medical purposes (or to ensure access to substance abuse treatment). In 1985, the Parliament of India passed the Narcotic Drugs and Psychotropic Substances Act to enforce international drug policy (e.g., the Single Convention). The Act's onerous regulations and extreme penalties (including the death penalty for certain drug-related crimes) resulted in more than a 90% decrease in the medicinal use of morphine.[144,145] This imbalance, referred to by some as "collateral damage from the war on drugs," disproportionately affects LMICs and continues to cripple access to analgesics for the majority of the world's population.[143] Such bias has also impaired scaleup of addiction treatment initiatives. For example, addiction treatment (methadone and buprenorphine) was not added to the WHO Essential Medicines List until 2006, approximately 100 years after the passage of the earliest narcotic regulations and 40 years after the list's creation.

The prohibitory biases of prior international drug policy has resulted in numerous national regulatory barriers that include limitations on who can prescribe, dispense, or administer opiates, as well as limitations on indications (e.g., postoperative but not cancer pain), dosages, or duration of therapy.[137] For example, in Armenia only oncologists with the approval of multiple providers can prescribe outpatient opiates, whereas in the Ukraine, healthcare providers must travel to the patients' homes to administer outpatient opiates. In Jordan, the maximum duration of an opiate prescription for oncologic pain is 10 days, and only three days for all other conditions.[146] These myriad regulations create an additional barrier by inducing fear of prosecution for noncompliance among health professionals, thereby reducing provider willingness to prescribe. Lack of adequate training opportunities for healthcare providers, especially in LMICs, coupled with the rare use of analgesics in clinical practice, create a cycle whereby fewer and fewer providers feel comfortable prescribing opiates.

Several amendments to the Single Convention have been enacted including the 1971 Convention of Psychotropic Substances, the 1988 UN Convention Against Illicit Traffic in Narcotic Drugs and Psychotropic Substances, the inclusion of morphine in the first WHO Essential Medicines List in 1977, and introduction of the WHO Pain Ladder in 1986. Despite these efforts most of the world's population remains without reliable access to analgesia. Nearly 60 years after the Single Convention, the number of drug abusers in many countries is near all-time highs while 150 countries still lack reliable access to analgesia. Even the UN's SDGs, which aim to set development priorities for the world, reflect the prohibitory bias of prior international policies. SDG 3.5 calls for improved prevention and treatment for substance abuse, including narcotics, but fails to mention pain or palliative care anywhere else in the SDGs.[29]

Advocacy and education efforts by the global stakeholders, including the anesthesia community, as well as rethinking of international analgesic policy (including the Single Convention) are essential for progress in addressing the global pain crisis.[125,147] Education for healthcare providers, policymakers, and the public can play a significant role in expanding access to analgesia. Such efforts should focus on pharmacologic treatment strategies, but should also emphasize better understanding and management of causes and contributors to pain, including social and economic determinants. Efforts by numerous Ministry of Health agencies have had small successes. In Vietnam and India, grassroots- and civil-society-led

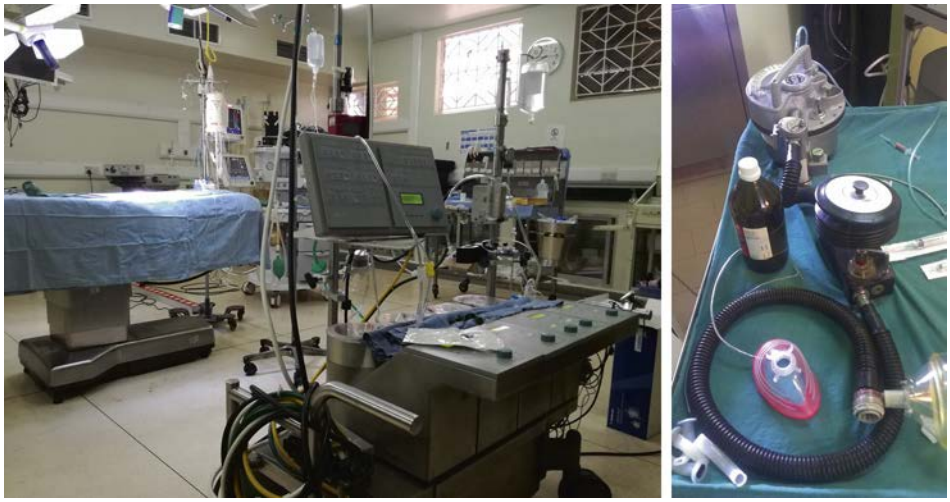

Fig. 2.14 Two operating theatre setups in Uganda, 2018. *Left,* The Ugandan Heart Institute. *Right,* Epstein, Macintosh, Oxford *(EMO)* ether vaporizer at a first-level hospital providing surgical services. (Copyright © 2018 Cornelius Sendagire, reproduced with permission.)

policy initiatives to allay opiophobia and reduce institutional licensing regulations have significantly increased access to analgesia without an increased diversion.[148–151] In Uganda, advocacy efforts by the nongovernmental organization Hospice Africa Uganda helped convince the Uganda Ministry of Health in 1993 to import morphine powder and to provide domestically made morphine liquid free to all cancer or HIV/AIDS patients. In 2004, the Uganda Ministry of Health legalized opioid prescribing by nurses and clinical officers with palliative care training, which significantly expanded access to analgesia especially in rural communities. The import and domestic packaging of oral morphine for palliative care has translated into greater access to oral morphine for the anesthesia and surgical communities. A similar model is currently being adopted in Rwanda, Nigeria, Kenya, Swaziland, and Malawi.[152]

Section 2: Evolution of Anesthesia Care Models and Challenges Around the World

In the mid-19th century the use of inhaled anesthetics (e.g., most notably ether) began in HICs and spread relatively quickly even to many relatively less resourced countries as a consequence of colonial systems. Today, more than 170 years later, ether is still used in some LICs (Fig. 2.14). The practice of anesthesia has changed significantly, though these changes—including large improvements in patient safety—disproportionately occurred in HICs. The practice of anesthesia varies widely between, and even within, countries. Of the numerous challenges and factors that have shaped this heterogeneity, many are shared by multiple countries regardless of income level. These include common challenges such as inadequate workforce (number, composition, or distribution); high cost of care; limited access for rural and poor populations; and lack of standards for practice and training.

This section explores anesthesiology in six geographic regions of the world, providing examples from countries of diverse economic, political, and population backgrounds. Regional variation in anesthesia care models including key milestones in the development of these systems as well as current challenges they face for providing access to safe, affordable anesthesia care are highlighted. This section is not intended to be comprehensive but to provide examples that are representative of the diversity in anesthesiology despite shared common objectives and many similar challenges.

AFRICA

Africa is the second largest continent, with 1.2 billion people, and the youngest population of all the continents (median age ~19 years vs. 38 years in the United States). Africa is also the poorest continent. Recent estimates by the World Bank demonstrate that 11% of the world's population lives on less than US$1.90 per day, and most of the world's extreme poor (over 400 million people) live in Africa (Fig. 2.15).[153]

Economically, Africa is growing fast with an annual change in GDP for most countries of approximately 3% to 6% (Uganda—an LIC 6.3%, South Africa—an upper middle-income country 1.2%).[154] Total health expenditure (THE) has grown more rapidly than GDP with average increases in THE/GDP from 4.8% in 1995 to 5.9% in 2014 for the continent. Out-of-pocket payments as a proportion of THE have also been decreasing (South Africa decreased from around 17% in 1995 to approximately 5% in 2014, and in Uganda from around 45% to around 40%).[155]

African countries have widely disparate health systems. According to a recently published study on outcomes after surgery in Africa, countries participating in the study reported poor outcomes relative to higher-income regions (despite healthier patients) and attributed worse outcomes to limited resources and lack of access to surgical care.[65] The public healthcare sectors of Uganda and South Africa are, in many ways, representative of the current state of anesthesia and surgical care in Africa.

Uganda (Mary T. Nabukenya and Sarah Hodges)

Uganda (population ~40 million) is one the youngest and most rapidly growing nations in the world (fertility rate

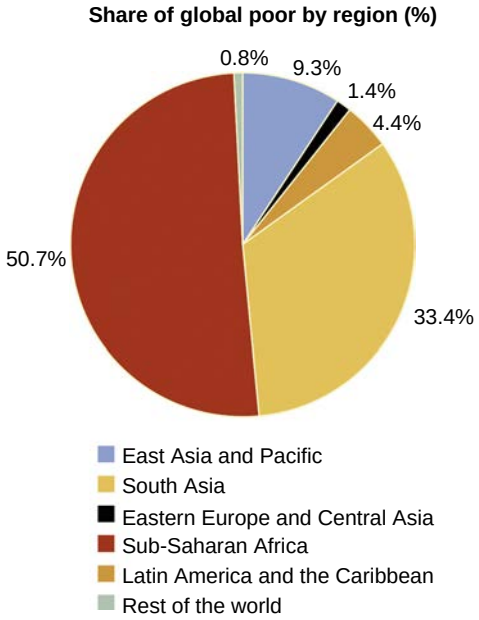

Fig. 2.15 Where are the global poor living? The global poor, by region, 2013. (Source: Most recent estimates, based on 2013 data using PovcalNet [online analysis tool], World Bank, Washington, DC, http://iresearch.worldbank.org/PovcalNet/. [Figure originally appeared in The World Bank Group. Taking on Inequality, Poverty and Shared Prosperity 2016. Copyright © 2016 The World Bank. This image is reproduced under the CC BY 4.0 license.])

~6). Uganda has a gross national income per capita of $630 (see Table 2.1) and despite recent increases in THE/GDP (7.2% vs. 17.10% in the United States), many healthcare challenges exist (life expectancy 56 years), especially with regard to anesthesia and surgery.[76,156]

The first recorded anesthetic in Uganda was a cesarean delivery in 1879 with the use of banana wine as the anesthetic.[157] The first modern anesthetic (chloroform) was given by Sir Albert Cook in 1897.[158]

Anesthesia was initially most commonly given by surgeons. Theater attendants and medical assistants were also trained on the job to administer anesthesia. In the 1970s and early 1980s, a 2-year anesthesia diploma program (anesthetic assistants) was created. In 1985, during a meeting of the Commonwealth Health Ministers of the East, Central, and Southern Africa region, it was established that a medical background was vital for anesthesia provider training. This resulted in abolishment of the "anesthetic assistant" programs and creation of a 2-year diploma (anesthetic officers) in 1986 that required a diploma in clinical medicine, nursing, or midwifery as a prerequisite.

Until the 1980s, training of Ugandan physician anesthesiologists was primarily foreign-based, and due to political turmoil, few returned to Uganda to practice. One anesthesiologist returned in the mid-1970s and started the Department of Anesthesia at Mulago Hospital (Kampala, Uganda). Together, with an Australian anesthesiologist, they established a 1-year Diploma in Anesthesia in 1985, and the following year the Anesthesia Master of Medicine (MMED), a 3-year residency program at the Makerere University Medical School. In 1990, with a total of 4 physician anesthesiologists and roughly 100 nonphysician anesthetists in the country, the Uganda Society of Anesthetists was founded.

Today there are two physician MMED and three nonphysician diploma programs in Uganda. A new nonphysician, 4-year Bachelor's in Anesthesia program was also started in 2017. Each institution awards a qualification to its graduates, as currently there is no accrediting body for anesthesia in Uganda. Regionally, the College of Anesthesiologists for East, Central, and Southern Africa (CANECSA) was founded in 2014 but has not started accreditations.

From 2000–18, the number of physician anesthesiologists in Uganda has increased from less than 10 to over 80, with the majority working near the capital (Kampala). Nonphysician anesthetists outnumber the physician anesthesiologists by almost 6 times and are distributed widely throughout the country where they usually practice without supervision or team support. Despite increasing numbers in recent years, vast shortages in the anesthesia workforce limit access to care throughout the country. Over the past decade, about 10% of physician anesthesiologists have moved to other countries in Africa. This brain drain has been reported in many other countries, including Francophone Africa under the Cotonou program, where brain drain was reported at nearly 18%.[108] In addition to this external brain drain (i.e., emigrating to another country), internal brain drain (e.g., leaving the public sector for private practice, staying in urban centers, or leaving the field of anesthesiology) is also a significant challenge throughout the region. These moves are motivated by economic incentives and political changes.

In 2007, the Ugandan health ministry established health sub-districts in each county (about 150 countrywide), each with an operating theater for provision of emergency obstetric and surgical care. Unfortunately, they were ill-equipped, and many are nonfunctional. None of the 33 district hospitals have a physician anesthesiologist (despite position vacancies), and only 4 of 13 regional referral hospitals have an anesthesiologist on staff. There are currently 25 anesthesiologists in the national referral hospital together with the teaching faculty in the two MMED programs. All other physician anesthesiologists in Uganda are working in private hospitals and universities.

Safety standards in Uganda are based mainly on WFSA guidelines, however, these are not strictly enforced.[3] Compliance rates with the WHO Surgical Safety Checklist are low as is capacity to comply with the checklist requirements. A survey of utilization of the checklist in major East African hospitals showed variable compliance (19% to 65%).[94]

Administration of ether anesthesia with the Epstein, Macintosh, Oxford (EMO) vaporizer is still used in remote locations of Uganda, although its use has declined significantly in recent years. Throughout the country there are a wide range of configurations ranging from EMO drawover setups to modern anesthesia machines for cardiac bypass surgery (see Fig. 2.14). Limitations in reliable power, disposables, and oxygen are among the many infrastructure challenges that affect daily anesthesia care in almost all locations. Even with monitoring, there are significant differences in what is available ranging from a basic stethoscope and blood pressure cuff to monitors allowing for invasive monitoring. In recent years, the scope of practice

has expanded as more providers are completing subspecialty training abroad (e.g., pediatrics, cardiac, obstetrics, critical care, and regional) and returning to practice and teach locally.

Besides the nearly universal problem of remuneration, the greatest challenge for anesthesia in Uganda is the massive imbalance between the workforce and the workload. This imbalance coupled with ill-equipped workplaces makes the provision of safe care difficult, and provider burnout is commonplace.

South Africa (Hyla Kluyts)

South Africa is home to approximately 56.5 million people of diverse ethnicity and culture.[159] Since the first democratic election in 1994 and the adoption of the South African Constitution in 1996, the country has been struggling to address its inequalities. In health care, there have been successes such as the decreasing incidence of HIV infections and increasing life expectancy (from 55.2 years in 2002 to 62.4 years in 2016). South Africa has a gross national income per capita of $5,480 (upper middle-income country), yet approximately 19% of the population live below the World Bank poverty line (US$1.90 per day) and only 17% of the population have private medical insurance.[76] The proportion of the population living below the extreme poverty line is much higher than that of many other middle-income countries. A recent collaborative report by the World Bank denotes South Africa as "one of the most unequal countries in the world."[160] The South African Department of Health is working toward universal health coverage and a draft National Health Insurance Bill was published in June 2018.[160a]

Ether was first used for dental extractions in Cape Town in April 1847, and the first major operation under anesthesia was performed in June of the same year. The first specialist anesthetist, British-born and -trained Dr. Bampfylde Daniel, was appointed at Johannesburg Hospital in 1907. The South African Society of Anaesthesiologists (SASA) was founded in 1943 and was a founding member of the WFSA in 1955. SASA published its first Practice Guidelines in 1987, with five subsequent revisions, including 2012 and 2018 revisions that adhere to the WHO-WFSA International Standards on the Practice of Safe Anaesthesia.[161]

Physicians are trained and accredited to provide anesthesia care as general practitioners or specialists. General practitioners are registered as independent practitioners after completing 6 years of undergraduate study and 3 years of supervised training as interns and subsequent community-service medical officers. A general practitioner can obtain a Diploma in Anaesthesia after 6 months of full-time supervised practice in an accredited institution. Specialists can register as such after completing a 4-year postgraduate training period, completing of a research project, and successfully passing the South African College of Anaesthetists' final Fellowship examination.

The Health Professionals Council of South Africa (HPCSA) certifies medical professionals and is the accreditation body for anesthesia training. Eight university departments across the country are responsible for the academic input and implementation of training pathways, whereas the Provincial Departments of Health dictate the number of posts within these training pathways. The curricula are determined by the Colleges of Medicine of South Africa, which also is responsible for assessments and examinations.

Anesthesia providers in South Africa consist of independent practitioners (general practitioners or specialists in both private and public sectors) supplemented by interns, community service medical officers, specialist trainees, and foreign physicians who do not qualify for registration as independent practitioners and must work under supervision in the public sector. Anesthetists in private practice in South Africa are not hospital based and travel between hospitals according to demand from surgical colleagues. The SASA therefore plays a significant role in the private sector as a representative body for clinician interaction with other stakeholders. In contrast, all public sector anesthetists are employed by the provincial Departments of Health at specific hospitals.

The already limited specialist anesthesia workforce is also unequally distributed between the private and the public sector, and between rural and urban areas in South Africa. For example, approximately 1800 specialist anesthesiologists were registered with the HPCSA in 2017, of which around 1100 specialists are SASA members, and of these, 790 work in the private sector. Roughly 9 million patients are insured and cared for in the private sector.[161] Unsatisfactory working conditions and remuneration are the most commonly quoted reasons for anaesthetists leaving the public sector for the private sector after registering as specialists.

There is limited information available regarding the number, distribution and training of non-specialist anesthesia providers in South Africa. The number of non-specialists choosing full-time anesthesia practice as a career is relatively low and likely does not significantly address the lack of anesthesia services available to the population in either sectors of the healthcare system. At best, the estimated total number of anesthesia providers per 100,000 of the population is half of the minimum required for safe care. No non-physicians provide anesthesia in South Africa. Attempts have been made to train more doctors and to recruit doctors to areas of need (e.g., implementation of rural allowance payments). Anesthetists also form part of the District Clinical Specialist Teams alongside the family physicians, primary healthcare nurses, and specialist obstetricians. These teams were created to improve maternal and neonatal mortality and morbidity at a district level, though anesthesia posts within these teams remain largely unfilled and are not considered mandatory for "minimal team" standards.

Access is a major barrier because of the country's geography and distribution of available resources. About one third of the poorest population in South Africa have to travel at least 20 km to the nearest hospital.[160] Often these level 1 facilities provide obstetric surgery services but not surgical services for the bellwether procedures largely because of the failure to recognize basic surgical care as a public health issue.

Information on anesthesia-related outcomes is not available on a national level, but some useful data are obtained through reports from the National Committee for the Confidential Enquiry into Maternal Deaths.[71] Surgical outcomes for South Africa and Africa have been reported following

recent multicenter studies.[65] Regulation of healthcare expenditure, improving access to essential surgical care in rural parts of the country, and increasing data perioperative care and on resource distribution will be critical to improving anesthesia and surgical care in South Africa.

NORTH AMERICA

North American countries have widely different economic, political, and healthcare systems. This section describes examples from two HICs (Canada and the United States) and one middle-income country (Mexico). These two HICs have extremely different models of health care as well as anesthesia services. Canada has a predominantly physician-based system and universal health coverage, while the United States is split nearly equally between physician and nonphysician providers. Mexico is physician-based, but with a novel and controversial rural physician anesthesia program. Haiti is the only LIC in North America and suffers from shortages of healthcare providers that are orders of magnitude worse than other countries in the region. There are fewer than 100 anesthesiologists for the country's population of 10.85 million, and most only work in the capital city. In 1998 Médecins Sans Frontières began a nurse anesthetist training program in collaboration with the Ministry of Public Health and Population (independent from The Haitian Medical Association and the Haitian Society of Anesthesiologists), though numbers of nurse anesthetists remain critically low.[100,162]

Canada (Tyler Law)

The first reported anesthetic in Canada was administered in 1847, just after Morton's demonstration in Boston, as a result of the ship carrying the news from Boston to London, via Halifax.[163] The first formal anesthetic training program began in 1910 in Toronto, and anesthesia as a profession became formalized with the creation of the Canadian Anesthesiologists Association in 1943.[164]

PAPs undertake a 5-year specialist anesthesia residency directly from medical school, or through the International Medical Graduate program designed to train practicing physicians from other countries to national standards. This training focuses on the progressive, successful demonstration of task competency (termed entrustable professional activities [EPAs]), rather than time-based rotation training. The EPAs are consistent across residency programs, and residents receive frequent feedback on their performance. Residents must demonstrate competency in EPAs before advancing to the next phase of training.[165,166]

The Royal College of Physicians and Surgeons of Canada sets accreditation standards and required competencies for anesthesiologists in conjunction with the training programs. In conjunction with EPAs, the Royal College certifies a national examination with written and oral components that tests knowledge, application of knowledge, and clinical judgment. Standardized simulation scenarios are being gradually introduced as a component of specialty certification.

The count of physician anesthesiologists in Canada has increased significantly from 2500 in 2005 to 3300 in 2018, resulting in a provider density of 9 anesthesiologists per 100,000 population. In Canada, anesthetics are largely given by specialist physicians, with several additional healthcare provider cadres also administering anesthesia care. Graduates of the two-year Family Medicine residency may opt to take a 1-year "added skill" training program in anesthesia. They practice anesthesia independently for less acute patients and procedures, often in a community or low-volume setting.

A small number of dentists administer both general anesthesia and sedation for dental procedures, typically in ambulatory settings in the clinic or hospital. A 3-year training program undertaken after the completion of dental school enables them to care for ASA physical classification 1, 2, and stable 3 patients.[167] The anesthesia care team also includes anesthesia assistants, who undertake a prescribed educational program (most often 1 year in duration) and provide technical assistance with equipment and perform clinical tasks (such as intubation or intraoperative medical management) under the supervision of an anesthesiologist.

Guidelines for anesthesia practice have been established by the Canadian Anesthesiologists Association and are regularly updated for the core elements of anesthesia practice in Canada, and guidelines from the ASA and other international societies are commonly referenced. Notable elements of recent guidelines include encouraging the use of a structured handover protocol, and requiring capnography monitoring for moderate or deeper sedation.[168]

Most anesthesiologists practice in academic health centers and community hospitals.[169] The costs of most surgical, anesthetic, and postoperative inpatient care services are covered under provincially administered public health insurance schemes. Only 0.7% of private health spending is directed toward physicians, so the market for private anesthetic services is small and usually restricted to services not covered under public plans, such as dental and cosmetic procedures.[170]

Despite universal health coverage and a relatively large number of anesthesia providers, Canada still faces several challenges relevant to anesthesia and surgical care. Canada is the second largest country (by land mass) in the world, and while much of the population is geographically clustered, rural areas suffer from the lack of consistent access to health care, particularly lack of access to specialists including anesthesiologists. Many northern communities have sizable First Nations (indigenous) populations, who are disproportionately underserved. Similar to the United States, tension among anesthesia provider roles is an ongoing issue.

Mexico (Gerardo Prieto)

The Aztec and Maya were among the earliest anesthetists in Mexico and known for using herbal beverages to produce analgesia, with adjuncts such as rattlesnake fangs, leeches, porcupine needles, and the maguey needles to produce local numbness.[171] The Maya witch doctors were divided into specialty groups according to the diseases that they either cured or produced. The first mention is a witch doctor who produced *"sleepiness"* called Ah Pul Uenel, who used plants that produce hallucinations and nervous system stimulants. Also mentioned is Pul-Yahob who treated wounds and pain with different rituals, plants, and animals.

As in many countries, surgeons provided the first contemporary anesthetics in Mexico. The first ether anesthesia in Mexico was performed in 1847 by the military surgeons E. H. Barton and Pedro Vander Linden for a cannon ball wound amputation, during the U.S. Intervention War in Veracruz.[172] In 1852, Dr. Pablo Martinez Del Rio used ether in an obstetric patient during a session of the Medical Society. Dr. Ramos Alfaro is attributed as the founder of Mexican anesthesia with his introduction of chloroform anesthesia in 1852.[173] In 1900, Dr. Juan Ramon Pardo Galindo performed the first spinal anesthetic in Mexico and Latin America. In 1934, the first formal diploma in anesthesiology (DA) was awarded, and The Mexican Society of Anesthesiology (Sociedad Mexicana de Anestesistas) was formed. In 1957 the first contemporary anesthesia residency programs were formed, and in 1973 the Mexican Council of Anesthesia was registered and was active until 2013 when it became the National Council of Certification in Anesthesia (CNCA).

In Mexico, anesthesia training programs are 3 to 4 years in duration after medical school and authorized by a university and a recognized institute of medicine. Once this program is completed, trainees must pass the National Council of Certification in Anesthesia to receive a 5-year license. Mexico has subspecialty training in cardiac, pediatric, neuro, obstetrics and gynecology, and trauma anesthesia.

Mexico City is one of the most populated cities in the world, absorbing an estimated 70% of all Mexican anesthesiologists in a 300-mile radius. Many factors make medical access extremely difficult for large parts of the population, such as the broad geographic distribution of the Mexican population, rural indigenous tribes speaking different dialects, low per-capita income (gross national income per capita US$16,176), and the concentration of healthcare resources in urban areas.

In the wake of Mexico's economic crisis in 1994, the country was forced to evaluate how to improve access for the most impoverished and marginalized parts of the population. The program that emerged was called PROGRESA (Programa de Educación, Salud, y Alimenación) and was designed to alleviate poverty by developing human capital. Part of this program aimed to fill the shortage of specialists working in rural environments. The government and Mexican Social Security Institute established the idea of training "rural specialists" in surgery, obstetrics, pediatrics, and anesthesiology. Medical school graduates who did not pass the national examinations for admission to residency programs were enrolled and trained to work in rural areas for as little as 6 months to 2 years (often with limited educational resources). In many instances these providers migrated to the larger cities or towns. Approximately 500 graduates have been trained by this program, and in 2016 the government ordered the National Council of Certification in Anesthesia to allow rural anesthesia graduates to take the national examination. If these providers pass, they are given a certificate for rural practice only. If they do not pass the written examination in three attempts, they are given the opportunity to complete a practical examination. The efficacy of this training and impact of the program overall remain controversial.

In Mexico there are approximately 13,000 certified anesthesia practitioners for 128 million people (7 per 100,000 population), with 70% located in central Mexico. Approximately 85% of surgical procedures are performed in Government Social Hospitals and 15% in private practice. The Mexican Social Security Institute estimated that 2.5 million procedures were performed in 2015, and when including all the government hospitals and private practices, it is estimated that well over 5 million anesthetic procedures are performed each year.[8]

Mexico faces significant challenges providing access to anesthesia services outside of a few urban settings. In 2012, it was estimated that 21.5% of the population (~25 million people) lacked access to health services. The country has relatively sufficient anesthesia training capacity and increasing numbers of specialist anesthesiologists, yet provider maldistribution is currently the dominant factor limiting access. Additional challenges facing the anesthesia community in Mexico include provider burnout, addiction, and limited data on anesthesia safety.

A number of anesthesia patient safety initiatives are ongoing in Mexico, including legal mandates (the "Norma Oficial Mexicana de Anestesiologia 006") that specify practice requirements for anesthesiologists and hospitals. Success of these efforts will be contingent on addressing each of the challenges discussed previously.

United States (Ronald D. Miller and Adrian W. Gelb)

Anesthesia slowly gained acceptance as a medical specialty in the United States after the initial ether demonstrations by Morton in 1846. It was taught irregularly and informally throughout the early 1900s as a task performed by medical students, interns, or nurses. A large proportion of anesthesia in the United States was provided by nurses, even though the designation of Certified Registered Nurse Anesthetist (CRNA) was not formalized until 1956.

The first anesthesia society in the United States was the Long Island Society of Anesthetists, established in 1905, and the first department of anesthesia and residency program was established by Ralph Waters at the University of Wisconsin in 1927. This program produced several key leaders in anesthesiology directly (e.g., Cullen, Apgar, and Rovenstein) and indirectly (Stoelting, Miller) (Fig. 2.16). The American Board of Anesthesia (ABA) was formed in 1938 to serve as the certification body for anesthesiologists. Anesthesia was recognized as a specialty by the American Medical Association (AMA) in 1940, and the ASA was established in its current form in 1945.[163]

Physician anesthesiologists in the United States must obtain a medical degree (Doctor of Medicine or Doctor of Osteopathic Medicine) followed by specialty (residency) training in anesthesia. An undergraduate bachelor's degree (3-4 years) is required before entering medical school.[174] Residency in anesthesia lasts 4 years: 1 year of general medical internship and 3 years of anesthesia and perioperative medicine training. Residents rotate through the operating room (including subspecialty cases), pain medicine, and at least 4 months of intensive care. Residency training requirements are prescribed by the Accreditation Council for Graduate Medical Education (ACGME). Graduates of an ACGME-approved program are eligible for ABA certification after passing two written examinations (BASIC and ADVANCED), a standardized oral examination, and an objective structured clinical examination. Board

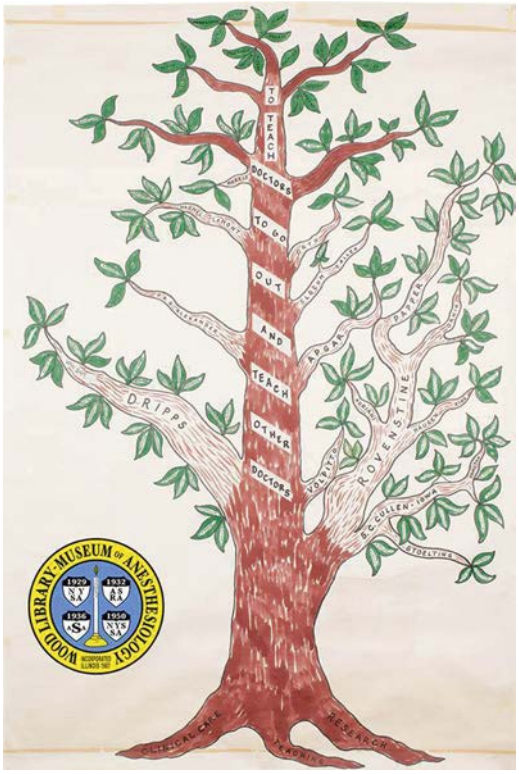

Fig. 2.16 The Aqualumni tree (created by Lucien E. Morris, Ralph M., and Jean P. Morris) depicting names of chairpersons or heads of academic anesthesia centers that came from the lineage of the world's first postgraduate academic residency program in anesthesiology led by Dr. Ralph Waters at the University of Wisconsin. (Copyright © 2018 https://www.woodlibrarymuseum.org. Image reproduced courtesy of the Wood Library-Museum of Anesthesiology, Schaumburg, IL.)

certification is a prerequisite for most hospital-based jobs in anesthesia.

Nurses with at least 1 year of practice in critical care are eligible to train as CRNAs. Training ranges from 24 to 42 months and confers a master's-level degree or higher. Training guidelines are specified by the Council on Accreditation of Nurse Anesthesia Educational Programs and mandate at least 465 hours of classroom education, exposure to a minimum of 600 clinical cases, and 2000 clinical hours.[175] Like physicians, CRNAs who complete an accredited program may take the National Certification Exam administered by the National Board of Certification and Recertification for Nurse Anesthetists.

Certified Anesthesiologist Assistants are a relatively new anesthesia provider group in the United States. Although the first training program opened in 1969 in an attempt to address significant provider shortages that existed in the United States at that time, the cadre has been relatively slow to increase numbers. Certified Anesthesiologist Assistants complete an undergraduate degree with pre-medical studies and then enter a 2.5-year anesthesia training program that is done in collaboration with an anesthesiology department. They conduct anesthesia as directed by a supervising anesthesiologist, and work in close collaboration with the anesthesiologist who leads the care team.

Physician anesthesiologists in the United States are involved in all aspects of perioperative care, including preoperative optimization in outpatient clinics, management of acute postoperative pain, obstetrical anesthesia services, and responding to traumas and inpatient emergencies. They also frequently manage ICUs after completing subspecialty training in critical care.

There are approximately 50,000 physician anesthesiologists, and 50,000 registered CRNAs in the United States, for a combined density of approximately 31 providers per 100,000 people.[176,177] The composition of the anesthesia care team may include from physician anesthesiologists only, to physician anesthesiologists supervising either CRNAs or anesthesia assistants, to CRNA-only models. Federal regulations mandate physician supervision of CRNAs, but 17 states have opted out of this requirement following the introduction of legislation in 2001.[178] Among the 17 states that have opted out, 14 require some degree of physician oversight (not necessarily by an anesthesiologist) and only 3 allow completely independent CRNA practice.

While it is unproven if nonphysician cadres in the United States increase access to anesthesia or provide care with different quality outcomes, data demonstrates that CRNAs are more likely to practice in rural locations and perform more anesthetics under sedation (i.e., MAC) than physician anesthesiologists.[179,180]

Although overall provider density is high in the United States, there is stark geographic maldistribution with providers concentrated in urban areas. Many less populated areas report significant surgical delays due to the lack of anesthesiologists.[95] Access to subspecialists is also limited. For example, nearly one third of the United States pediatric population lives more than 50 miles from the nearest pediatric anesthesiologist.[181]

Maternal mortality has increased in the United States in the last 10 years, though anesthetic-related maternal mortality has declined.[182] The causes are multifactorial, may be attributable to the changing risk profile of obstetric patients, and pose a dynamic challenge to anesthetists.

The high costs of care and incomplete financial coverage (insurance) are two additional, evolving challenges in the United States with significant repercussions and relevance for anesthesia care. Lastly, significant ongoing debate exists over anesthesia provider roles.

EUROPE

Although Europe and the European Union (EU) may appear as one entity, the countries represented are diverse with regard to population, economic situation, culture, and political leadership. Similar diversity is also seen for the training and organization of anesthesiology services in these countries. The official EU title of the specialty is "Anaesthetics," and the only EU training requirement is that its duration should be 3 years.[183] In reality, the duration of training is anything from 3 to 7 years, and the involvement in anesthesia, intensive care, pain, and critical emergency medicine varies to a great extent among countries.[184] The European Section and Board of Anaesthesiology (EBA) of the European Union of Medical Specialists (UEMS) is the political branch of European anesthesiology. The UEMS aims to promote and harmonize the highest level of training of the medical specialists, medical practice, and health care within the EU, and to promote free movement

of specialist medical doctors within the EU. The EBA/UEMS has published training guidelines to encourage countries to aim for an agreed standard.[185] In cooperation with the scientific branch of European anesthesiology, the European Society of Anaesthesiology (ESA), the UEMS offers the European Diploma of Anaesthesia and Intensive Care (EDAIC). Another building block for European Anaesthesiology is the Helsinki Declaration on Patient Safety in Anaesthesiology, which was introduced in 2010.[186] In the following paragraphs we describe the situation in two countries—Romania, a middle-income EU member state with a population of 19.7 million and physician-only service, and Norway, a high-income, non-EU member state with a population of 5.2 million and where the team approach is the anesthesia service model.

Norway (Jannicke Mellin-Olsen)

In Norway, the first ether anesthetic was provided at Rikshospitalet (the National Hospital) in Oslo on March 4, 1847.[187] In April, the first ether inhalation for labor followed. At that time, younger surgeons and GPs and later nurses were in charge of anesthesia delivery. In the 1930s two surgeons (Carl Semb and Johan Holst) facilitated anesthesia training opportunities for physicians Otto Mollestad and Ivar Lund in London and Boston (Massachusetts General Hospital), respectively. Dr. Mollestad was hired without salary in 1939, and as the first consultant in anesthesiology in 1947.

The Norwegian Society of Anaesthesiology was founded in January 1949 with only seven members. The founding members faced significant difficulties promoting the specialty, but the anesthesia nurses welcomed physician involvement and leadership.

Physician specialty training is 5 years. There is no final examination, but there are course exams and procedure checklists, in addition to continuous individual assessment. Trainees are encouraged to take exams for the EDAIC. The nurse anesthetist training program is 1.5 years after 3 years of nursing education. Both physician anesthesiologists and nurse anesthetists are accredited by the Directorate of Health.

The first guidelines that described the scope of practice and dynamics of the anesthesia team were authored by both physicians and nurses in 1993.[188,189] It was agreed that anesthesiology is a medical specialty. A physician is responsible for all anesthetic procedures, although nurses are allowed to provide anesthesia for ASA physical classification 1 and 2 adults with indirect supervision. At induction and emergence, there must always be two anesthesia-trained persons immediately available. The "flexible anesthesia team" usually consists of one physician and one nurse.

Anesthesiology is an attractive and prestigious specialty in Norway (second to thoracic and neurosurgery only), and works closely with almost all other hospital specialists, including the surgeons.[190] In contrast to many other countries, anesthesiologists in Norway are highly respected by the general public. This is partly due to increased visibility, as anesthesiologists provide leadership not only in anesthesia, but also perioperative medicine, pain management, intensive care, and critical emergency medicine (including prehospital services). There are currently 1329 physician anesthesia providers (25.5 per 100,000 population) and 2000 nurse anesthesia providers.[100] Anesthesiology is among the medical specialties with the lowest female representation (30%). As Norway has generous paid maternity and paternity leave, the norm is that both sexes stay in the profession and work full-time.

Health care in Norway benefits from the country's economic prosperity, robust public programs, and emphasis on patient safety. The Norwegian Society of Anaesthesiology was among the first signatories of the Helsinki Declaration on Patient Safety in Anaesthesiology, and the WHO Surgical Safety Checklist is distributed and used nationwide. Norwegian health care is funded primarily by the government. Hospital care is free of charge for the patient, as are medication costs once a specified amount is surpassed. Private hospitals exist but provide mostly elective surgery.

Current challenges facing the anesthesia community in Norway include concerns about costs and quality, although in general, hospitals are well equipped. In recent years there has been increasing frequency of medicine shortages, mostly due to the lack of domestic production and export policies of drug companies that can have adverse safety consequences.

Romania (Daniela Filipescu)

The first anesthetic in Romania (ether for a limb amputation) was documented in the journal "TemesvarerWochenblatt" and took place on February 13, 1847.[190a] The world's first-ever use of opioids for intrathecal anesthesia was presented by a Romanian in Paris in 1901.[191] Thoma Ionescu further developed the technique and published the first textbook of intrathecal anesthesia—*La rachianesthésie générale.*[191,192]

The first anesthesia training course in Romania was held in 1951, and a formal 1-year training course began in 1959, after the recognition of Anesthesia and Intensive Care Medicine (AICM) as an independent medical specialty.[190a] The first ICU was instituted in 1958, but it was only in 1972 that AICM departments were formally introduced in the Romanian medical health system.

The first AICM study group was founded by Zorel Filipescu in 1958. The study group was included later as part of the Romanian Society of Surgery and separated as an independent Romanian Society of Anaesthesiology and Intensive Care (RSAIC) in 1972. The RSAIC joined the WFSA the same year.

In Romania, specialist physicians are the only formal anesthesia provider cadre. After graduating from medical school (MD), physicians may enter specialty training after passing a written national examination. The number of places for each specialty is decided by the Ministry of Health, and admission to a specialty depends on candidate preference and performance on the written examination. Usually, AICM is among the top specialties chosen for training due to the wide range of opportunities to work abroad. The Romanian MD and specialist diplomas are automatically recognized in EU countries.

The AICM specialty training is five years and includes two years in intensive care medicine. Romania endorsed the competency-based European Board of Anaesthesiology Curriculum for Anaesthesiology, Intensive Care, and Pain Therapy, but this has been only partially implemented. For obtaining the specialist certification, written and oral examinations must be taken at the end of the training period. Romania adopted the EDAIC Part I examination organized

by the ESA as the national written examination since 2010. All physicians practicing in Romania have to be evaluated and re-licensed based on a minimum 200 continuing medical education (CME) credits accumulated every 5 years. There are no specialized anesthesia nursing cadres recognized in Romania, but general nurses may apply for posts in AICM departments where they are trained locally for the job.

An estimated 1400 anesthesiologists are currently practicing in Romania, and approximately 180 trainees are entering the specialty each year. Trainees are distributed to 12 academic centers in the country, although most trainees are taught in the five largest academic centers. The majority of anesthesiologists work in public hospitals though a small number work in private centers and some in both.

Safety in AICM is promoted by the RSAIC, which signed the Helsinki Declaration on Patient Safety in Anaesthesiology, endorsed the WHO checklists, the ESA clinical guidelines, and launched national guidelines. Despite this attention to patient safety, the European Surgical Outcomes Study (EuSOS), which included 17 hospitals and 1298 patients from Romania, demonstrated a higher postoperative mortality (6.8%) after nonemergent general surgery in Romania than the European mean value (4%).[193] Subsequently, a national program for critical care was implemented, and the more recent International Surgical Outcomes Study (ISOS), which included 1875 patients from 26 Romanian hospitals, demonstrated improved outcomes.[194]

The anesthesia community in Romania faces several challenges. A key challenge limiting anesthesia access in Romania is the shortage of providers (anesthesiologists and trained AICM nurses) as well as equipment technicians. Reasons for these shortages include internal and external brain drain (mostly to Western Europe).[195] Workforce shortages particularly affect ICU activities as well as operating theaters where a provider may be assigned multiple rooms simultaneously. Another barrier to scaling the workforce is the lack of a nationally standardized AICM nurse curriculum and training. Additional challenges routinely encountered in Romania include the uneven distribution of specialists and equipment as well as significant infrastructure limitations and drug shortages. For example, ultrasound and certain essential medications (e.g., tranexamic acid, amiodarone) are not universally available. Although the practice of AICM includes perioperative care, there are no formal anesthesia preoperative evaluation or pain therapy centers organized in the public hospitals in Romania. A final and significant challenge facing anesthesia providers is the unavailability of adequate malpractice coverage options which has resulted in defensive medical practices.

Despite the current challenges, the AICM is one of the most dynamic specialties in Romania, with a tremendous development led by dedicated RSAIC leadership.

ASIA AND THE MIDDLE EAST

Asia is the largest continent with a population of 4.43 billion. There is a wide socioeconomic variation among the countries with the GDP PPP (at purchasing power parity) per capita income ranging from 1944 International dollars for Afghanistan to 127,480 for countries like Qatar.[76] Anesthesia services also vary widely. Anesthetic societies are functional in the majority of the countries and a number of societies located in the same geographic regions have voluntarily come together to form regional societies. The officially recognized regional sections of the WFSA in Asia are the Pan Arab Federation of Societies of Anesthesia, Intensive Care and Pain Management (PAFSA) founded in 1884, Confederation of ASEAN Societies of Anaesthesiologists (CASA) as part of the Asian Australasian Regional Section founded in the 1970s, and the South Asian Association of Regional Co-operation—Association of Anaesthesiologists, which came into existence in 1991.

India (Bala Krishnan Kanni)

The first administration of ether anesthesia in India was on March 22, 1847, and the first chloroform anesthesia was administered on January 12, 1848. Chloroform and ether continued to be used until the mid-1950s in many hospitals. Halothane was introduced in 1960 and isoflurane in 1992.[196] Regional anesthesia (with cocaine) was first reported in 1894 and spinal anesthesia with hyperbaric Stovaine (amylocaine) was reported in 1908. In 1935, the first Boyle's apparatus machine arrived in India, and the same year the first oxygen plants were established in Calcutta (Kolkata). The Indian Society of Anesthesia (ISA) was established in 1947. The first official Journal of the ISA was published in July 1953, and in 1956 the ISA joined the WFSA as a founding member.

Formal anesthesia training for undergraduates in India officially started in 1906, followed by diploma (1946) and MD/MS degree programs (1955) in anesthesia. The National Academy of Medical Sciences started Diplomate of National Board of Examinations in 1970 followed by PhD programs in anesthesia. Today, all anesthesiologists in India are required to undergo one of three training pathways prior to independent practice. These pathways take place after completing 4 years of medical school (Bachelor of Medicine, Bachelor of Surgery–MBBS) and 1 year as an intern or "house surgeon." The first training pathway requires physicians to complete 3 years of postgraduate anesthesia training with a dissertation at a university hospital. The second potential pathway is called the Diplomate of the National Board (DNB) and requires 3 years of training as well as a dissertation at a hospital approved by the National Board of Examinations. Physicians can also pursue a 2-year postgraduate diploma program at a university hospital without dissertation. Holders of this latter postgraduate Diploma in Anesthesia often practice with supervision of more senior anesthesiologists. There are no nurse anesthetists in India, and the total number of anesthesiologists in the country (population 1.34 billion) is approximately 25,000 (see Table 2.3).

There have been several attempts to train non-anesthesiologists as stop-gaps for the ongoing workforce crisis. In 2002 the Indian government started a short-term training program for doctors but this could not be sustained due to problems in implementation and lack of support from the government. One ongoing program provides 6 months of training to physicians post-medical school to carry out cesarean sections and lifesaving anesthetic skills for emergency obstetric care in rural facilities where no anesthesiologist exists.[197,198] This program is controversial and not universally supported. India also trains Operation Theatre Technologists (OTT) or Assistants who may undergo

a 3-year diploma or 6-month to 1-year training program straight from secondary school. These cadres have limited scopes of practice (e.g., can place IVs or administer medications) and must practice under direct supervision of anesthesiologists. Although the OTTs are not permitted by the ISA to perform tasks such as intubation or neuraxial anesthesia, there are significant concerns that such practice takes place in some centers.

In addition to shortages in number, the anesthesia workforce in India also suffers from inequitable distribution, with a disproportionate number of providers in urban areas. Because anesthesiologists in India are also responsible for many services outside of the operating theaters (e.g., preoperative preparation, postoperative care, and critical care), these services are also frequently unavailable.

The ISA is actively engaged in several activities to promote anesthesia safety throughout India. With initial financial assistance from WFSA, the ISA started a CME program for rural anesthetists to update knowledge and techniques. The ISA endorses the WFSA and WHO guidelines for minimum monitoring standards, the WHO Safe Surgery Checklist, as well as many other anesthesia safety practices (e.g., color coding of drugs, syringe labelling, machine checks, and appropriate records of anesthetic care). Significant efforts have also been made to educate the public about anesthesia and its safety by holding public education programs.[199]

Although safe anesthesia services are available in many institutions both public and private throughout India, access to modern equipment and facilities are not universal. Much like providers, anesthesia infrastructure is also concentrated in urban areas. Anesthesia subspecialties such as neuro, cardiac, pain, pediatrics, and obstetrics are available in most urban hospitals but few rural facilities.[200] As a result, many rural facilities lack capacity for safe anesthesia care. Additional challenges limiting access to safe anesthesia care in India include poverty, distance to care, social and cultural barriers, and comorbidity.

Lebanon and The Middle East (Patricia Yazbeck)

The oldest medical writings in the region were found in cuneiform tablets and Eber's papyrus in Mesopotamia and the Nile valley, describing herbal treatments like Belladonna, Cannabis, and Mandragora. Phoenicians also obtained artificial sleep by using calming herbs, opium poppy, and juniper leaves. In the Middle Ages, prominent Arab scholars (Avicenna, Al Razi, Ibn Al Quff, Al Baghdadi, and others) made important contributions to the field of medicine.

In 1835, the first Arab medical school in the Middle East was established by Dr. Clot in Kasr-Al-Aini Hospital, in Cairo. Graduates practiced in all the large cities of the region. In 1860, American, French, and British powers intervened in the region and with the inflow of missionaries, more medical schools and hospitals were established. In Lebanon, the Syrian Protestant College (American University of Beirut) was founded by American missionaries in 1886 while the French Medical School (St Joseph University) was founded by the French Jesuits in 1883. The first use of inhalational anesthesia occurred in 1865 by Dr. George Post, an American missionary surgeon who administered "kulfera" (chloroform) in the village of Abeih-Lebanon. Dr. Post is considered the pioneer of modern anesthesia in the Middle East (Fig. 2.17).[201]

At the end of WWI, the practice of anesthesia still depended on foreign surgeons, and on local and foreign nurses or technicians, administering ether or chloroform. But the beginning of oil production in the region contributed to economic improvement and led to the foundation of many faculties of medicine in Syria, Sudan, and Iraq. After 1950, Middle Eastern countries established fully independent anesthesia departments with their own structure, staff, residency training, research, and certification by international academic institutions. In addition, in the 1960s and 1970s, many countries founded their own national anesthesia societies and in 1985 a Pan Arab Society of Anesthesia, regional section of the WFSA, was founded.

Anesthesia departments in the Middle Eastern countries are staffed by highly qualified faculty certified either by the Arab Board or by foreign academic bodies, such as the American, French, or European Boards of Anesthesiology or by the RCoA.

A residency program of 4 years in a recognized center may be followed by 1 or 2 years of fellowship in pain management, critical care, obstetric anesthesia, cardiopulmonary anesthesia, or others as recognized by the national anesthesia societies, which also track CME.

Anesthesia is routinely administered by a qualified anesthesiologist. Trainee anesthesiologists or anesthesia nurses can administer anesthesia under the supervision of a qualified anesthesiologist. The density of physician anesthesia providers per 100,000 population is less than three in Morocco, Syria, and Iraq, and less than one in Yemen and Sudan while it ranges from six to more than 10 in countries like Egypt, Oman, Jordan, Lebanon, United Arab Emirates, and Kuwait.

The responsibilities of the anesthesiologist include preoperative assessment and preparation, premedication, as well as staffing PACUs and ICUs. Anesthesia is administered in the operating room, delivery suite, radiology department, and as ambulatory anesthesia. In addition, acute or chronic pain management is becoming routinely practiced. Departments and societies of anesthesiology in the Middle Eastern countries are responsible for setting practice guidelines, matching the standards approved by international societies, such as the American, French, or European Societies of Anesthesiologists. Anesthetic machines, monitoring equipment, and agents adhere to the international standards.

The major key challenges and barriers to safe anesthesia in the region are the consequence of the recent turmoil occurring in many Middle Eastern countries (e.g., Syria, Iraq, Libya, Sudan, and Palestine) resulting in limitations of workforce and anesthesia access and safety in parts of these countries.

Pakistan (Fauzia Khan)

From the time Pakistan gained independence (1947) until the late 1950s, the practice of anesthesia was mostly limited to spinal or open-drop ether after induction with ethyl chloride. The first chair of anesthesia was established at the King Edward Medical College, Lahore, in 1959, and a 2-year diploma course (DA) was introduced at the same institution in 1960. The first ICU in Pakistan was established in 1976 at Mayo Hospital, Lahore, and the Pakistan Society of Anesthesia (PSA) was founded in 1971 in Karachi. A higher

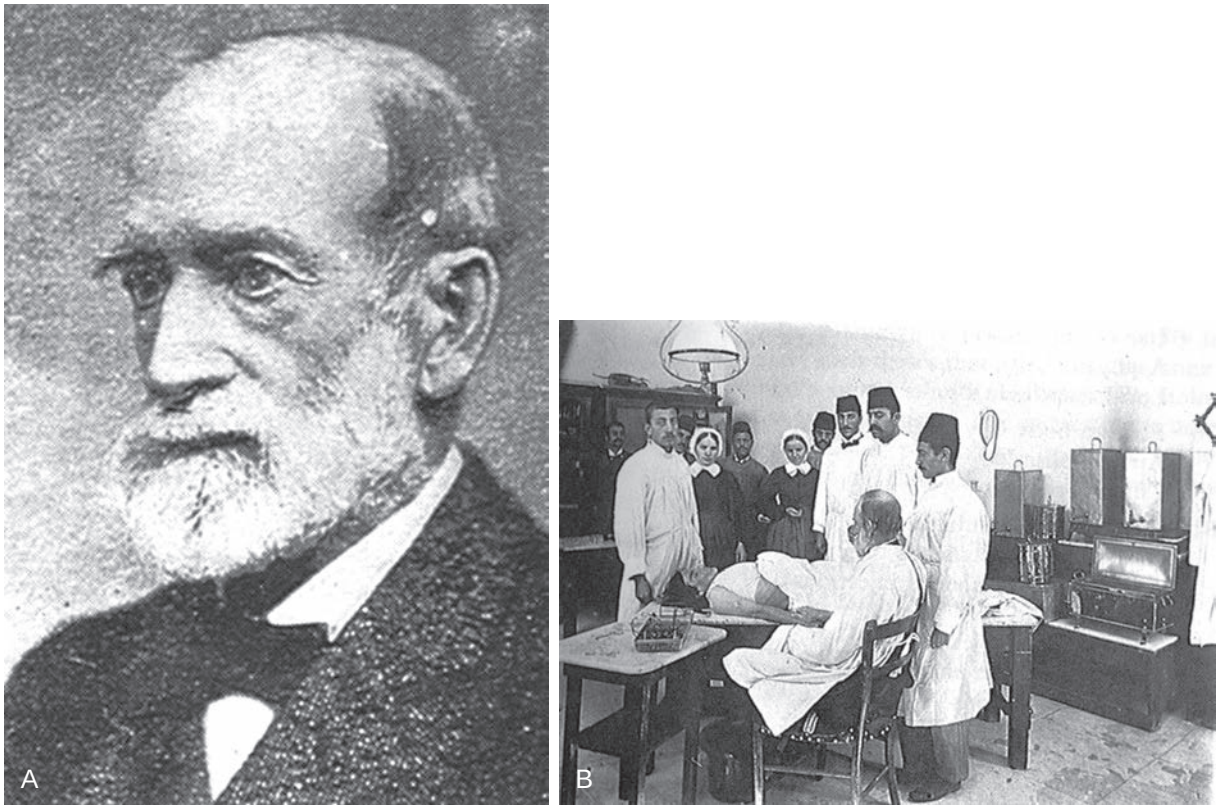

Fig. 2.17 Dr. George Post (A), in an operating room with a female patient on the table (B).

diploma, the Fellowship of the College of Physicians and Surgeons of Pakistan (FCPS), was instituted by the College of Physicians and Surgeons of Pakistan (CPSP) in 1972.

The CPSP includes anesthesia faculty and accredits all physician training programs in the country. Two training tracks are offered for anesthesia: (1) a higher professional diploma (FCPS) that requires 4 years of competency-based standardized training; and (2) a Membership of the College (MCPS) that requires 2 years of training after medical school and 1 year of internship. Only FCPS diploma holders can progress in the academic ladder in university anesthesia jobs. Certification in either track requires written, practical, and oral examinations. License to practice is provided by a separate body, the Pakistan Medical and Dental Council.

The anesthetic workforce in Pakistan is comprised of 3100 physician specialists (1.64 physician anesthetists per 100,000 population) (see Table 2.3). Anesthesia almost always is provided by physicians, although in some remote areas surgeons may administer local blocks or even spinal anesthesia. The main clinical responsibility for the majority of anesthesiologists is to provide operating room anesthesia and preoperative assessment, but in several institutions they also lead ICUs and chronic pain management clinics.

Health care in Pakistan is provided mainly by the private sector, with the government contributing only about 20% of services. Government-owned institutions are tiered into teaching, district, and county (taluka) hospitals. A system of basic health units provides primary health care. The majority of anesthesiologists hold two jobs as remuneration from just one is not sufficient. Only a few public institutions allow in-house private work by anesthesiologists. Brain drain is an ongoing issue with a significant proportion of the workforce emigrating to the Middle East or Europe.

There are currently no national guidelines relating to anesthesia and little awareness of international safety standards. There are also limited data on anesthesia outcomes in Pakistan.[202] There is no national body responsible for quality and safety in health care, however, the Punjab Healthcare Commission (PHC) is an autonomous health regulatory body created by the provincial government for the Punjab province (96 million people). The PHC aims to improve quality, safety, and efficiency of healthcare service delivery for the population of Punjab by implementing Minimum Service Delivery Standards (MSDS) in all areas and all disciplines including anesthesia. This model is soon to be replicated in the other provinces.

Anesthesia care varies significantly among health facilities within the country. Larger hospitals in bigger cities have access to modern equipment and monitors comparable to HICs. Many government teaching hospitals and secondary health centers are underfunded and have only basic equipment for monitoring (e.g., ECG and noninvasive blood pressure). Medication shortages are a frequent occurrence as several routine anesthetic medicines like fentanyl, inhalational agents, antiarrhythmics, and vasoactive drugs are imported. Even drugs manufactured within the country like morphine and ephedrine are frequently unavailable. Remifentanil, sufentanil, esmolol, S-ketamine, and clonidine are among many drugs not available at all due to licensing issues.

Additional challenges currently facing the Pakistani anesthesia community include maldistribution of human

resources, limited biomedical technician support, and lack of political will. There is great necessity for regional collaboration to collect data on anesthesia and surgical need, resources, and outcomes to help improve safety and better allocate resources.[203]

China (Yugaung Huang)

Modern anesthesia was introduced along with Western medicine into China in the early 20th century. In the 1950s, only simple anesthesia care was available in China, including open-drop ether, tracheal intubation under inhalational anesthesia, and single-shot procaine spinal anesthesia together with peripheral nerve blocks. Because of economic limitations from the 1950s to the 1980s, intravenous procaine combined with opioid anesthesia and even acupuncture anesthesia were common. Anesthesiology in China has evolved in the past 2 decades as a crucial medical specialty that is integral to multidisciplinary surgical care and collaboration. This has resulted in modern anesthesiology shifting from narrowly focused on surgical anesthesia to perioperative medicine.

The training of anesthesia practitioners remains a big challenge. Currently in China, medical school studies range from 5 to 8 years resulting in an inevitable variation in educational quality. The national resident training program was initiated in 2000 and standardized in 2014, which will make the specialty catch up with the international standards of training and help to eliminate disparities due to difference in initial medical education.

To ensure patient safety, it is emphasized that clinical anesthesia is provided by anesthesiologists rather than anesthesia nurses. To meet the rapidly increasing needs outside of the operating room, anesthesiologists are required in nonsurgical diagnostic and therapeutic procedures for endoscopy, painless labor, and delivering optimal care to improve the quality of patient care throughout the hospital. With the economic boom, the majority of Chinese hospitals are equipped with sophisticated anesthetic machines and monitors and have a modern work environment. However, there are obvious variations in the quantity and quality of anesthesia devices and services among the different regions of China. In some small or medium-sized hospitals, there are no anesthetic gas monitors, defibrillators, or target-controlled infusion pumps.[204]

With the support from the National Health Commission (NHC), Chinese anesthesiology has been shifting from only operating room anesthesia to perioperative medicine and moving from a volume-based healthcare system to a value-based healthcare system. Anesthesia safety and quality assurance are of vital significance and great concern. The National Quality Assurance Center for Anesthesia was established with Professor Yuguang Huang as its leader in 2011. Thus far 31 Provincial Quality Assurance Centers have been established throughout mainland China. There have been only sporadic studies so far providing data on anesthesia safety and these have come from several large hospitals, while the current status in resource-limited medical settings remains to be explored.[205,206]

The anesthesia workforce shortage has become one of the greatest challenges in China as the number of surgeries has grown and the anesthesia demand increased without a concomitant increase in the number of anesthesiologists. The density of physician anesthesia providers is only 5.12 per 100,000 population in China, which is approximately 25% of that in the United States. To meet the urgent healthcare needs, Chinese anesthesiologists are struggling with heavy workloads, and thus have high burnout and low job satisfaction.[207] Long working hours, heavy workload, high acuity, and fast work pace are all factors associated with burnout and patient safety. Even with this effort only 10% of pregnant women can receive epidural analgesia during labor, and patients undergoing endoscopy have to be on long waiting lists for analgesia and sedation since anesthesia practitioners are mainly occupied with surgery in the operating rooms. To bridge the workforce gap, the Chinese government has made great efforts to emphasize the importance of anesthesiologists and anesthesiology nationwide with supportive documents focused on improving the perceptions and roles of the anesthesia specialty in medical care not only for patients but also for anesthesia professionals. It is encouraging to see that an increasing number of medical graduates are willing to join the profession of anesthesiology, which prognosticates well for the future.

With great efforts by the Chinese Society of Anesthesiology and Chinese Association of Anesthesiologists, Chinese anesthesiology has developed rapidly to provide patients with safer anesthesia and better quality of life. Challenges include variation in anesthesia safety, shortage of workforce, occupational burnout, and unbalanced working conditions across the country. Further efforts are anticipated to make anesthesia practice even better in China.

Vietnam (Thi Thanh Nguyen and Thang Cong Quyet)

The modern history of anesthesia in Vietnam dates as far back as 1975 only due to the loss of records during the war. During the war, anesthesia was usually administered by surgeons, and only occasionally by an anesthesiologist who had mainly been trained by French or American specialists. During the war, U.S. military anesthesiologists made multiple seminal discoveries that changed modern transfusion practices.[208,209] Following the war, Vietnamese doctors gradually took up anesthesia and in 1979, the Vietnam Society of Anesthesiologists was founded in Hanoi with 100 members and Professor Ton Duc Lang as its first president. The membership continued to expand and currently there are more than 1000 anesthesiologists in Vietnam. In 1980, with the help of Dr. J. Beiboer from The Netherlands, the Vietnam Society of Anesthesiologists joined the WFSA, the CASA, and various other specialist societies throughout the region.

During the past decade, the role of physician anesthesiologists in Southeast Asia has changed remarkably. Physician anesthesiologists have gained recognition by peers and the populace. Training in anesthesia was initially undertaken by surgeons concurrently with surgical training. In 1993 the first department of anesthesia was established at Hanoi Medical University. Other departments were soon established in Ho Chi Minh City, Hue, Can Tho, Thai Nguyen, and Hai Phong. Several different forms of training varying in duration from 1 to 5 years were introduced in order to fulfill different requirements throughout the country, and contemporary anesthesia training is based on both the American and French systems.

Medical school is 6 years in duration, though during times of war a 4-year option has existed for trainees who have already completed a 2-year nursing program. After medical school, graduates can enter a 3-year residency in anesthesia (24 months clinical and 12 months research), for which there are 30 spots per year in the country. Residents do not receive remuneration during training unless they are bonded to a hospital where they worked as a general practitioner between medical school and residency. Upon completing residency, graduates are awarded a Master's degree and can work as a "first specialist" anesthesiologist. Thereafter they can pursue additional training in either an academic pathway (2-year PhD) or a "practical" pathway with "second specialist" training (2 years of apprenticeship and consultant work). The "second specialist" certificate allows these providers to function as a consultant, head of anesthesiology or as a trainer in the practical training system. An additional anesthesia training pathway exists for medical school graduates who are not admitted to residency. These physicians must pass a 1-year anesthesia training program, pursue 2 years of clinical anesthesia practice, and then return to a medical university to complete 2 more years of anesthesia training. At the conclusion of this pathway, these providers receive a "first specialist" anesthesiologist certificate, functionally equivalent to anesthesiologists who have completed the practical pathway previously discussed. There are approximately 100 training spots available per year in the country for this anesthesia training pathway. There are no formal, accredited subspecialty training programs in Vietnam, although several institutions offer 6-month to 1-year certification programs for select subspecialties. Additional training opportunities for Vietnamese anesthesiologists have been introduced in France and Southeast Asia. Numerous Vietnamese anesthesiologists have participated in the Bangkok Anesthesia Regional Training Center (BARTC), a 1-year fellowship supported by the WFSA and the Royal College of Anesthesiologists of Thailand to train anesthesia educators in Asia.[210]

In addition to the courses for physician anesthesiologists, several courses for nurse anesthetists were also introduced, which varied in duration from 1 year for registered nurses to 3 years for new nursing students. Nurse anesthetists are required to always work with a physician anesthesia provider or with permission from the manager of the hospital. Physician and nurse anesthetists are now able to staff over 1000 hospitals and clinics throughout the country where surgery is undertaken. In 2012, the Ministry of Health issued guidelines for anesthesiologists to become involved in pain management and critical care in addition to preoperative, intraoperative, and postoperative care. These specialties require additional training and formal anesthesia subspecialty fellowships do not exist in Vietnam.

Prior to 1990 the major techniques used were inhalational anesthesia, first with ether and subsequently with halothane. Induction was with thiopentone or ketamine and regional anesthesia with spinal or epidural. Since 1990 the responsibilities of anesthetists have expanded to include specialist areas such as extracorporeal circulation for open heart surgery, organ transplantation, ultrasound-guided regional anesthesia, chronic pain management, preoperative assessment clinics, and out of operating room activities such as epidural analgesia for patients in labor, and anesthesia for endoscopic procedures. The WHO Surgical Safety Checklist is commonly applied in every operating room and clinical practice guidelines are selected from ASA or ESA guidelines. There is still a maldistribution of anesthesiologists, a shortage of essential medications, and lack of necessary infrastructure, which can endanger patient safety.

The Vietnam Society of Anesthesiologists is striving to raise standards of education in anesthesia to be at par with international standards in order to enhance the safety of the practice in the country, encourage scientific research among members, establish professional guidelines, and support working with the Ministry of Health to advance the specialty of anesthesia. At present there are no national examinations for certification.

SOUTH AMERICA

South America is a vast continent with a population of 420 million and economies ranging from the eighth largest in the world (Brazil) to some of the poorest in the world (Bolivia).[210a] Some cities or areas of cities have HIC health care including hospitals with top-level research and Joint Commission certification (77 in 6 countries) whereas many others do not even comply with national standards.[211] This is a reflection of the social difficulties of the continent where most countries have poor Gini indexes (measure of distribution of income of a country's residents) ranking among the worst in the world.[212]

Anesthesia workforce density in South America varies by more than 10-fold among countries (Uruguay 13.7 vs. Peru 1.7).[100] Substantial differences exist in practice models, ranging from physician-only anesthesia practice in Colombia to Paraguay where 50% of anesthesia is provided by nonphysicians. This translates into dramatic differences in resources where some hospitals have anesthesia information systems and sophisticated monitoring equipment (e.g., intraoperative transesophageal echocardiography with tissue Doppler, electroencephalograph monitoring), while most still rely on paper records and limited anesthesia machines. Training quality and capacity are also highly variable and few homogenizing mechanisms exist to guarantee a minimal standard of training, as certification mechanisms are virtually absent.

Paraguay (Rodrigo Sosa Argana)

The first reports of anesthesia in Paraguay are of chloroform use during the war Paraguay fought against the Triple Alliance (Brazil, Uruguay, and Argentina) between 1864 and 1870.[213] The country's first recorded physician anesthesia provider was Dr. Roberto Olmedo in 1928, and the first trained anesthesiologist Dr. Luis Ramirez is credited with starting the specialty in Paraguay in 1948. After this time, the number of anesthesiologists who trained abroad began to increase.[214]

The Sociedad Paraguaya de Anestesiología (SPA) was founded in 1973 by the 18 anesthesiologists practicing in the country at the time. The first anesthesia training programs were started in 1982, and the first formal anesthesia residency program (3 years in duration) was created in 1992 by the Hospital de Clinicas of the Universidad Nacional de Asunción.

In addition to physician anesthesiologists, the Ministry of Public Health and Social Welfare also licenses two types of

nonphysician providers, technicians and diplomates. Technicians have no formal prerequisites and receive minimal if any formal training (most are taught as apprentices, historically most often by surgeons). Diplomates complete a 3-year anesthesia training program after high school that consists of once-weekly training days. These providers currently administer anesthesia in the most remote areas and public hospitals throughout the country, whereas physician anesthesiologists provide the majority of care in urban settings and the private sector. In the urban and private setting, the nonphysician cadres often work alongside physician anesthesiologists in a supportive role and with close supervision. The Ministry of Public Health has defined a scope of practice for nonphysicians in Paraguay such that they can perform anesthesia independently in remote locations where no anesthesiologists are present. In such circumstances, the nonphysicians are supervised by the surgeon and generally perform cases of lower complexity, most often under spinal anesthesia. There has been significant tension between all anesthesia cadres in the country. The technicians and diplomates consider their training and expertise as equivalent despite significant differences in prerequisites, training, and practice (see Table 2.3). In recent decades the number of physician anesthesiologists has increased relative to the number of nonphysician providers. There are approximately 258 anesthesiologists and 491 nonphysician providers (technicians and diplomates) in Paraguay (10.7 anesthesia providers per 100,000 people).

A major challenge in Paraguay at present is ensuring standards for anesthesia provider training. The SPA has lobbied the government extensively to curb nonphysician training in Paraguay due to ongoing concerns about the quality of training standards. In the last decade the SPA has been successful in enacting high-level education reform to improve anesthesia practice standards and has organized multiple international meetings including a recent large Latin American Anesthesia conference (CLASA 2013).

Colombia (Pedro Ibarra)

The first documented anesthetic in Colombia was provided in 1849 using chloroform.[215] In these early times, underperforming medical students were often relegated to providing anesthesia, and for many years anesthesia services were provided by poorly trained, and often nonmedical, personnel (e.g., technicians, healthcare students, and nurses). Dr. Isaac Rodriguez was the first Colombian physician dedicated to anesthesia, and the first formally trained anesthesiologist was Dr. Juan Jose Salamanca who trained under Dr. Henry Beecher at Massachusetts General Hospital in 1940. The Sociedad Colombiana de Anestesiologia y Reanimacion (SCARE) was founded in 1949 and was one of the founding societies of the WFSA in 1955. The first formal anesthesia training programs in Colombia were established in the 1960s, at Universidad Nacional and Universidad de Antioquia (UdeA). The Universidad Nacional program had input from Dr. Gustavo Delgado, who trained with several pioneers in anesthesia including Dr. Robert Dripps (see Fig. 2.16). The UdeA program was developed by Dr. Nacianceno Valencia, a second-generation "aqualumni" trained by Dr. Perry Volpitto (see Fig. 2.16).[216,217]

The first anesthesia residency programs (2 years in duration) began to increase the number of anesthesiologists in the 1960s, but the large magnitude of the workforce shortage forced several medical schools to introduce strong anesthesia training during medical school. This allowed medical school graduates to provide basic anesthesia care during their mandatory rural service year after graduation. They gradually reduced nonphysician anesthesia care in the 1970s in small towns. Many of these physicians remained in remote towns providing anesthesia care, until 1991 when the first law prohibiting anesthesia practice without a diploma was issued. Since the late 1990s, anesthesia care in Colombia has been exclusively provided by physician anesthesiologists.

Most of the 23 anesthesia residency programs are 3 years in duration (two programs are 4 years in duration) and are overseen by the Ministry of Education, which establishes curricular requirements based on input from the SCARE and the periodic Anesthesia Education Seminars that have been held since 1974. There is no national examination, and license for practice is issued by the Ministry of Health.

Currently there are approximately 3600 anesthesiologists in Colombia for a density of 7.9 anesthesiologists per 100,000 people. Approximately 115 anesthesiology trainees graduate each year, and a nearly matching number of foreigners or foreign-trained Colombians are incorporated into the workforce. In recent years, political and economic uncertainties in Venezuela have increased the influx of foreign-trained anesthesiologists into Colombia. In some cases, this increased supply has driven down remuneration and created tension with locally-trained anesthesiologists.

Rural anesthesia staffing is a significant challenge in Colombia. The needs of remote areas are often met through economic incentives and temporary positions. Rural hospitals pay premium salaries for positions that are difficult to fill and are able to do so because nearly 100% of Colombian citizens have healthcare coverage through the government-funded, multi-institutional insurance scheme. This single-payer approach allows rural hospitals to receive reimbursement comparable to institutions with higher-income, urban patient mixes. Because competition for anesthesia jobs is less in rural than urban settings, some rural hospitals are able to put together competitive compensation packages and recruit more easily than some public institutions in urban settings where reimbursement is lower and competition for jobs is higher.

The first Colombian anesthesia standards were published in 1985, and in 1992 a modern version based on the ASA Standards was published by SCARE and adopted by the Colombian government. The WHO Surgical Safety Checklist was adopted in 2008 and has contributed to the decreasing incidence of malpractice cases involving anesthesiology. Malpractice suits are a significant challenge in Colombia as well as a driver for improved safety. In 1993, SCARE created an anesthesia malpractice defense fund, FEPASDE, which became the major malpractice insurer for the country. To maintain the economic health of the fund, SCARE has adopted national healthcare education strategies for adverse outcome prevention.

Colombia's healthcare system faces several additional challenges. One is economic sustainability, due to healthcare benefits in excess of national resources. A second is regional inequity, where healthcare quality differs dramatically between regions. An additional major challenge

is the ongoing workforce shortage. One driver of the health worker shortage is the present training system, which requires residents to pay tuition during specialist training. There is an effort in the Congress of Colombia to eliminate this practice. As with many other LMICs, remuneration is a major challenge for anesthesia providers in Colombia who frequently work more than one full-time position to increase salary. This has expanded anesthesia coverage but also increased the risk of provider burnout.

OCEANIA

There are 16 independent nations in the region of Oceania. This area of the South Western Pacific accounts for approximately 30% of the world's surface area but has less than 40 million people with over 70% of people living in Australia and New Zealand. Of the independent island nations, Papua New Guinea is the most populous with over 8 million people and Tuvalu the least populous with approximately 11,000 people. The region consists of many remote islands and is economically diverse with only Australia and New Zealand being considered as HICs. Australia and New Zealand will be considered together and the independent island nations of Fiji, Solomon Islands, Vanuatu, Tonga, Papua New Guinea, Marshall Islands, Micronesia, Nauru, Samoa, Tuvalu, Palau, and Kiribati will be considered as one group.

Australia and New Zealand (Rob McDougall)

News of the first use of ether for anesthesia reached Australia by sailing ship in May 1847 and soon after, ether was used for a dental procedure in Sydney and general surgery in Launceston.[218] Later that year saw the first use of anesthesia in New Zealand, again following news by ship.[219] In 1888 "chloroformists" were first appointed in Australian hospitals but it was not until 1944 that the first university diploma course in anesthesia was established.[220] The Australian Society of Anaesthetists was established in 1934 and the New Zealand Society of Anaesthetists (NZSA) followed in 1948.

Anesthesia in Australia and New Zealand is provided by physicians. Training, examination, and accreditation of Australian and New Zealand anesthesiologists is the responsibility of the Australian and New Zealand College of Anaesthetists (ANZCA), which was founded in 1992. Prior to this time, specialist training was administered by the Faculty of Anaesthetists of the Royal Australasian College of Surgeons, which was formed in 1952. ANZCA established the Faculty of Pain Medicine in 1998 and pain medicine was recognized as a medical specialty in Australia in 2005. In addition, ANZCA is responsible for the standards of clinical practice of anesthesia and pain medicine in Australia and New Zealand.

Australia and New Zealand have among the highest density of anesthesia providers, in population terms, in the world with 23.09 and 21.79 anesthesia providers per 100,000 population, respectively.[100] A minimum of 7 years of postgraduate training is required to become a specialist anesthesiologist.

Specialist anesthetists account for almost the entire anesthesia workforce in New Zealand, however, Australia has an active body of over 250 GP anesthetists, who predominantly work in regional and remote areas which cannot sustain full-time specialist anesthetists.[221] The training and accreditation of GP anesthetists is overseen by ANZCA and the Royal Australian College of General Practitioners. The provision of high-quality anesthesia in remote areas of Australia continues to be a challenge.

In 2014, the average age of the Australian anesthesiologist workforce was 49 years and 27% of the workforce was female. Australia and New Zealand have publicly funded universal health care but both countries have a private health sector. Just over 50% of work by Australian anesthesiologists was in the public sector.

ANZCA has produced triennial reports on anesthesia-related mortality in Australia and New Zealand since the first comprehensive report for 1985–87. For 2012–14 the anesthesia-related mortality for Australia was 2.96 deaths per million population per annum or 1 death for 57,023 episodes of anesthesia care.[222] In addition, New Zealand is one of the few countries to comprehensively collect and report 30-day POMR. POMR is one of the core indicators recommended by the LCOGS for monitoring safe surgery and anesthesia. Thirty-day POMR in New Zealand for 2010–15 was 0.55% of hospital admissions receiving general anesthesia.[223]

In spite of its huge size, Australia is one of the world's most urbanized countries. This aids centralization of health care but does create equity of access challenges for those living in remote areas. This is a particular problem for indigenous Australians who account for almost half the population of very remote areas.

Australian and New Zealand anesthesiologists are involved in global health activities, particularly in the Asia Pacific region. Both the Australian Society of Anaesthetists and NZSA are active members of the WFSA and also have their own global outreach committees. ANZCA also has a strong Overseas Aid Committee. The Overseas Development and Education Committee of the Australian Society of Anaesthetists has long supported the development of anesthesia in the Pacific, in partnership with the Pacific Society of Anesthetists and the Fiji National University (FNU). ANZCA has similarly supported Papua New Guinea in partnership with the Society of Anesthetists of Papua New Guinea and the University of Papua New Guinea (UPNG). Similar partnerships exist between professional organizations in such countries as Mongolia, Myanmar, Timor-Leste, Micronesia, Solomon Islands, Laos, Cambodia, and other Pacific Island nations. Essential Pain Management, Primary Trauma Care, and Lifebox are examples of programs coordinated by Australian and New Zealand professional bodies in the Asia Pacific region.

Fiji and Pacific Island Nations (Sereima Bale)

The remote geographic locations of the myriad of small and large islands that comprise the Pacific Island nations and their diverse populations make the training and the practice of anesthesia a massive challenge.

In Fiji, Papua New Guinea, and Pacific Island countries, Assistant Medical Practitioners or Anaesthetic Technical Officers were trained as apprentices by expatriate consultant anesthetists during the various colonial eras before each country gained independence. Anesthesia became a recognized specialist discipline in 1970 in Fiji even though doctors (registered as "Native Medical Practitioner") had been practicing as "anesthetists" since the 1920s.

In the early 1970s, many Pacific Island nations (Fiji, Tonga, Kiribati, Niue) sent their doctors for training in the DA program offered by the Anesthesiology Center for the Western Pacific (Manila, Philippines) in collaboration with the WHO Western Pacific Regional Office. Currently the two specialist training institutions in this region are the College of Medicine, Nursing and Health Sciences of the Fiji National University (FNU), which started anesthesia training in 1996, and the University of Papua New Guinea (UPNG), which established anesthesia training in 1989 as the Fiji School of Medicine. These programs offer physicians a 1-year DA, that may be followed by a 3-year anesthesia Master's of Medicine (MMed) as the specialist qualification. Since 1996, FNU has graduated 92 doctors with the DA, and 39 of these have gone on to receive the MMed. There have been 32 anesthesia specialists that have graduated—23 from Fiji and 16 from other Pacific nations.

FNU trains only physicians while UPNG also offers a 1-year diploma course for healthcare workers who train as Anaesthesia Scientific Officers (ASOs). These NPAPs provide 90% of anesthesia services in Papua New Guinea, often in remote provincial and mission hospitals with no physician supervision. Other Pacific Islands that utilize this latter cadre of NPAPs to complement their physician capacity are Vanuatu, Tonga, and Solomon Islands. Other islands in the northern Pacific, including former U.S. territories, employ American-trained nurse anesthetists.[224]

Two issues significantly limit the development of the anesthesia workforce in the Pacific: (1) few students graduate from medical schools in Fiji and Papua New Guinea to supply any specialties and keep pace with growing populations; and (2) few job opportunities are funded by national Ministries of Health. In Fiji for example, there are 23 physician specialist anesthesiologists for a population of 800,000, but only 5 consultant positions supported by the Ministry of Health, which employs all Fijian FNU graduates. Additional challenges routinely faced in the region include limited access to equipment, geographic isolation, and an influx of medical graduates from other regions who may be ill-prepared for postgraduate training or practice in this setting.

In 2018, Fiji (population 800,000) had 18 specialists. Unless there is significant expansion of job opportunities for specialist anesthesiologists, limited access to specialist-level care is likely to continue regardless of numbers of graduates. There is continuing brain drain among graduate specialists in Fiji. Of the 23 MMed graduates, only 17 remain in government employment with minimal opportunities for private practice. Some of these graduates, however, remain in practice in the Pacific, just not in their country of origin.

Other Pacific Islands are continuing to build their capacity and are retaining their graduates: Kiribati (2 MMeds, 1 DA: population 33,000); Solomon Islands (4 MMeds; population 600,000). The volume and range of cases in the smaller island nations pose different challenges. The solo anesthetist who may provide anesthesia for 1 to 2 surgical lists per week may also be required to cover other clinical or administrative services as necessary. In addition, this officer is also expected to cover for emergencies and is permanently on call. Outdated skills and knowledge can develop as can burnout as a result of professional isolation and lack of support.

Papua New Guinea is a LMIC on the eastern half of the island of New Guinea (the second largest island in the world) and has only 19 physician specialist anesthesiologists and 130 ASOs, of which only 50% are currently employed. The challenges of the provision of safe surgery and anesthesia in Papua New Guinea relate to its terrain and poverty. Eighty percent of the population live in remote highland, coastal, and island villages and may be days away from a hospital that can provide the three bellwether procedures. Currently Papua New Guinea has 0.25 PAPs per 100,000 compared with Australia and New Zealand where the anesthesia workforce is 75 times greater.[224]

There are three main anesthesia societies in the western Pacific outside of Australia and New Zealand: The Pacific Society of Anaesthetists (28 members); the Micronesia Society of Anesthetists (7 members); and the Society of Anaesthetists of Papua New Guinea (16 members). All Pacific societies have received varying support from the Australian and New Zealand governments, the ASA, the NZSA, ANZCA, and the WFSA, and hosted joint meetings for the first time in 2014.

Section 3: Essentials for Practice in Resource-Constrained Settings

CLINICAL AND TECHNICAL SKILLS

The practice of anesthesia anywhere in the world is reliant on four principle factors: personnel, equipment, medications, and patients with their comorbidities. Disruption, change, or lack of any of these factors may limit the safe practice of anesthesia. Whether practicing in a rural HIC setting, an LMIC, a military or humanitarian field hospital, or other resource-constrained setting, all of these will be modified. Data guiding practice in these settings are limited and may be interpreted differently. There are numerous instances of well-intentioned, evidence-based practices from HICs producing unintended negative consequences in LMICs.[225]

Clinical practice in resource-constrained settings may be extremely different from what one may be accustomed to, so it is important to understand the local context before attempting to change anything. There is often a logical reason why practice patterns diverge from the "standard," and frequently this has less to do with local providers "not knowing the right way" and more to do with local challenges related to personnel, equipment, medications, or patients. This section will briefly discuss select aspects of anesthesia practice in resource-constrained settings through the lens of these four factors.

Personnel. Limitations in anesthesia workforce are one of the most significant barriers to the safe provision of anesthesia care worldwide. Beyond low absolute numbers of providers, the competencies of existing anesthetic providers may be highly variable. Many practitioners who provide anesthesia in resource-constrained settings may have completed inadequate training and often work in isolation with negligible supervision or colleague support. Many are highly skilled and competent within a narrow spectrum of clinical cases, and often learn to deliver a "recipe" type anesthetic that may not be adaptable or appropriate for more complex cases.

When working in resource-constrained environments, it is important to understand the level of knowledge and

experience of the local anesthetic provider. Regardless of training level, there are always opportunities for mutually beneficial bidirectional learning. The role of the anesthetic provider in many resource-constrained settings is often limited to the operating theater, as the concept of perioperative care is underdeveloped and not part of training. Personnel shortages routinely limit capacity for adequate preoperative evaluation (including resuscitation) or routine postoperative monitoring. Staffing (e.g., perioperative nursing) may be entirely lacking, and routine elements of postoperative care such as monitoring or providing regular pain assessments with analgesic administration are rarely available. Thoughtful planning is required especially if higher-level care is needed postoperatively (e.g., ventilation), as this usually will become the responsibility of the anesthesia provider or even family members (who are frequently recruited to help with monitoring or even manual ventilation). The PACU may consist of an unstaffed corridor or a small designated space near the operating room complex exit. In this setting, it is paramount to ensure patients are more fully recovered from their anesthetic when they arrive in the recovery area than may be routine in well-resourced PACUs.

Equipment. Anesthesia Machines: Most modern anesthetic workstations cannot function without pressurized gases and electricity, both of which may be in short supply in many resource-constrained environments. In these settings, familiarity with drawover anesthesia may be essential. In-depth discussion of drawover anesthesia is beyond the scope of this chapter, however, knowledge of drawover anesthesia is highly relevant in many practice settings, and several comprehensive resources for learning drawover are included at the end of this chapter. Here we provide a brief overview of the basics of drawover anesthesia.

An inhalational anesthesia system must be able to deliver accurate concentrations of volatile agent, avoid rebreathing of carbon dioxide, have a provision for intermittent positive-pressure ventilation (IPPV), and provide oxygen-enriched gases. Unlike more complex anesthesia machines, drawover systems do not require compressed gas or power, can function on room air, and cannot deliver hypoxic gas mixtures (which is especially relevant where inspired oxygen monitors may be lacking). A drawover system consists of a temperature-compensated or buffered, low-resistance vaporizer (calibrated to the agent), a self-inflating bag or bellows with a one-way valve upstream to ensure unidirectional gas flow to the patient, and a non-rebreather valve at the patient end to avoid rebreathing of carbon dioxide (Fig. 2.18). Drawover setups that can function with multiple volatile agents are most versatile (i.e., in the event that one volatile agent is unavailable), and providers should be familiar with technical aspects of using the same vaporizer for different volatile agents. The self-inflating bellows (SIB) can be used for IPPV (by hand) and may show movement or a small palpable pressure change with respiration that enables the anesthesia provider to monitor respiratory rate in the spontaneous mode. Air is the "driving" gas (although "sucking" gas might be a more accurate description) in a drawover system, but oxygen supplementation is possible with addition of oxygen at the vaporizer inlet or with the addition of a piece of reservoir tubing or bag. The ability to function on ambient air is a critical safety feature of all drawover setups. Without some form of reservoir, it is impossible to achieve a fraction of inspired oxygen concentration (FiO2) above 0.3 regardless of oxygen flow. With just one meter of standard adult reservoir tubing (22 mm diameter), 4 L per minute can give an FiO_2 of over 0.6 and a flow of 1 L per minute gives an FiO_2 of 0.3. The gas flow, which is dependent on the patient's tidal volume and respiratory rate, is highly variable, but most vaporizers (OMV, DDV, EMO) (see Fig. 2.18) remain extremely accurate as long as the gas flow is intermittent. However, they often lose their accuracy when the system is converted to a continuous flow mode.

Although the drawover system is low resistance, in some situations it may be advisable to convert it to a continuous flow system when anesthetizing babies to overcome the dead space at the level of the non-rebreather valve. This can be done manually by creating a flow using either an Oxford inflating bellows or self-inflating bag. The bellows are jerked up to their full capacity and then released slowly. This is done 6 times per minute to create a continuous flow through the vaporizer. This flow of oxygen-enriched air supplies an Ayre's T-piece attached to the outlet of the bellows. Both valves need to be in use to ensure unidirectional flow as this is still a low-pressure system (Fig. 2.19). If using a self-inflating bag then it must be squeezed and released 12 times per minute. This manual system mimics adult drawover with a more intermittent flow, and the vaporizers tend to still provide an accurate reading as opposed to full continuous flow using either a Farman's entrainer or direct attachment of an oxygen source to the inlet of a vaporizer. Whatever equipment you have at your disposal it is probably simpler to follow these approximate guidelines:

If <5 kg, assisted ventilation for whatever the length of the operation.
If 5-10 kg, spontaneous ventilation for short cases and assisted ventilation for longer procedures.
If >10 kg, spontaneous ventilation for most operations, unless paralysis is required or the procedure is prolonged.

There are a small number of all-in-one drawover anesthetic machines based on the same principles as the portable drawover systems (Fig. 2.20). They are not plenum machines, and supplemental oxygen can be supplied from a cylinder or an integrated oxygen concentrator. These machines are significantly less expensive and relatively easier to maintain than many other anesthesia machines. They can also function without power and without supplemental or pressurized oxygen, making them ideal for some resource-constrained settings. Integrated, uninterruptable power supplies (UPS) provide power for certain functions (e.g., monitors) in the event of power failure, and some versions include integrated ventilators. The companies that manufacture the Universal Anesthesia Machine (Gradian Health) and the Glostavent (Diamedica [UK] Ltd) both invest considerable resources to ensure local expertise for operation, training, and service support. These elements are critical for successful utilization of equipment in resource-constrained settings. Regardless of the anesthesia setup employed, a plan for power or oxygen failure is essential and likely to differ based on the setting.

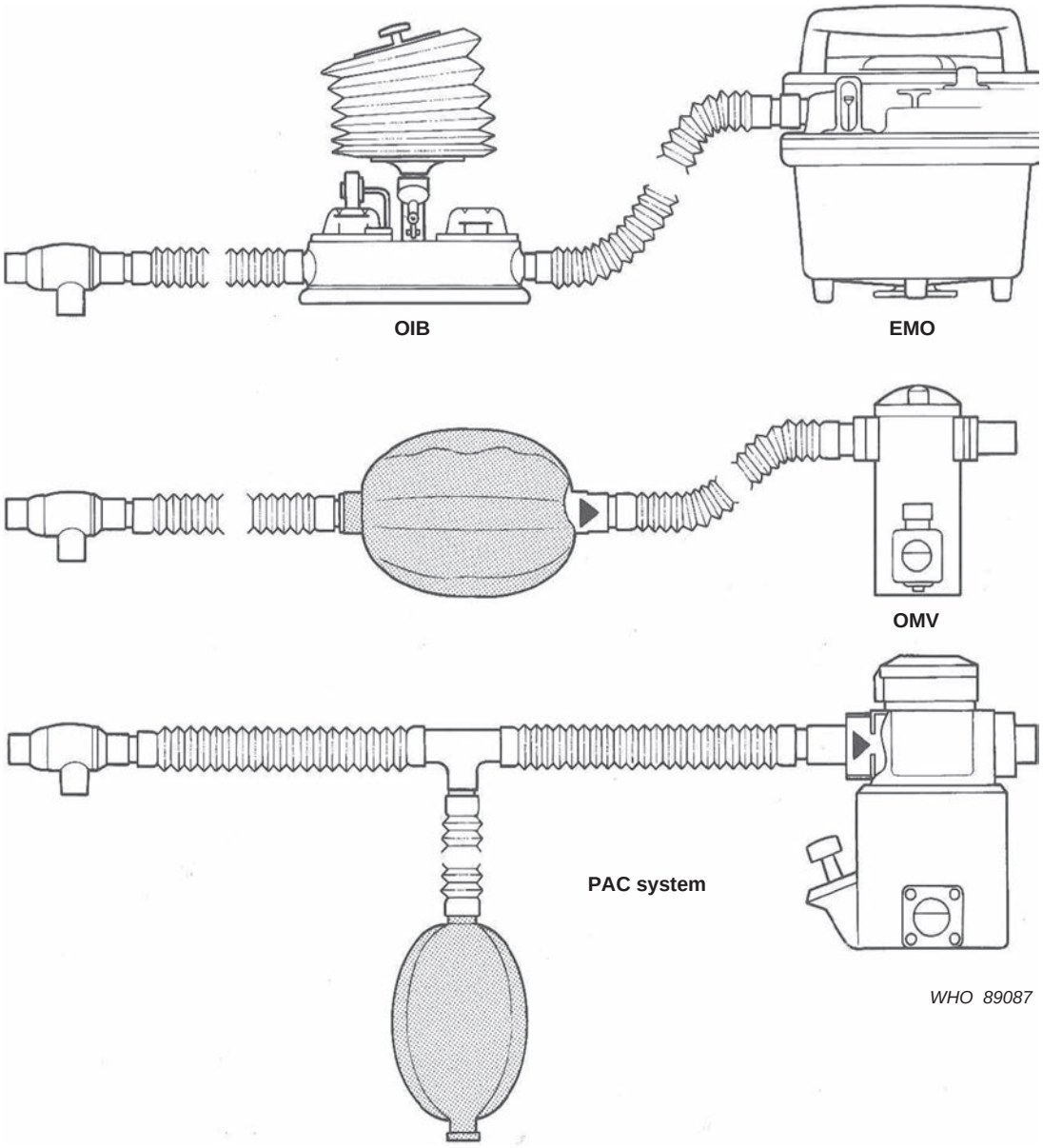

Fig. 2.18 Inhalational drawover anesthesia setups. (Reproduced with permission from the WHO. Dobson MB, World Health Organization. *Anaesthesia at the District Hospital*. 2nd ed. Geneva: World Health Organization. http://www.who.int/iris/handle/10665/42193.)

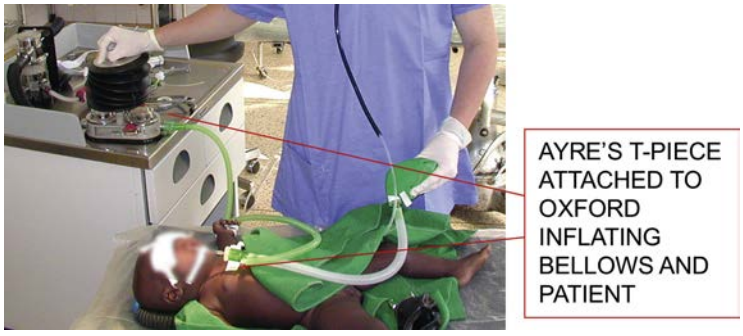

Fig. 2.19 Drawover anesthesia using an Oxford-inflating bellows and Ayre's T-piece with a pediatric patient in Uganda. (Copyright © 2018 Sarah Hodges.)

Fig. 2.20 All-in-one drawover anesthesia machines. *Left,* The Universal Anesthesia Machine by Gradian Health (including ventilator module). *Right,* The Glostavent Helix by Diamedica (UK) Ltd. (Copyright © 2018 Gradian Health and Diamedica [UK] Ltd.)

Oxygen Concentrators: In many countries pressurized oxygen is available primarily via cylinders, but the supply may be unreliable or cost prohibitive, and therefore a backup is essential. Providers working in resource-constrained settings should have familiarity with at least the basics of function and maintenance for various oxygen delivery solutions including concentrators. Oxygen concentrators use a technique called pressure swing adsorption and zeolite crystals to extract nitrogen from air to produce oxygen with 90% to 96% purity, although purity drops to around 85% with higher flow rates. In principle, most oxygen concentrators are relatively similar, and non-engineers can often diagnose and fix common problems (e.g., dirty filters, low voltage, compressor or valve system failure, excess flow, or hot ambient temperatures)[226] (see the Appendix 1 for links and useful resources including the WHO guide to oxygen concentrator maintenance). In reality, not all oxygen concentrators are designed to function in all climates, and many do not conform to WHO guidelines.[226,227] In a performance study of eight oxygen concentrators, only two models delivered greater than 82% inspired oxygen concentration at 35°C and 50% relative humidity.[228] Oxygen concentrators can be used to provide supplemental oxygen in the operating theater (via drawover system), the PACU, or the ward. Makeshift splitting of a single oxygen source to supply multiple patients on the ward is a common practice although it can easily result in inadequate inspired oxygen fractions. A small, portable oxygen analyzer can be useful to test the output of concentrators and cylinders as some facilities lack the infrastructure to ensure necessary quality control. Submerging the terminal end of parallel oxygen delivery circuits into cups of water can allow for comparison of gas flow rates.

Monitors: Many operating theaters around the world have minimal monitoring options despite the international standards set out by the WHO and WFSA.[3] In this environment there is increased reliance on clinical skills (e.g., change in palpable pulse volume, degree of chest expansion, pupil size, and change in compliance of bellows, self-inflating bag, or bag on Ayre's T-piece). Because electricity may be unreliable, ideally monitors should have a functional internal battery. Pulse oximetry is invaluable but not universally available. Some inexpensive pulse oximeters meet international quality standards, however, few are designed for harsh environments, and many are extremely inaccurate.[229] The Lifebox initiative is one of the first initiatives to help design and distribute pulse oximeters that meet the demands of LMICs (i.e., affordable, accurate, durable, with audible alarms and specially designed, reusable probes that work with neonates and adults).[230] Precordial stethoscopes are particularly useful and can be made from an ordinary stethoscope with an extension (e.g., suction tube or oxygen tubing). Precordial stethoscopes provide an excellent beat-to-beat heart rate monitor and continuous, audible verification of respiratory rate, airway patency, and endotracheal tube placement. Hypovolemia may be detectable by a decrease in heartbeat tone that is apparent prior to alarms on other monitors.

Airway Equipment: In resource-limited settings it is often absolutely essential to maintain spontaneous respiration and oxygenation with a difficult airway until the airway has been secured. Face mask ventilation with a Guedel or nasopharyngeal airway, regional anesthesia, or ketamine-based anesthetics may be safer than attempting complex airway management. An awake look with direct laryngoscopy can often assist in airway management planning. Safety is key and it may be preferable to opt for a tracheostomy under local anesthesia as the surgical skills may be superior to what is feasible with the limited anesthetic equipment and ability. As advanced airway equipment and experienced assistance is likely to be lacking, excellent technique and positioning for laryngoscopy is crucial for success. Many hospitals providing surgical care will have only a Macintosh size 3 laryngoscope blade, and rarely additional equipment such as a bougie. Retrograde intubation and blind nasal intubation can be useful skills to master. Airway topicalization can be accomplished many ways, including transtracheal lidocaine injection or by gargling or spraying water-based lubricant jelly, lidocaine, and epinephrine. For blind nasal intubation, the tube is pushed forward during inspiration following the base of the nose, listening to the noise of breathing (similar technique to a Patil guide). If the tube enters the esophagus the neck should be extended, and if it impinges on the anterior part of the larynx, the neck should be flexed. Lifting the jaw will stop the endotracheal tube from hitting the epiglottis. Rotating the tube or inflating the cuff slightly may also assist with entering the trachea. If capnography is not available then condensation in the tube, movement of the bag with respiration, auscultation of the chest, and in rare circumstances an esophageal bulb can help verify correct placement. In LMICs, laryngeal mask airways may not be available and face masks, Guedel or nasopharyngeal airways, and endotracheal tubes are often washed and reused. There are a number of products that can be used to easily decontaminate endotracheal tubes, laryngeal mask airways, and other airway equipment, however, access is highly variable. When processing and reusing such equipment, damage to the cuff and increasing stiffness of the plastic are significant challenges.

Endotracheal tube stylets are infrequently available. Improvised endotracheal tube introducers have been crafted

by carefully inserting a piece of wire into an appropriately sized suction catheter, taking care that the metal tip is not protruding. Learning safe, sensible techniques that are reproducible without the use of expensive, specialized equipment is fundamental. Where traditional electric suction is unavailable, bulb suction (for neonates) and foot pedal suction devices are invaluable.

Equipment for regional anesthesia: Spinal anesthesia is universally taught and used in many settings though may be used for a wider variety of cases than is commonly done in HICs (e.g., appendectomy). The needles vary in quality and blunt tips can be overcome by using a 21-gauge hypodermic needle as an introducer. The most commonly used local anesthetic is hyperbaric 0.5% bupivacaine. All anesthetic providers are taught to do spinals, but not all are taught how to prevent supine hypotension during spinal anesthesia. Teaching how to fabricate a simple wedge for uterine tilt with pregnant patients, or learning to reposition patients in varying degrees of reverse Trendelenberg position may prevent untoward incidents especially where an adjustable operating table may not exist. Although a spinal might seem like an easier and safer option, appropriate patient selection is critical, especially where preferred vasopressors and fluids may be in short supply. In that situation 0.5 mg epinephrine has been diluted in a 500 mL bottle of 5% dextrose and administered cautiously to treat the hypotension. Epidurals are rarely available in low-resource settings for several reasons: providers may not be proficient with the technique; needles are not commonly found; preservative-free local anesthetic drugs are not readily available for postoperative infusions; and more importantly, the staffing ratio may be inadequate and the knowledge may be insufficient to manage an infusion in the postoperative setting. In some settings where electronic drug infusion pumps are unavailable, low-cost elastomeric bulb pumps can be used to deliver a fixed rate of medication. Caudal blocks using a 22-G cannula are commonly used in children for postoperative pain management although the only safe preparation of local anesthetic may be the spinal bupivacaine.

Ultrasound or nerve stimulators are rarely available but many blocks can be performed using landmark or blind techniques (e.g., ankle, digital, axillary, penile, wrist, fascia iliaca, femoral, and rectus sheath blocks). Local field blocks may be used for a wide variety of procedures, including hernias, which are often done under local anesthesia in the outpatient setting. Where ultrasounds are available, other regional supplies may be lacking such as ultrasound gel, probe covers, echogenic needles, and appropriate local anesthetics. Several workarounds to these common challenges have been well-described. Although many blocks can be done relatively easily and safely without ultrasound or nerve stimulation, serious complications can still occur. Anecdotal reports of local anesthetic toxicity fatalities during penile blocks for circumcision are still encountered in some LICs and attributed to preventable causes (incorrect dosing or technique).[231] In general, distal blocks with lower volume and shorter-acting local anesthetics may be safer options, especially where safety equipment may be limited (e.g., intralipid).

Equipment for venous access: Intravenous cannulas are almost universally obtainable but variable quality may limit use. Needles may be blunt or extend quite a few millimeters beyond the tip of the cannula. Scalp veins are a common site for insertion in critically-ill infants, and with appropriate training, rapid placement of a cannula in the right internal jugular vein or in the peritoneal cavity can be lifesaving in a child dying from hypovolemic shock (e.g., cholera) as you look for a more permanent solution. Intraosseous needles are not easily found, but 18-G or 16-G needles can be used in the tibia of an infant. Butterfly needles, if available, are particularly useful because of the limited length. Twisting is essential to pierce the cortex until a sudden give when entering the medullary cavity. It is feasible to perform anesthesia for an entire operation with such access (Fig. 2.21).

Infusions pumps are often not available in LMICs and when present, are frequently limited by the availability of compatible disposables (i.e., appropriately sized syringes or proprietary tubing). It is important to not only be proficient with calculating infusion rates based on drop factor (drops per mL) but also be aware that infusion sets vary in size and quality, often making accurate calibration challenging.

Drugs. Volatile agents: Ether has now been removed from the WHO Essential Medicines List, and its use has reduced dramatically since 2013. Both isoflurane and halothane are included in the WHO Essential Medicines List, and due to the price differential (e.g., in Uganda 250 mL of halothane ~$21; 250 mL of isoflurane ~$39; 250 mL of sevoflurane ~$250), halothane is the most commonly used agent in many rural or non-teaching hospitals in LICs. Halothane is potent (MAC 0.8%) and sweet smelling, but the blood gas partition coefficient is 2.4 making the onset and offset of anesthesia slower than some agents. This can be useful if managing a difficult airway and intubation under halothane alone. Halothane is a cardio-depressant and arrhythmogenic especially in the presence of an elevated end-tidal carbon dioxide. It is useful for inhalational induction, but it is important to rapidly reduce the inspired concentration once intravenous access is

Fig. 2.21 Improvised intraosseous access catheter in a pediatric patient in Uganda. (Copyright © 2018 Sarah Hodges.)

secured. Nitrous oxide may be obtainable in some locations (primarily urban areas) but can be extremely expensive. Because medical-grade air (FiO_2 0.21) is often 4 to 5 times more expensive than oxygen, it is often unavailable and cases may be done on 100% inspired oxygen concentration.

Induction agents: The use of propofol is widespread but ketamine (in addition to volatile agents) remains the most ubiquitous induction agent in many LMICs. Thiopentone (thiopental) is also frequently encountered outside of HICs. Ketamine resembles an intravenous preparation of ether (sympathomimetic, does not depress airway reflexes, causes excessive salivation, and has excellent analgesic properties). S-ketamine is a useful adjunct for regional anesthesia. Ketamine can be used as an infusion (intravenous or subcutaneous injection) postoperatively for the management of pain especially if opioids are in short supply.[232] Ketamine can also be used for total intravenous anesthesia for a variety of procedures (e.g., laparotomies), but the wakeup can be very prolonged, and the patient may experience disturbing hallucinations as benzodiazepines are often not used (provider more likely to encounter diazepam than midazolam in resource-constrained settings). Ketamine is the "go-to" induction agent for any patient in hypovolemic or septic shock, but it can cause cardiac arrest in patients who are maximally sympathetically stimulated. Ketamine may be advised against as the sole anesthetic for pregnant patients undergoing non-obstetric procedures due to its potential oxytocic effects. Ketamine can also cause apnea in neonates, despite the appearance of the neonate moving in response to surgery. Special attention and caution must be emphasized in these patient populations. Because of ketamine's overall safety profile, the drug has been used as the basis for a 5-day course to teach mid-level non-anesthesia providers to administer emergency anesthesia in rural sub-Saharan Africa when no anesthesia provider is available. This program has generated significant controversy and highlights many of the challenges facing the provision of anesthesia in LMICs.[233,234]

Analgesics: Morphine is often the most readily available opioid, although for many LMICs it is frequently challenging to obtain. In some countries where palliative care is more developed (e.g., Uganda), the oral formulation is often available for postoperative analgesia. Pethidine (meperidine) is commonly encountered in LMICs and used routinely for perioperative analgesia. Of note, pethidine is not included in the WHO Essential Medicines List, and it is not recommended for routine acute postoperative pain because of its variable efficacy and side effects. Nonetheless, pethidine may be the only option for analgesia in some LMICs and general familiarity with its pharmacology could be highly useful in select settings (see Chapter 24). As discussed earlier in this chapter, opiophobia and access limitations significantly restrict the use of opiates. As a result, if available, opiates are rarely prescribed beyond 48 hours postoperatively in many resource-constrained settings. Many analgesics (e.g., ketamine, morphine, and pethidine) are frequently given by intramuscular injection, which may have benefits in terms of feasibility and safety, although supporting data are limited.[232] Patient-controlled analgesia is generally unavailable, but in some settings has been substituted by using a small subcutaneous cannula, often placed over the deltoid muscle, used solely for parenteral opiate analgesics. This avoids repeated intramuscular injections especially in children and can remain in place for 48 to 72 hours. Tramadol is pervasive, inexpensive, and often used for perioperative pain management in resource-limited settings. Use of tramadol requires an understanding of its limitations including side effects, abuse potential, and inferiority in many instances to opioid analgesia.

Paracetamol (acetaminophen) is widely available as tablets, suppositories, syrups, and as an intravenous preparation as are nonsteroidal antiinflammatory drugs. Parenteral preparations vary from country to country as does the potency depending on the country of manufacture. Diclofenac is commonly found and intramuscularly injected. One of the major challenges with prescribing analgesics is conveying the concept of multimodal analgesia. Although the full spectrum of analgesic modalities may not be available, multiple analgesic options, including regional anesthesia, are often feasible in low-resource settings.

Muscle relaxants: Suxamethonium (succinylcholine) is a universally available muscle relaxant and may be the safest paralytic to use if there are no means for mechanical ventilation or availability for reversal. It rarely causes malignant hyperpyrexia although it can induce masseter spasm especially in children with neurologic or muscular disorders. Both atracurium and suxamethonium lose potency with exposure to heat and maintaining cold storage is a significant challenge in many settings. For cases where surgeons prefer paralysis for closure (e.g., laparotomy), a small dose of suxamethonium can be administered at the end of the case to facilitate closure of the peritoneum and rectus, while hand ventilating the patient and allowing faster offset of the volatile agent. The availability of nondepolarizing neuromuscular blocking agents is highly variable, and providers should be prepared to use drugs they may not readily use in HICs.

Lack of access to transfusion services (as discussed in the section, Anesthesia and Global Health) is another commonly encountered problem that may require improvisation. Providers in resource-constrained settings may be tasked with ABO typing (e.g., EldonCard) and cross-matching and should be familiar with these techniques. Whole blood transfusion may be more common than component therapy, although there are several notable limitations (including potential loss of platelet and clotting factor activity with refrigeration). Absolute transfusion thresholds are lacking but can create significant dilemmas. For example, is it safe to perform a hernia with a hemoglobin of 9, 8, 7, or lower if no blood products are available? Direct donation from patients or relatives as well as mandatory exchange (i.e., someone must donate in order for units to be released from the blood bank) are variably practiced in LMICs. Other practices such as preoperative normovolemic hemodilution and makeshift intraoperative blood salvaging (e.g., by using a cup, gauze filter, anticoagulant, and a 60 mL syringe) have been reported, but as of yet there is no safe, effective substitute for transfusion services in many settings.[235,236]

Patients. Anesthesia providers in resource-constrained settings must be comfortable with a wide range of potential surgical patients, especially trauma, obstetric (e.g., postpartum hemorrhage), and pediatric patients. In many LMICs, more than 50% of the population is under the age of 18,

and most have fewer comorbidities and less polypharmacy than in HICs. On the other hand, patients often present late with advanced pathology. This may be due to a wide range of factors affecting access to care, including physical access to the health unit (unpassable roads in the rainy season, or insecurity on the roads), or they have been consulting the local healer or bone setter and have not seen any improvement, or they are financially destitute and all health care is financially and socially draining.

As relatives often provide most of the in-hospital care (e.g., cook the food, wash the bedding and clothes), an inpatient stay is extremely time consuming and no family will want their patient to be in hospital longer than necessary. Patients will mobilize more rapidly but may also be less compliant with postoperative instructions. Although patients may have lower incidence of chronic cardiac and respiratory comorbidities, many may be anemic, malnourished, or harboring low-grade malaria or helminth infections. If major surgery is being considered, existing maladies may need to be treated first and can prolong the inpatient stay. Multiple preoperative investigations may not be affordable or feasible and many decisions are made solely on clinical judgment.

Anesthesia providers practicing in LMICs must be familiar with perioperative optimization of commonly encountered conditions. Treatment for universally common conditions such as hypertension or diabetes may require context-specific approaches and insights (e.g., where and how to provide temperature-stable, noncounterfeit medications).

The practice of anesthesia in the resource-limited setting is shackled by many issues, and it can be challenging to attempt to administer a high level of care as advocated by many professional entities. Anesthesia safety is an essential component of care. Are there standards of care that are immutable across the globe? If a full term pregnant woman is admitted to hospital with a severe antepartum hemorrhage that requires an emergency cesarean section to save the mother and baby, what is the anesthetic of choice? Is it local anesthetic infiltration alone, intermittent aliquots of intravenous ketamine and oxygen via nasal cannula, rapid sequence induction with ketamine, suxamethonium, and halothane? Then add to that decision the reality that the anesthetic provider may be a nurse with 1 year of training in anesthesia, only 250 mL of compatible blood is available in the hospital, and there is no pediatrician to resuscitate the baby. What is the safest anesthetic technique? It is difficult to answer that question, but for anyone planning to work in an LMIC as an anesthetic provider it is indispensable to learn about the local resources, to listen to the local providers, to have the humility to not have all the answers, but above all to focus on the care and safety of the patient.

GLOBAL HEALTH COMPETENCIES

Although the number of global health opportunities for medical trainees has skyrocketed in recent years, most are short-term, elective-based rotations, and relatively few programs offer structured training in global health competencies.[237]

Although many anesthesia providers may not be directly involved with formal global health initiatives or careers that focus on underserved populations, there are fundamental global health competencies that are relevant to all anesthesia providers (whether in high, middle, or LICs). A broad understanding of key concepts is universally relevant and should be incorporated into anesthesia training for all providers. These include access and affordability, local and global disease burden, structural and social determinants of health, medical ethics, health equity, and social justice. The Consortium of Universities for Global Health (CUGH) has identified 11 competency domains, with four levels of competency per domain (ranging from level I for all providers with any relation to global health, to level IV for providers planning to have significant lifelong engagement in global health) (Box 2.5).[238]

For anesthesia providers who intend to spend a portion of their career focused on global health, additional training should be considered in topics such as: epidemiology, statistics, qualitative research, health policy, health systems, health economics, medical anthropology, demography, ethics, and implementation and management sciences, among others.

Providers from relatively well-resourced settings benefit from preparation before working in resource-constrained settings, even if only for short-term visits.[239] Several nonclinical challenges and pitfalls are routinely encountered in resource-constrained settings, including failure to provide context-appropriate interventions (see discussion on equipment donations in the section on infrastructure challenges), failure to have a follow-up plan, failure to adequately engage local stakeholders, overemphasizing short-term solutions, and draining local resources.[240,241] Certain ethical challenges are also commonly encountered and often relate to the appropriate scope of practice, the equitable distribution of local and external resources, and an inadequate understanding of local social and cultural norms.

In a survey of surgery and anesthesia trainees at a large Ugandan university with numerous visiting international collaborators, most trainees (75%) agreed that visiting groups improve their training. However, 40% of trainees reported that international groups had a neutral or negative impact on patient care. Only 15% felt that research

BOX 2.5 CUGH Global Health Competency Domains

Domain 1—Global Burden of Disease
Domain 2—Globalization of Health and Health Care
Domain 3—Social and Environmental Determinants of Health
Domain 4—Capacity Strengthening
Domain 5—Collaboration, Partnering, and Communication
Domain 6—Ethics
Domain 7—Professional Practice
Domain 8—Health Equity and Social Justice
Domain 9—Program Management
Domain 10—Sociocultural and Political Awareness
Domain 11—Strategic Analysis

CUGH, Consortium of Universities for Global Health.

projects conducted by international groups were in local priority areas, and approximately one third of trainees (31%) reported discomfort with the ethics of clinical decisions made by visiting faculty.[242]

It is incumbent upon institutions that offer global health opportunities to provide formal training. Numerous resources exist to help equip trainees, providers, and institutions with the knowledge necessary to manage these challenges and maximize the positive impact of global health efforts (see the Appendix for links and useful resources).[243–246]

In some countries (e.g., the United Kingdom), anesthesia trainees can pursue 6-month to 1-year-long global health experiences, with formal curriculum and relatively long-term clinical, research, and educational components. Trainees are required to complete standardized assessments, including clinical evaluations and case-based discussions as outlined by the RCoA.[247] A relatively small yet increasing number of anesthesia programs in the United States and other countries are providing formal global health tracks for interested residents as well as formal anesthesia global health fellowships.[248] Academic institutions and the global anesthesia community at large must continue to expand training and career development opportunities that increase the number of anesthesiologists interested in and capable of improving equitable access to safe anesthesia worldwide.

Conclusions

Despite dramatic changes in anesthesia around the world over the past century, improvements in safety, access, and affordability have not been universal. At present, the majority of the world does not have access to safe anesthesia, surgical, or analgesia services, and relatively few resources are being devoted to address this growing crisis. The massive and growing surgical and pain crises disproportionately affect LMICs, where severe shortages of workforce and infrastructure, and impractical international regulations limit access to care. Despite many common misperceptions, anesthesia, analgesia, and surgical services are feasible in resource-constrained settings and are as cost-effective as many other public health interventions (e.g., vaccinations).

The neglect of pain and surgical disease by the global health community has resulted in one of the most inequitable global public health crises the world faces today. It has been only in recent years that the surgery, anesthesia, and global health communities have accelerated investment in research, education, and advocacy initiatives that aim to improve access to safe anesthesia and surgical services for the world's poor. These efforts are in their infancy and must be expanded and supported by the global anesthesia community. Factors affecting access to care, safety, and cost are relevant in all countries regardless of income level. All anesthesia providers should maintain awareness of the fundamental challenges facing the global anesthesia community, with the hope that increasing numbers will devote their careers to addressing issues of global health equity. There are many different ways for anesthesia providers to engage in global health at the patient level or system level, including research, advocacy, education, and clinical service.

The role of anesthesia in global health is easy for many to overlook, but the global anesthesia community must quickly increase efforts to actively lead global health initiatives that aim to improve infrastructure, expand workforce, increase translation of data into policy and practice, improve financial risk protection mechanisms for surgical patients, expand referral and prehospital systems, provide essential medicines, and ultimately improve access to safe and affordable anesthesia, surgical, and pain services worldwide.

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Appendix 1 Links and Useful Resources

- WHO Essential Surgery: http://www.who.int/surgery/en/
- Surgical Care at the District Hospital: http://www.who.int/surgery/en/
- World Federation of Societies of Anaesthesiologists (WFSA): www.wfsahq.org
- WFSA Workforce Map: www.wfsahq.org/workforce-map
- WFSA Anesthesia Facility Assessment Tool: www.wfsahq.org/afat
- Open Anesthesia Global Health: http://www.openanesthesia.org/subspecialty/global-health/
- American Society of Anesthesiologists Global Humanitarian Outreach: https://www.asahq.org/gho
- Consortium of Universities for Global Health: www.cugh.org

- Royal College of Anesthetists e-Learning Anaesthesia: www.rcoa.ac.uk/e-la
- Royal College of Anesthetists Anaesthesia for Austere Environments modules: https://www.rcoa.ac.uk/e-la/anaesthesia-humanitarian-austere-environments
- Institute for Health Metrics and Evaluation: http://ghdx.healthdata.org/
- Global Health Ethics Course (Johns Hopkins): http://ethicsandglobalhealth.org/
- Essential Pain Management Course: www.essentialpainmanagement.org/
- "Anaesthesia at the district hospital" by Mike Dobson: http://apps.who.int/iris/handle/10665/42193
- Developing Anaesthesia Handbook: http://www.developinganaesthesia.org/
- *Primary Anesthesia*, Book by Maurice King
- International Association for the Study of Pain (IASP) Guide to pain management in low-resource settings: http://ebooks.iasp-pain.org/guide_to_pain_management_in_low_resource_settings
- *Developing Global Health Programming: A Guidebook for Medical and Professional Schools.* By Jessica Evert et al: www.cfhi.org/sites/files/files/pages/developingglobalhealthprogramming_0.pdf
- *The Right Stuff*, Michael Dobson, MD Publications, 2017

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3 Perioperative Medicine

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KEY POINTS

- The practice of anesthesiology continues to evolve with health care for patients undergoing new and, in many cases, more complicated procedures in the operating room as well as minimally invasive or interventional procedures performed in other nonoperating room settings. With the rapid growth of nonoperating room anesthesia, traditional operating room anesthesia care no longer dominates most anesthesia practices.
- The number of anesthesia subspecialties has also increased to include pediatric, cardiothoracic, obstetric, neuroanesthesia, critical care medicine, acute and chronic pain management, palliative care, and sleep medicine. Anesthesiologists' skills and expertise in subspecialties have grown paralleling the respective surgical specialties.
- The diversity of anesthesiology skills and clinical capabilities has created opportunities for anesthesiologists to take advantage of the changing healthcare environment and assume a more expansive role in perioperative care in both hospital and nonhospital settings, providing management of patients through the continuum of the perioperative or periprocedural period, and extending to home care and other settings.
- With changes in healthcare delivery, anesthesiologists will have to not only reassess current practices, but also define ways to adapt to new models of care. New approaches to care, while exciting for the specialty will be challenging to implement. While expanding the scope of practice, anesthesiologists must also continue to fulfill the traditional operating room roles and maintain the commitment to safe and high-quality intraoperative anesthesia care.
- To successfully transition to these new models of practice, anesthesiologists must acquire a more comprehensive understanding of the economics of health care and the role their perioperative care has in determining costs of care, outcomes, quality, and safety.
- The electronic health record and access to big data can serve as valuable resources in identifying opportunities to advance care and improve quality. To use the electronic record effectively will require that anesthesiologists acquire skills in biomedical informatics and data sciences to advance perioperative care.
- Public and private insurers are implementing new payment models to replace traditional fee-for-service payment for clinical care. They are transitioning from fee-for-service to "value-based" payment methodologies that better align quality, costs, and goals of care. At the same time, both government (e.g., Medicare) and private payors (e.g., insurance companies) are implementing new alternative payment models including bundled (fixed) payment methodologies designed to transfer the financial risk from patients and payors to providers, both physicians and health systems. Anesthesiologists must understand these new payment models and how they will impact clinical management and compensation for anesthesia services, particularly as anesthesia services and perioperative medicine evolve.
- Providing optimal perioperative care in the current healthcare environment requires implementation of new and creative models of value-based care that encompass the patient's entire clinical course as well as development of new partnerships and collaborations with other providers across the healthcare system. Anesthesiologists are well positioned to take a more prominent role in perioperative management, integrating their understanding of the surgical and medical needs of patients during and after surgical procedures. Concurrently, other physicians, including hospitalists, are partnering with surgeons to optimize perioperative inpatient care. Collaboration with hospitalists, medical specialists, and others is critical to improving perioperative care and in clarifying the roles anesthesiologists can play in providing value-based perioperative care. For some patient populations, co-management agreements can be executed to coordinate perioperative care and optimize transitions through the continuum of care.
- A variety of models for perioperative medicine are being successfully adopted in the United States and other countries. The perioperative surgical home (PSH) and Enhanced Recovery After Surgery (ERAS) protocols are examples of new approaches to collaborative multidisciplinary care that have demonstrated significant benefit for a number of patient populations—aligning goals for patients, providers, hospitals, and payors.

Introduction

The primary focus of anesthesia practice has traditionally been on the intraoperative management of patients undergoing surgical procedures in hospitals or ambulatory settings. Over the past few decades, anesthesiologists have been acknowledged for the significant improvement in perioperative safety and quality.[1] As a result of advances in anesthesia care as well as surgical and diagnostic capabilities, anesthesia services have expanded to include a wide variety of hospital-based and ambulatory settings outside of the operating room. While the diversity of anesthesia services has expanded, the basic elements of anesthesia care remained relatively consistent—preoperative assessment, intraoperative management, and postoperative care provided to ensure safe transition through the perioperative period. With increasing subspecialty training opportunities and changes in healthcare delivery and payment, new opportunities have developed for anesthesiologists to assume a broader role in both perioperative care and management of patients in the operating room and beyond. At the same time, the increasing capabilities and high costs of health care, particularly in the United States, is undergoing significant pressure to improve quality and safety while delivering value-based care consistent with patient wishes.[2,3] The changes create opportunities for anesthesia practices to evolve and for the role of anesthesiologists to extend beyond current clinical practices.

This chapter reviews the changes taking place in healthcare delivery and financing that create challenges and opportunities for anesthesiologists to expand their practices to incorporate concepts of perioperative medicine.

THE ANESTHESIOLOGIST AND PERIOPERATIVE MEDICINE

Perioperative medicine is an evolving field that focuses on optimizing the health and healthcare delivery of patients who will be undergoing surgery, and providing medical care for those patients following surgery. Anesthesiologists are well suited to advance their role as specialists in perioperative medicine and provide better care for surgical patients. New anesthetic techniques, monitoring capabilities, and evidence-based approaches to perioperative management have made anesthesia safer and improved the quality and safety of perioperative care.[1] Advances in surgery and development of minimally invasive techniques have had major impact on how anesthesia care is provided and expanded the locations in which anesthesia services are needed. At the same time, in part as a result of these changes, the patient population presenting for anesthesia has changed. Patients with significant underlying medical conditions who in the past were not considered candidates for surgery are now able to undergo complex surgical procedures successfully. These changes have had major impact on health systems, significantly increasing complexity and costs of care, while also putting pressure on healthcare resources including hospital bed capacity.[4,5]

For anesthesiologists, the advances in care, diversity of patients requiring anesthesia services, and the high costs of care create both new opportunities and challenges. Most significant to the practice of anesthesia has been the expansion in scope of clinical responsibilities in perioperative care of patients beyond the traditional operating room roles, and the need to improve operational efficiency in perioperative/periprocedural care and reduce costs. The challenges also provide the opportunity for anesthesiologists knowledgeable about operating room management to assume health system leadership roles and improve healthcare delivery for the surgical patients.

The change in scope of anesthesia practice is related to a number of different factors. The extension of anesthesia care to other inpatient and outpatient settings is based on management strategies and lessons learned in optimizing care in the operating room. The expansion of anesthesia services to interventional radiology, endoscopy, and cardiology suites has resulted in improved clinical management and, in some cases, better throughput.

Anesthesiologists have also modified clinical practices to optimize clinical care and improve efficiency. For example, preoperative assessment has been refined to improve clinical outcomes, but also reduce costs associated with laboratory testing and other preoperative testing that add no value.[6,7] At the same time, anesthesiologists have had a greater role in optimizing patients prior to surgery. Preoperative *management* of patients with underlying medical conditions, including diabetes, cardiopulmonary disease, and renal insufficiency, has improved the perioperative course and minimized the likelihood of postoperative complications. In some cases consultation with other medical specialists is required, but for most patients, the anesthesiologist's role is critical to optimizing the patient's conditions preoperatively as they best understand the interplay of the various perioperative variables including patient factors, anesthesia, and surgical techniques. As a key aspect of optimal perioperative medicine, anesthesiologists are able to provide postoperative management, including critical care and pain management for many of these patients based on their individual preoperative risk assessment and intraoperative course. In many respects, these changes have redefined anesthesia to encompass perioperative medicine.[8]

The expansion of anesthesia training in multiple subspecialties, as well as critical care medicine and acute and chronic pain management, also provides advanced and diverse skills that allow anesthesiologists, in collaboration with the surgical specialists, to ensure a coordinated approach to perioperative management. As a result, many anesthesia subspecialists have successfully expanded their roles in perioperative care. As one example, transplant anesthesiologists (also see Chapter 60) are often involved in discussions about patient selection, preoperative optimization, and transitions of care from the operating room to the postoperative period. Based on the collaboration of anesthesiologists, transplant surgeons, and medical specialists, anesthesiologists participate in selection discussions to provide their perspective on the perioperative implications of transplantation. For many transplant services, collaboration with the anesthesiologists has resulted in reengineering of care. Many patients who previously required postoperative care in the intensive care unit (ICU) can now bypass the ICU and have reduced hospital lengths of stay.[9] Similar outcomes have been documented for patients who have anesthesiologists participate in their perioperative management for cardiac surgery (also see Chapter 54), pediatric surgery

(also see Chapters 77-79), neurosurgery (also see Chapter 57), or other subspecialties. In each of these examples, collaboration among the surgeons, anesthesiologists, and the overall team of providers both within and beyond the operating room environment is critical to realizing improved outcomes and reduced costs of care.

Anesthesiologists with advanced training in pain medicine and critical care are able to facilitate and optimize perioperative management. Pain management strategies have significant positive impact on the care of patients with both acute and chronic pain (also see Chapters 51, 80, and 82). Employing multimodal approaches to perioperative pain management, particularly for patients with longstanding chronic pain, perioperative pain medicine teams have had positive impact on perioperative outcomes, including reduced need for opioid analgesics and in some cases shortened the length of stay in hospital and improved patient satisfaction.[10-12] Similarly, critical care anesthesiologists play a large role in improving perioperative management of patients requiring ICU care. The value of the critical care physician on ICU utilization in reducing complications of mechanical ventilation, providing early diagnosis and treatment of sepsis, and improved management strategies for patients with renal dysfunction are well documented (see Chapters in 80, 84, and 85).[13-15]

An equally important factor contributing to anesthesiologists assuming greater responsibility in perioperative management is related to their knowledge of the overall perioperative environment, its complexities, and associated high costs. Advances in anesthetic management have facilitated implementation of new surgical techniques and allowed patients previously considered poor risks to undergo complex surgical procedures with good outcomes. These advances in care have contributed to the escalating cost of health care, particularly in the United States.[2] Not only are the high costs specifically related to the procedure, there are often substantial additional costs associated with complications of care, postdischarge care, and readmissions.[16,17] Anesthetic management has impact on costs of perioperative care, hospital length of stay, need for prolonged postoperative ICU stay, and other clinical outcomes. For example, intraoperative management can contribute to postoperative complications, such as pressure ulcers, central line infections, renal failure, aspiration and ventilator-associated pneumonia, cognitive dysfunction, and other complications. When these complications occur, hospitalizations are lengthy and rehabilitation (skilled nursing, physical, and rehabilitation services) needs are significant.

The need to address costs associated with managing complications of care is taking on greater importance. Over the past few years in the United States, government and private payors have raised concerns about the costs associated with managing complications of care, some of which are relevant to anesthetic management. These payors are reducing payment for costs associated with complications and denying payment for costs associated with readmissions.[18,19] As part of perioperative medicine, anesthesiologists have to identify these perioperative risks and, when clinically appropriate, identify ways to modify management to improve outcomes and reduce costs.

Another factor that has precipitated a need to address perioperative care in a more coordinated manner is the impact of changes in payment methods being implemented by both government and private payors as a way to control costs of care. In the United States, the primary method of payment to physicians remains fee based. While the implications of fee-for-service (FFS) payment methodology on quality of care and resource utilization are widely debated, FFS payment models are associated with overuse of some services, higher costs, and poor coordination of care.[20] In response to these issues, a number of alternative payment models (APMs) have been implemented including bundled payment methods and incentive-based payments associated with reduced costs of care and penalties when costs remain high. Under the Medicare Access and CHIP Reauthorization Act of 2015, Medicare has implemented a number of APMs and a Quality Payment Program that includes a Merit-Based Incentive Payment System (MIPS), each designed to compensate physicians for improving patient outcomes at reduced cost.[21] Medicare is also encouraging development of accountable care organizations (ACOs) in which health systems assume clinical and financial responsibility for managing a population of patients, improving quality, and reducing overall costs.

These changes in care management and payment methodologies have significant impact on all physicians and health systems. They shift responsibility and risk to the providers and are forcing physicians and health systems to implement value-based care. Anesthesiologists are knowledgeable about the complexities associated with perioperative care and have the ability to manage many aspects of the care and systems needed to optimize it. Consequently, they can help define new models of care and extend their role and assume greater responsibility for managing the perioperative course of some patient populations. For example, if anesthesiologists can help reduce costs during the course of care for a surgical patient, they can benefit financially under bundled payment methodologies, shared savings plans, and when participating in ACOs. Although issues related to payment methodologies are very different from one country to another and are beyond the scope of this chapter, the goals and implications of these newer payment methodologies should be understood by all anesthesiologists, since they have significant implications on the practice of anesthesia and the role for the anesthesiologist in perioperative medicine broadly.

While anesthesiologists are well suited to positively impact perioperative care, anesthesiology departments will need to adjust their focus and priorities to be better engaged in perioperative medicine. When provided in a coordinated way, perioperative care is cost effective and improves outcomes.[22] At the same time, the expansion of anesthesia practices, diversity of roles and responsibilities, and the subspecialization of anesthesia care have in some ways compromised the ability of anesthesiologists to fulfill their potential as perioperative providers. Compartmentalization of perioperative care and subspecialization have the risk of fragmenting care and undermining the development of a coordinated approach to perioperative management. At many hospitals, preoperative care is now provided in a dedicated preoperative evaluation clinic, physically separate from the operating room or other clinical sites. The evaluation is performed at some time prior to the surgical procedure; communication about the patient's status and

clinical plans is most often done electronically with no face-to-face dialog or communication with the anesthesiologist who will deliver care during the procedure. Operating room care is provided by an anesthesiologist either personally or as part of the anesthesia care team model. Postoperative management—including care in the postanesthesia care unit, pain management, and ICU care—is often provided by another set of care providers. Perioperative medicine requires collaboration among all anesthesia providers, incorporating the knowledge and skills of each of the participants, including those providing preoperative management, intraoperative care, critical care, pain management, and so on. As much as each of the providers is critical to the care of the patient, the coordination of care among the anesthesiologists as a group is also a critical element in optimizing care, understanding and fulfilling the patient's goals for care, and improving efficiencies.

Perioperative Management

Throughout this text, the role of the anesthesiologist in various aspects of perioperative management is discussed. Each component is critically important to the quality, safety, and costs of care. The overall approach to care from the time a case is scheduled until the patient has recovered from anesthesia and surgery and resumed normal activities should be of concern to the anesthesiologist. Just as anesthesia as a specialty is acknowledged for advances in safety and quality in the intraoperative case, it should extend its focus and responsibility to the entire perioperative period—coordinating assessment, management, and responsibilities with the surgeons, hospitalists, other physicians, and nurses. By optimizing each of them independently and then coordinating the care across the continuum, the benefits of providing perioperative medicine will be achieved—with improved clinical outcomes, safer care, and reduced costs.

PREOPERATIVE ASSESSMENT AND MANAGEMENT

Chapter 31 emphasizes the changing patient needs and role of the anesthesiologist with respect to preoperative assessment and management. The chapter provides a more comprehensive discussion. To summarize current practices, for most healthy patients, a formal preoperative assessment is usually not required.[6,7] In fact, anesthesia providers have been able to reduce preoperative testing and other costs through the implementation of evidence-based protocols to standardize preoperative management for many patients.[7] Rather than requiring a preoperative visit, laboratory testing, and radiologic studies, most patients now have a phone consultation, often performed by a nurse practitioner to assess preoperative status and perioperative needs, and to address a patient's questions or concerns. For other patients, particularly those with underlying medical conditions or complex comorbidities, a more comprehensive evaluation and preoperative management and optimization of underlying conditions may be required.[23] For this subset of complex patients, preoperative assessment and management are an integral part of the continuum of perioperative care for which the anesthesiologist has a significant role. In some cases, additional diagnostic studies, such as an echocardiogram or focused pulmonary function studies, may be helpful in determining how best to manage a patient during the perioperative period. In this situation, interpretation of the studies may be done in coordination with a consultant or physician who has provided care to the patient preoperatively and who will resume care after the procedure is beneficial. The preoperative anesthesiologist may require a formal consultation with another specialist, such as a cardiologist, nephrologist, or pulmonary medicine physician, although these are needed for only a select few patients. For those patients with significant underlying conditions that will influence the perioperative course, particularly the postoperative recovery, referral for additional preoperative management (prehabilitation) can be helpful in optimizing their clinical status prior to proceeding with a major surgical procedure.[24-26] For most patients, the specific management strategies required to optimize the patient for anesthesia and surgery are often best defined when input is provided by the anesthesiologist who is most knowledgeable about the impact of chronic conditions on perioperative care needs as well as the implications of anesthesia on underlying physiology.

INTRAOPERATIVE (INTRAPROCEDURAL) MANAGEMENT

A number of initiatives have been implemented in hospitals throughout the world to improve intraoperative management, minimize complications, and reduce costs. The implementation of checklists has been demonstrated to improve patient safety in the operating room (also see Chapter 5).[27-29] Similarly, the routine briefing (i.e., time out) before beginning a surgical procedure reduces the incidence of wrong-site surgery, facilitates communication among providers, and ensures optimal patient care.[30] Some hospitals and surgical services also conduct debriefings at the end of each surgical procedure to define what procedure has been completed, clarify the postoperative expectations for the patient, and ensure that all supplies and materials have been appropriately retrieved from the surgical field.[31] These initiatives have reduced complications during surgery and, in some cases reduced costs of care. For example, the British National Health Service instituted "The Productive Operating Theatre" to improve productivity and patient outcomes during surgical procedures.[32,33] The program includes both briefings and debriefings to identify critical issues during and after a surgical procedure. This process has reduced errors and facilitated the transition from the operating room after a surgical procedure. Operating room utilization has increased, turnaround times shortened, and waste reduced. Significant financial savings have also resulted from this effort. The National Health Service is implementing similar initiatives in other hospital settings, such as "The Productive Ward" to build on the success achieved in the operating room environment.[34] Anesthesiologists need to be part of such initiatives that ensure there is an integrated approach to management during the intraoperative periods in order to demonstrate a significant and sustained impact on outcomes.

POSTOPERATIVE MANAGEMENT

The transition out of the operating room represents another important opportunity for anesthesiologists to enhance the quality and safety advances achieved in the operating room and improve perioperative patient outcomes. Advances in anesthesia safety have been acknowledged by the Academy of Medicine (formerly the Institute of Medicine) of the National Academy of Sciences[1] and other groups as a result of better anesthetic drugs, new anesthetic techniques, and improved monitoring. Although the incidence of intraoperative complications has been dramatically reduced, complication rates in the postoperative period remain high. The impact of variability in anesthetic practices on postoperative outcomes—beyond the immediate postoperative period—has received increasing attention for both patients who remain hospitalized and those who experience unintended and often unrecognized sequelae of anesthesia and surgery after discharge. For example, after a surgical procedure requiring tracheal intubation, a significant number of patients experience postextubation stridor or dysphagia that may last for days. These findings compromise the ability to protect the airway, particularly during sleep.[35] Does the dysphagia contribute to postoperative pneumonia that may not become clinically apparent until after discharge? Similarly, the most common healthcare–associated infections are pneumonia and surgical site infection, supporting the concept that intraoperative management is an important determinant of postoperative outcome.[36] Many other intraoperative strategies also impact long-term outcomes beyond the immediate postoperative period. Three examples support this conclusion. First is the influence of intraoperative fluid and vasopressor management on postoperative metabolic status and renal function.[37,38] Second, intraoperative glucose control can have a major impact on wound healing.[39] Finally, and more recently, anesthetic management can influence postoperative cognitive dysfunction for both adults and children.[40,41] As a result of these findings, anesthesiologists have a responsibility and an opportunity to understand the causes for these and other complications. We need to understand how anesthetic management contributes to adverse outcomes and how we can modify both intraoperative and postoperative care to reduce them.

COORDINATED PERIOPERATIVE MANAGEMENT STRATEGIES

While each of the components of perioperative care have specific requirements and approaches to optimize management, improve outcome, and potentially to reduce cost, perioperative management strategies must be assessed collectively, often using evidence-based clinical pathways to ensure that the goals of perioperative medicine are met.[42,43] Anesthesiologists have the opportunity to address these needs. To achieve these goals, however, anesthesiologists must reassess current models of care and modify some practices. One critical challenge to effectively coordinate care is the complexity of the perioperative course and management. In most clinical situations, it is no longer possible, nor appropriate, for a single anesthesia provider to participate in all aspects of the perioperative course. Perioperative, intraoperative, and postoperative care are often provided by different anesthesiologists, including pain medicine and critical care anesthesiologists in selected cases. To optimize perioperative management under this model requires improved communication and collaboration *among the anesthesia providers* as well as with others who participate in a patient's care. For some patient populations, such as geriatric patients or those with complex comorbidities, co-management agreements with other specialists can be executed to optimize care across the perioperative continuum, while clarifying roles and responsibilities.[44] The electronic health record is a valuable source of clinical information, but cannot substitute for more direct communication among providers, particularly in the management of complex clinical problems (also see Chapter 6).

The collaborative approach to care may not seem essential for healthy patients undergoing straightforward procedures. However, the value and opportunities for anesthesiologists to take a larger role in perioperative care is clearly evident for almost all patients—and the coordinated approach is appreciated by patients who are often confused about who is managing their care.[45] For example, patients undergoing "simple" procedures often have postoperative clinical issues that are underrecognized and require assessment and management. Anesthesiologists, surgeons, and nurses provide patients with instructions and information to help them manage their postoperative course, often at a time when they are not able to understand or process the information. As a result, even in these cases, the anesthesiologist can be instrumental in addressing postoperative anesthesia-related problems and coordinating the transition of the patient's care back to the primary care provider. The surgeon can provide information about the surgical procedure by forwarding the operative note to the primary care provider, but it rarely addresses any issues related to anesthetic management, concerns about the airway or potential for airway obstruction, or sequelae related to anesthetic agents, narcotics, muscle relaxants, or regional anesthetic blocks. In many cases, a phone consultation or teleconference is sufficient to address clinical needs. In other cases, a formal postoperative office visit may be required, as some anesthesia practices offer. Expansion of the postoperative assessment and management can be very helpful to patients, the surgeons, and other providers at the facilities to purvey a level of support to the patients that is often unavailable. The adoption of information technology resources and continued evolution of medical informatics (see Chapter 4) can enhance communication between patients and physicians during the entire perioperative period.

Besides the desire for a more coordinated approach to the entire perioperative course for every patient, a more formal and robust perioperative management strategy must be available for those patients with underlying medical conditions, those undergoing complex surgical procedures, and those needing prolonged hospitalization. In addition, for patients who require skilled nursing or rehabilitation services after discharge and for those needing home health services, the transitions of care create challenges for ensuring that postoperative management strategies are maintained, responses are assessed, and therapy is modified as needed. By its very nature, perioperative care for these patients is collaborative, requiring input and expertise from a number

of different disciplines, including, but not limited to, anesthesia subspecialty expertise, surgeons, and medical subspecialists. Diverse perspectives and clinical expertise are essential, particularly for the more complex procedures in patients with multiple comorbidities. At the same time, the coordination of care must be assumed by a provider who is able to integrate the diverse perspectives into a comprehensive plan of care consistent with each patient's needs and goals. In the distant past, this coordination was provided by the patient's primary care provider, who maintained a role throughout the perioperative period. With the increasing complexity of perioperative care, changing demographics, and need to provide more efficient and coordinated care to reduce overall costs, the anesthesiologist has the opportunity to assume a more involved role in the management of some of these patients. To do so will require the commitment of the anesthesia practice to this new model of care and, in many cases, the acquisition of new clinical and management skills to deliver optimized care that is efficient and consistent with patient expectations.

One of the most prominent barriers for an anesthesia department to assume a greater role in perioperative management is its own members. It is imperative that there be consensus from all members of the department that a coordinated strategy is important and consistent with their expectations. To achieve department support, it is vital to clarify that perioperative management is a comprehensive approach to care that involves a diverse group of providers. Every member of the group must participate in the overall commitment to perioperative care. The care will be provided by a number of different anesthesiologists, each with different clinical expertise. One example of this coordinated approach to perioperative care is the management of a patient with a history of chronic severe pain who undergoes a complex surgical procedure. The patient will undergo extensive evaluation and optimization of care in the preoperative evaluation programs. Intraoperative care will be provided by another anesthesiologist, one who has communicated with the patient and understands all of the clinical issues identified and addressed preoperatively. When the patient is transferred to the ICU for postoperative care, which includes ventilator support, intensive respiratory care, hemodynamic monitoring, and fluid management, the transition from the anesthesiologist who provided intraoperative care to the critical care anesthesiologist is seamless. Pain management is provided by the pain service in collaboration with the critical care anesthesiologist (also see Chapters 51 and 82). The remainder of the patient's course of care will be managed by a member of the anesthesia department to facilitate transition to another care facility or home, and to ensure effective communication with the primary care provider or other caregivers. Although this model is foreign to many practices, it represents one of many approaches to optimizing perioperative management and takes advantage of the expertise of anesthesiologists in the overall care of the patients they anesthetize.

Finally, new approaches to perioperative management also require that each practice acquire the necessary operational, clinical, and financial data, as well as the analytical capability to interpret it. Larger regional and national organizations have the broad expertise available to analyze the practice and determine where improvements in processes can benefit patients and enhance the efficiency of the practice. For smaller practices, it can be challenging to have this broad level of expertise and access to information, although some have very successfully incorporated these strategies. As a consequence, in the United States there has been considerable consolidation of anesthesia practices by large regional and national organizations.[46] This consolidation has enabled the larger, often multi-institutional group to provide the resources needed to help anesthesia practices optimize perioperative management and document the value of the anesthesia services from both a clinical and financial perspective. Some groups have transitioned to multispecialty groups or recruited hospitalists or other providers to the anesthesia practice to supplement the clinical skills of the anesthesiologists so that the department has the diverse clinical and management expertise needed to optimize perioperative care. This multidisciplinary approach to perioperative care enables the group to expand its scope of practice and to develop clinical and administrative databases that allow them to document the value of their services to both patients and the institution. From an administrative perspective, this strategy better positions the practice to negotiate with representatives from the hospital or health system, particularly when advocating for the share of bundled payments. Because the administrative and analytical capabilities are essential to optimize delivery of perioperative care, each practice of whatever size will need to identify the most effective ways to develop this expertise and acquire the data needed to successfully address the many challenges facing anesthesia practices.

Models of Perioperative Care

Most health systems and providers are challenged to identify ways to become more efficient and reduce costs while maintaining or improving the quality of care, particularly perioperative care. Accomplishing these diverse goals is difficult and no single model of care works for every patient population or healthcare setting. As a result, many approaches to delivery of perioperative care have been implemented, some of these successful and some for which the outcome remains unknown. Although models of perioperative management include the anesthesiologist, other providers have participated in the preoperative and postoperative management of complex patient populations, each with variable success. Based on these experiences, the key aspects for any model for perioperative management include: (1) an understanding of the specific patient population included in the model (e.g., specific surgical procedure), (2) sufficient clinical and financial information to allow evaluation of the management strategies and their implications, and (3) coordination and collaboration among all providers participating in the model.[47] As models for perioperative management have evolved, they have taken advantage of the experiences from the hospitalist model for inpatient care and the medical home model for chronic disease management.

PATIENT-CENTERED MEDICAL HOME

The medical home model, also referred to as the "patient-centered medical home" (PCMH) refers to the model of care

in which a primary care physician provides comprehensive care to improve health outcomes for a population of patients.[48] The critical element of the PCMH is the coordination of care to reduce emergency room visits and hospitalizations. In managing the patient population, a number of strategies are implemented to reduce costs and improve outcomes. These models often utilize additional providers, including advance practice nurses, respiratory therapists, physical therapists, and patient advocates to manage chronic diseases such as asthma, chronic obstructive pulmonary disease, heart failure, and diabetes mellitus. Payment for the PCMH includes FFS payments for episodes of care as well as payment to coordinate care. This model has been successful in improving care, particularly for patients with selected chronic diseases, although the financial success has not been consistently achieved.[49-51] In some cases, the PCMH actually resulted in increased hospital admissions.[52] Despite the variable success of the PCMH, there are some lessons that can be applied to perioperative care. First, preoperative assessment must be comprehensive enough to identify underlying clinical problems and effectively manage them, both preoperatively and postoperatively (also see Chapter 31). For the anesthesiologist managing the perioperative period, chronic conditions must be addressed; the management of these cannot be deferred to other providers. The implications of the perioperative needs must be taken into account when managing chronic diseases during the course of surgical care. Second, the underlying medical conditions must be considered as part of the proposed procedure and its implications for postoperative management. This broader perspective requires coordination with the surgeon and for some patients, the hospitalist, other specialists, and the primary care provider. For example, a patient with peripheral neuropathy associated with diabetes mellitus may be unable to participate in traditional approaches to rehabilitation; care must be tailored to the specific needs of each patient in consultation with others who can modify care as needed to optimize likelihood of achieving the desired outcome. Third, while participation by anesthesiologists is essential, many aspects of perioperative care can be managed by other providers, including other physicians and advance practice nurses. The keys to successful perioperative management, however, require that there be a single physician responsible for coordinating care among the team of providers, ensuring consistent and ongoing communication about patient care needs, and the availability of data that can be used to analyze clinical and business practices, costs of care, and outcome measures. The responsible provider during the perioperative period may be the anesthesiologist, surgeon, or hospitalist. As the patient recovers, the responsible provider may transition to the primary care provider, as long as there is good communication and appropriate "hand-off."

SURGICAL HOSPITALIST

Another model that has been implemented in many hospitals in the United States and other parts of the world is the surgical hospitalist model, which builds on the hospitalist model of care for inpatient medical patients. Many studies have documented the clinical values and other advantages associated with implementation of a robust hospitalist program.[53,54] Most of the programs have been focused on the care of patients with acute (and perhaps underlying chronic) medical problems rather than patients undergoing surgical procedures. For the surgical patient, the role of the surgeon is evolving for a number of reasons: the percentage of surgical inpatients is increasing, and inpatient clinical needs are becoming more complex and difficult for the surgeon to manage without additional support. As a result, many hospitals are recruiting hospitalists to provide perioperative care for surgical patients.[53,54] In some cases hospitalists work with specific surgical services (or an individual surgeon) to manage overall care and transitions of care into and out of the hospital environment. The models for surgical hospitalist programs vary, in some cases incorporating hospitalists with primary training in internal medicine or pediatrics, and in some cases, having a surgeon with interest in perioperative care take on the hospitalist role. In each model, the clinical management issues are similar, though the knowledge and skill to manage patients with complex comorbidities may differ considerably.

Many of these surgical hospitalist models have been successful in optimizing care of both underlying medical conditions and perioperative needs related to the surgical procedure. Although there is limited experience to document the effect on hospital lengths of stay and readmission rates, the models have been effective at improving timeliness of interventions, and patient and staff satisfaction.[54] For this model to be most effective requires that the surgical hospitalist be knowledgeable about the idiosyncrasies of perioperative management related to the specific surgical procedures. Their effectiveness is most evident when the care of underlying medical conditions is carefully coordinated with the other perioperative needs of the patient. For example, the neurosurgical hospitalist must understand concepts such as cerebral autoregulation and the impact of clinical interventions on cerebral hemodynamics for the patient who has undergone a neurovascular procedure. Similar considerations must be addressed for hospitalists working collaboratively with other surgical services.

The surgical hospitalist model has been very effective in allowing surgeons to concentrate their efforts in the operating room. However, the optimal relationship between the surgical hospitalist (whether a surgeon who has assumed this nonoperative responsibility or a medical hospitalist) and anesthesiologist during the immediate perioperative period has not been standardized. In some cases perioperative care is transferred from the anesthesiologist to the hospitalist in the immediate postoperative period; in other cases, care may be transferred from the anesthesiologist to an intensivist (either a critical care anesthesiologist or another intensive care physician) while the hospitalist maintains responsibility for managing some of the underlying clinical conditions. In the latter case, the roles and responsibilities of the anesthesiologist, critical care provider, and hospitalist need to be clearly defined to ensure appropriate coordination and transitions. Either model can be effective when coordination of responsibilities is clearly delineated. Another important component in the perioperative care of the patient is the transition from the inpatient to outpatient setting. When possible, there should be good communication and coordination of the transfer of care to the outpatient physician who is provided sufficient information about

the intraoperative course and its implications, including any issues that arise as part of the anesthetic management that might impact postoperative management.

ENHANCED RECOVERY AFTER SURGERY

Enhanced recovery after surgery (ERAS) is another example of a creative approach to the perioperative management of patients who undergo major surgical procedures.[55,56] ERAS protocols are evidence-based pathways designed to improve care and outcomes as well as efficiency in the perioperative period. ERAS protocols require a multidisciplinary approach to perioperative care with particular emphasis on the entire perioperative course. The most successful ERAS programs are the ones that include participation by all of the healthcare and service providers who have a role in the perioperative course for the patient population.[57,58] Most ERAS protocols include preoperative education, perioperative antimicrobial management, pain management strategies, and early rehabilitation. In some cases, separate protocols have been initiated to address each period in the perioperative course, one to address the immediate perioperative management strategies and another to concentrate on the patient-care needs outside of the immediate postoperative period.[59] Many successful ERAS protocols have been implemented to optimize care of patients undergoing a variety of surgical procedures, including laparoscopic and other colorectal procedures, breast surgery, and urologic surgery.[60,61] Recently an ERAS protocol was implemented to optimize perioperative management of living liver donors[62] and another designed to improve perioperative management of patients undergoing elective craniotomy.[63] Each of these protocols has resulted in improved patient outcomes. For some patients, hospital lengths of stay and postoperative complications were reduced by as much as 30% and 50%, respectively[64,65]; for others postoperative pain management was improved despite administration of less opioids.[60-62,66]

As noted earlier, one of the most important features of the ERAS program, as with other pathways designed to improve perioperative care, is that the protocols are developed by a multidisciplinary group of providers that includes physicians, nurses, respiratory therapists, and others to ensure seamless coordination across the continuum from preoperative, intraoperative, and postoperative (postdischarge) periods.[67] The anesthesiologists offer essential information about key components of anesthetic management that can be modified to improve outcomes.

The outcomes associated with implementation of ERAS protocols have generally been positive for patients, providers, and health systems. In addition, the implementation of the protocols with participation of all providers involved in patient care enables a comprehensive review of the clinical course and outcomes, costs, and resource needs. The participants should be encouraged to review the clinical, financial, and other data regularly and, if appropriate, to modify the protocol to optimize care. One protocol recently implemented to improve care in colorectal surgery identified an increased incidence of acute renal injury.[68] The patients at risk for acute renal injury were those who had longer operative times and an associated diagnosis of diverticulitis. The findings emphasized a need to reassess the management strategies and to implement a goal-directed approach to fluid management intraoperatively and postoperatively. Follow-up will be required to determine if these changes in the protocol will be successful. These findings, however, emphasize the need to not only work collaboratively during the development of the protocol, but also review the experiences after implementation and modify the protocol when adverse outcomes occur.

Based on experiences with many of the ERAS protocols initiated to date, this approach to refining and improving care has been successful in improving outcomes and lowering costs. From a healthcare economic perspective, the ERAS protocols represent a value-based approach to optimizing care.[55] The development of the protocols give anesthesiologists an opportunity to engage in discussions with surgeons and other providers involved in the patients' care about how to optimize perioperative care and how to modify anesthesia practice and pain management strategies to facilitate recovery and potentially reduce complications. At the same time, while the reported improvements in outcome are impressive, anesthesiologists and other providers should ensure that outcome measures of most importance to patients are incorporated into future ERAS protocols in order to enhance their value.[58,69]

PERIOPERATIVE SURGICAL HOME

The expanding roles identified for anesthesiologists provide the foundation and framework upon which they can take on even broader roles as perioperative physicians.[70-72] The American Society of Anesthesiologists (ASA) in collaboration with other medical specialties has developed the perioperative surgical home (PSH) as a model for coordinating care throughout the entire perioperative period.[73-75] Many of the concepts incorporated into the PSH are built on the same foundation as those incorporated into the PCMH model. The PCMH is designed to better manage patients with complex medical problems and comorbidities in the outpatient setting,[49-51] whereas the PSH emphasizes clinical management of the patient from the time of scheduling of a surgical procedure through the entire perioperative period. The PSH is designed to specifically optimize outcomes during and after surgery, and to facilitate the transition of the patient back to the primary care provider. As with PCMH, the concept of the PSH model is to provide patient-focused care, consistent with patient goals and expectations. The goal for the PSH is to develop evidence-based clinical pathways designed to improve outcomes, and reduce overall costs-of-care across the continuum, including costs associated with home care and skilled nursing facilities.[76] Although the goals for implementation of the perioperative surgical home are clear, there is no single model nor list of specific guidelines one can follow when implementing a PSH. For some PSH models, the anesthesiologist assumes primary responsibility, whereas in other cases the surgeon is the lead provider. For some PSH models, co-management agreements with other providers has facilitated coordination of care and resulted in fewer surgical cancellations, less complications, lower lengths of stay, and fewer readmissions. For many PSH experiences, even when the anesthesiologist assumes a major role in the overall care of planning and execution, input from other providers (including hospitalist or medical

subspecialist) is obtained based on the clinical needs of the patient. The collaborative relationships that are developed under the PSH extend to the care of other patients and provide the opportunity for other providers to better understand the skills, roles, and responsibilities of the anesthesiologists. These relationships are also critically important in representing the value anesthesiologists have under bundled payment models.

Although the goals for the PSH and ERAS protocols have some similarities, the components and overall goals for the PSH are somewhat broader than the expected outcomes for ERAS protocols. As proposed by the ASA, the PSH has the following major goals:

- identify the patient and proposed plans;
- facilitate communication among the surgeons, anesthesiologists, and others as needed to coordinate care;
- provide thorough preoperative assessment and develop a care plan, including management strategies for associated diseases;
- develop and implement evidence-based protocols for clinical care throughout the perioperative period;
- manage clinical care across the continuum; and
- measure and publicly report outcomes and performance.

The fundamental components of the PSH are clearly desirable goals and build on many of the basic concepts of perioperative medicine. The PSH is generally more comprehensive, requires thoughtful leadership and institutional commitment beyond what is often required for an ERAS protocol designed to reengineer care for a focused surgical procedure.[76,77]

A number of examples of the PSH model have been successfully implemented for selected patient populations with impressive results.[78,79] Some are relatively straightforward evidence-based strategies to optimize perioperative care, whereas others are more comprehensive. The process for developing a PSH can be cumbersome and requires a great deal of coordination across both inpatient and outpatient settings and, in some cases, participation of different healthcare systems. The model requires a designated physician leader who has responsibility for overseeing the continuum of perioperative care. To implement a successful PSH requires that the physician champion have some training and experience in process improvement strategies.[80] The model also requires support from other providers, particularly surgeons and hospital administrators.[81] Although the PSHs have been implemented in a variety of healthcare settings, the most comprehensive models can be successfully implemented in "closed" healthcare systems, such as the Veterans Administration, Kaiser, and other fully integrated delivery models.[79,82-84] The implementation is more challenging when the PSH requires participation of providers and facilities from multiple different environments, as may be required for patients needing rehabilitation, skilled nursing, or home care.

Despite these constraints, the implementation of the PSH has been successful with improved clinical care, reduced costs, shorter lengths of stay, fewer hospital readmissions, and both provider and patient satisfaction. The fundamental components of the PSH are clearly desirable goals and build on many of the basic concepts described for perioperative medicine. The model has promise in addressing the challenges associated with care to patients with complicated medical problems who are scheduled to undergo a complex surgical procedure. How effectively this model can be expanded to address this broader patient population and engage more providers and health systems is still to be determined.[77,85]

Conclusion

Perioperative care continues to evolve, in large part because of the advances made in surgical and anesthesia management of patients undergoing complex procedures in the operating room and nonoperating room settings. Surgical procedures are now commonly performed on patients with underlying medical conditions that impact anesthetic and surgical management. At the same time, and, in part as a result of the changing patient population, the cost of care continues to escalate. Payors are concerned about the increasing costs of care and, in some cases, point to the lack of evidence to support some costly clinical practices. Medicare and some private payors are transitioning to MIPS with associated incentives for providing value-based care and penalties for poor performance.[86] At the same time, providers are being asked to assume greater risk by providing bundled payment for selected diagnoses. To address these dramatic shifts in payment and concerns about the overall costs of surgical care, new models of perioperative care and implementation of clinical pathways based on evidence have evolved. These new models of care require better cooperation and coordination among all providers. The concepts behind perioperative medicine provide the framework upon which to reengineer care to address these challenges. Although no single strategy is appropriate for all clinical settings and patient needs, the one critical component of perioperative medicine is the need to implement a model of care that ensures coordination, collaboration, and improved transitions across the continuum from preoperative assessment and management to postoperative rehabilitation. These elements provide the opportunity for anesthesiologists and anesthesia departments to expand their scope of practice, building on the successes in improving intraoperative quality and safety. A number of alternative approaches to optimizing perioperative care may be appropriate and in all likelihood, multiple strategies will be required to address the idiosyncrasies of each patient population, surgical procedure, and institutional capabilities. The PSH is an example of a new creative model that might have significant benefit for selected patient populations; aligning patient's, provider's, hospital's, and payor's goals; and significantly improving perioperative care by building on the experience and successes of other approaches including ERAS, the surgical hospitalist model, and the PSH. To successfully assume an expanded role, anesthesiologists will have to build on their clinical expertise, and will have to acquire and analyze data on outcomes and costs to document that the new models of perioperative care are fulfilling the needs of all providers, health systems, payors, and, most importantly, patients.

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4 Informatics in Perioperative Medicine

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KEY POINTS

- Individual computers are connected via networks to share information across many users.
- Information security is about ensuring that the correct information is available only to the correct users at the correct time.
- Healthcare information storage and exchange is regulated to protect patient privacy.
- Information regarding the provision of anesthesia care is highly structured and organized compared to most healthcare specialties.
- Anesthesia care documentation systems have evolved in complexity and are now widely adopted in the perioperative care of patients in the United States.
- Benefits of electronic documentation of anesthesia care typically emerge from integration with monitoring, scheduling, billing, and enterprise electronic health record (EHR) systems.
- Active and passive decision-support tools may suggest typical courses of action or call to attention patterns that are not apparent to the clinician.
- Secondary use of EHR data is valuable in understanding the impact of clinical decisions on patient outcomes and the measurement of quality of care.
- Electronic devices may act as distractions within the operating room (OR) care environment.

Introduction

Computers have become ubiquitous in modern life. Their use has penetrated every medical field and the practice of perioperative care is no different. Computers have given rise to the academic discipline of informatics, the study of information creation, storage, handling, manipulation, and presentation. Within health care this is referred to as medical, biomedical, or clinical informatics.

Computer Systems

At their most basic, computer systems are complex electronic circuits that perform mathematical operations (add, subtract, multiply, divide, and compare) on information available to them. Even the most complicated computer systems consist of these operations repeated millions of times per second, which collectively generate the activity specified by the user. Every operation performed within the computer begins with the retrieval of information in the memory, a mathematical operation within the processor, and the storage of the output of that operation back to the memory. This cycle of retrieval, processing, and storage repeats millions of times per second.

Software applications execute the instructions that a computer uses to process information. The operating system is the fundamental software that controls the communication among the components of the computer. The operating system controls the order in which a processor completes tasks, allocates memory among different applications, provides a structure for organizing files in the long-term storage, controls access to files, determines which applications may run, and manages the interaction between the user and the computer. Modern operating systems provide graphic interfaces that act as paradigms to describe the organization of information and methods of user-specified computer action.

A software application is a set of instructions for a computer designed to perform a specific set of tasks. Electronic health record (EHR) software is an example of a software application. Software may (via the operating system) interact with external hardware devices, data held in long-term storage, and the user by way of input devices and display devices.

Because of the proliferation of mobile devices, traditional laptop or desktop computer systems have been supplanted in many environments by tablets or smartphone computers. These devices are structurally similar to traditional computing devices; however, the operating systems and software applications feature user interfaces that have been re-engineered to support use by touch screen or voice control operation. These devices trade off computational power, portability (size- and weight-related), and duration of operation (battery power).

Computer Networks

Networks are the means for the exchange of information among computers, enabling the sharing of resources. These networks may be established using wireless (e.g., microwave radio spectrum) or wired connections (Fig. 4.1). Dedicated hardware (equipment) controls the sending and receiving of information across these links, with specialized devices required to ensure that information is sent correctly

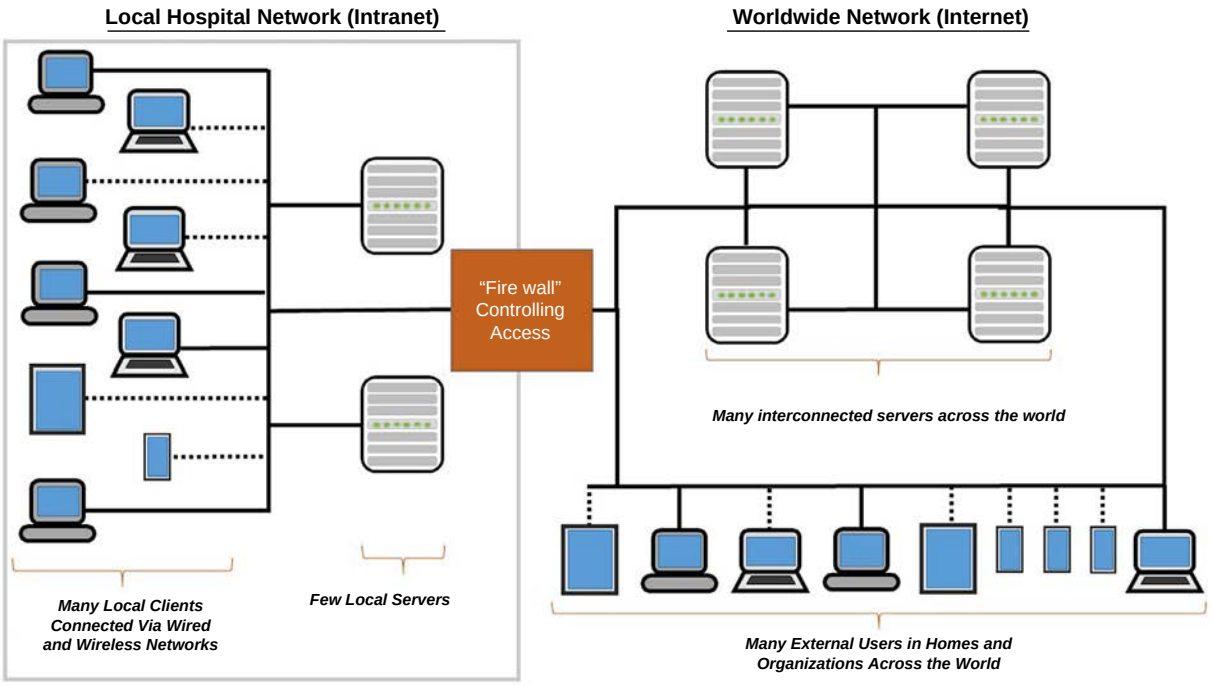

Fig. 4.1 Relationship between a local intranet (within an institution) and the wider Internet. Institutions may choose to use an external vendor to provide certain services hosted on external servers, this is referred to as "cloud" computing or services. Prevention of unauthorized access to the intranet from external parties while allowing users to access the Internet and other remote resources is of paramount concern. "Firewall" devices aid in the separation of the institutional network from the wider Internet and control access.

to the intended computers on the network. Software is used to ensure communication is performed according to predefined standards. In order for a computer to be accessible in the network, each computer must be given a unique address on the network so that information can be identified as destined for that computer. The process of obtaining and maintaining network addresses is performed within the local operating system and network hardware. This allows software applications to specify the information to be sent and the operating system and network hardware to manage how it is exchanged between computers.

Wired networks require the computer system and the receiving hardware to be physically connected by electrical or optical cable. This limits the flexibility in the connection points, which must be placed in preplanned areas, with any subsequent adjustments requiring re-routing of cables. However, information travelling on the network cannot be intercepted or accessed without physical access to the network cables or connection points.

Wireless network systems offer advantages of convenience and the ability to move around a work environment without maintaining a physical connection among the computer systems. However, this usually occurs at the expense of speed of information exchange. Information exchange via wireless links is an order of magnitude slower than the fastest wired connections. Because wireless systems require the availability of strong radio links between the computer and the network equipment, they are subject to issues of poor reception (possibly because of physical barriers) and interference, which manifest as inaccessible or degraded network performance. It is difficult to control the precise limits of where a wireless network is available (i.e., only within a building and not immediately outside of it), therefore processes to limit wireless network access to authorized users and to encrypt data transmitted across wireless links are required.

In practice, healthcare facilities use a blend of both wired and wireless networks to ensure that the advantages of each system are available to support the users.

In most settings, the network is organized as a "client-server" model. The computer that hosts the shared resources is referred to as the "server" and the computer accessing the resources is the "client." The server is responsible for ensuring the client is an authorized user of the shared resource (access control) and ensuring the resource remains available to multiple users, potentially by preventing one client from monopolizing the use of the resource.

The client-server concept stands in contrast to peer-to-peer architecture, whereby resources are distributed across systems, with each computer on the network contributing its resources (e.g., files or specialized hardware). All computers are both clients and servers in this arrangement. There is limited ability to control access in a planned and coordinated manner.

Use of a client-server infrastructure may allow for a significant amount of the computational tasks to be outsourced to the central server. When the client has very limited computational resources this is referred to as a "thin client." Computationally intensive tasks can be performed by the server and the client receives the results of the computation. Fundamentally, the thin client is viewing and interacting with a software application that is running on the server. The client is little more than a means of sending user input to the server and a dynamic display of application results. In order for this arrangement to work, there must be a limited, predictable set of software applications

that the client accesses on the server, with a reliable network connection. Without the network connection, the thin client has no functionality. This model may be easier to maintain because any changes are done centrally and need to be made once and then become available to every client connecting in.

An alternative model is the "thick client," where the client is capable of significant computational activities, retains a fully functional state when not connected to the network, accesses only the information required across the network, and processes it independently. However, these clients require individual maintenance.

A hybrid solution is the concept of "application virtualization," whereby a single software application is hosted and uses the computational resources centrally and the client systems access this application regardless of their configurations. This blends the advantages of a thin client—control of the application's availability, ease of maintenance, and ensuring compatibility (by not requiring any level of computational resources aside from running the connection to the server)—with users having a fully functional computer or device to use for the remainder of their tasks. Additionally, this hybrid enforces a separation between the information stored on the server and any applications running on the client and thus information can be secured within the server that is housed within the institutional network.

The Internet

The Internet is a global network of networks. Best known by two of the ways in which it can be used—websites and email—the Internet is at its simplest a method for transferring electronic information across the world. Internet service providers (ISPs) provide access to optical and electrical cables, which transfer information across the world. As these cables are all interconnected, multiple paths are available to transfer data at any one time. Routers control the flow of Internet traffic and ensure that it takes the most direct and fastest routes across the multiple paths available to it. Although the delay that a user may experience in accessing information varies widely and is dependent on many factors, the flow of information around the world can be measured in the order of hundreds of milliseconds or less.

Use of the Internet has led to the development of a series of technologies where computing resources are offered to multiple clients using an Internet connection as a means of distribution and interaction with the clients (see Fig. 4.1). These "cloud" platforms allow on-demand and scalable use of computing resources. Computing resources can be bought and sold based on the variable amount of time they are used or the amount of information stored; additional capacity can be flexibly added. These resources are accessible from anywhere with an Internet connection. Furthermore, cloud platforms give organizations the ability to transfer the management of the specialized computer hardware needed to provide these services to another party.

The integration of mobile phone data networks and the proliferation of increasingly powerful handheld devices (such as smartphones or tablets) has increased further the number of potential clients. For healthcare organizations, there is significant user pressure to be able to access healthcare information systems remotely or from these mobile devices.

The most ubiquitous usage of the Internet is in the delivery of "web pages." Information is stored on a "web server" and upon request from an application being run on a remote client computer (web browser), the information and display formatting instructions (i.e., size, shape, position of text, or graphics) are sent to the client. The web browser then interprets these instructions and displays the information according to the specified instructions. This process is highly dependent on well-defined and accepted standards of information exchange between client and server and rendering by the client.

These web pages have become increasingly sophisticated incorporating text, video, audio, complex animations, stylesheets, and hypertext links. Technologies have evolved into an interactive process that can dispense information specific to only one user (e.g., a record of the user's bank transactions) and that can be supplied in a manner that is generalizable to many different users (so all customers can access their bank transactions this way). When these instructions are assembled to generate specific business processes, they function as software applications that are web based and are referred to as "web applications" or "web apps." Interaction with web pages may lead to complex business processes being undertaken in the physical world. For example, the ability to buy a book over the Internet starts with a web page displaying the information and ends in someone delivering it to the door, with many physical steps in between. Healthcare organizations have embraced these technologies to support their delivery and administration of patient care, including scheduling systems, laboratory result reporting, patient communications, and equipment management systems, all of which are delivered in this manner.

Of note, information which is travelling across the Internet, without additional measures, is not necessarily private. A salient metaphor would be to consider the difference between information being conveyed in an envelope (where the contents are not visible) and information being conveyed on a postcard (where the message is clear to anyone who holds it).

Information Security

Although computing technology has significantly influenced the delivery of medical care, it has also brought a series of challenges that must be addressed. A major consideration is information security. Core to these considerations is ensuring that the correct information is available to the correct users at the correct time.

These threats to information security may come from within or outside an organization. Within organizations, an employee may access information that they are not authorized to so do or by transferring and storing it in an insecure manner. They may introduce security threats by using applications that may transfer information outside of the organization or by modifying an existing network by using a personal device. External threats may seek to improperly access information ("hacking") by obtaining passwords or

identities from legitimate users (via "phishing" attacks) or by introducing applications that degrade computer function to extort payment ("ransomware" attacks).

The paradigm used for controlling access to computing resources is users and accounts. Each person who uses the computer is considered to be a user. Users can be identified and mapped to real-world persons. Users may belong to groups that share common attributes. It should be known in advance which resources should be available to which users or groups of users. A group of users (i.e., anesthesia providers) may have access to particular resources (e.g., a document of anesthesia policies) but each user may also have access based on their individual parameters (e.g., an individual anesthesiologist may have sole access to his or her own private files). A group of users with similar functional roles who have a defined set of resource privileges is known as "role-based security." Changes in privileges affect all users in that functional group.

Users should be able to positively identify themselves; commonly this involves the combination of a username and password with the password being known only to the user and the computer system. However, other methods of authentication, such as biometric information (fingerprint, iris scan, or face scan) or physical access tokens (e.g., identification badges) are now commonplace. Password policies that enforce a mandatory level of complexity (minimum length, mixing letters and numbers, or special characters), specific expiry dates, and prevent password reuse are designed to make it harder for passwords to be guessed by an unknown party or to mitigate or minimize the risk of passwords being accessed or used externally. However, requirements for increasing complexity or frequency of changes may pose additional burdens on users that they consider unacceptable and may not decrease risk.

Organizations may also choose to adopt "two-factor authentication" methods, which can be summarized as requiring "something you know and something you have" to gain access to the computer system. The password fulfills the first part of this concept as it is meant to be known only to the user. Devices such as physical token code generators (which provide a predictable response to be entered alongside the password) or an interactive system (authentication via a smartphone application or phone call) may satisfy the second concept. Thus, in order for someone to impersonate the user they must have both the password (that may have been taken without the user's knowledge) and a physical device (that the user is more likely to detect the absence of). This makes remote access less likely because an external user on the other side of the world may be able to obtain or guess a password but is very unlikely to also be able to obtain the token or smartphone required for access.

Physical security is an integral part of information security. Ensuring that an unauthorized person does not have physical access to computer hardware or access to the means of connecting to that computer hardware are important considerations. This can be accomplished by physical measures (such as locked rooms, doors, and devices that prevent movement of computer hardware) and considerations of where computers containing controlled information are placed (to prevent an unauthorized person from having access to a computer that is available in a public area).

However, as alluded to before, these restrictions are balanced against desires for increased usability and portability of computing devices from computer users and the need to make information available to the provider at the point of clinical interaction.

Therefore, it is necessary to ensure secure access to information across wireless links and across the Internet. One method for doing this is to ensure that the information transferred is not readily visible along its means of transmission. This is performed by a group of processes known as encryption. Encryption is the process of transforming a piece of information from its original and accessible state to one that is not accessible and lacks meaning without an additional piece of information (an encryption key).

The transformation to and from encrypted text takes place in a manner that is relatively easy to perform with the known encryption key but is infeasible to do so without knowing this key. Encryption processes are based on mathematics involving multiplication of very large numbers, which creates many possible combinations of different factors that could have led to the same outcome. Therefore, it would be computationally infeasible, with current technology, to attempt to try all possible solutions.

External threats to an organization involve outside entities attempting to access services or applications that are meant for internal use only. Because healthcare organizations must be connected to the Internet to enable many information exchange functions, their data may potentially be available to every Internet-connected device in the world. "Firewalls" are used to ensure that only legitimate transactions and interactions with the external world are exposed to the internal hospital network. These hardware or software tools, collectively known as a firewall, prevent the creation of unauthorized connections from outside the organization to the internal computing systems. Firewalls can also limit the types of network traffic that are allowed to exit from the internal networked system. For example, it may restrict network traffic typically used for the sharing of files.

In order to allow legitimate external access, organizations may allow the creation of virtual private networks (VPNs). After appropriate authentication and verification, VPNs set up an encrypted path for information from an external Internet-connected computer to the organization's internal network. This allows the external computer to act as if it was physically connected to the organization's internal network and to access resources such as specialized software or shared files. This adds an additional layer of access security to the connection and ensures the communication is secure. A healthcare organization may require use of a VPN to access an EHR from outside the organization's network.

Standards for Healthcare Data Exchange

Although not always obvious, the EHR is typically an amalgamation of multiple computer systems and devices of various complexity. These systems exchange data according to common standards, languages, and processes.

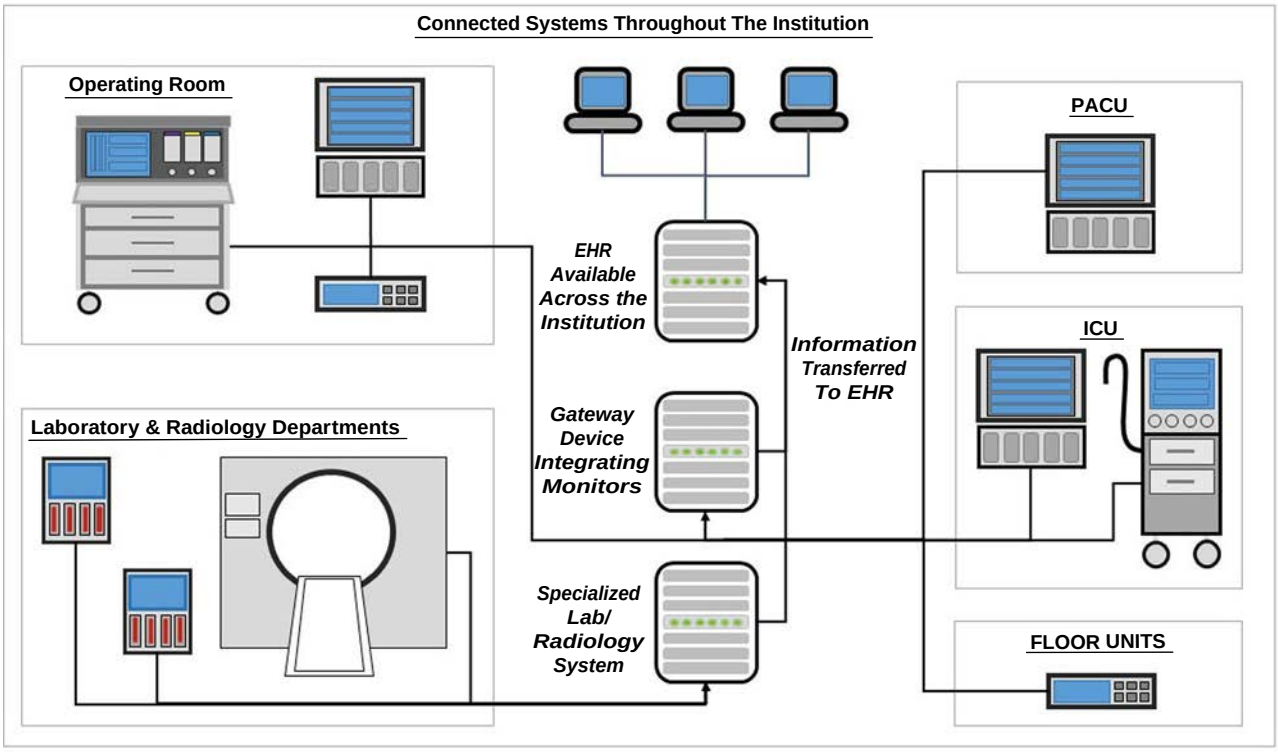

Fig. 4.2 Information flows from connected devices across the institution into the electronic health record (*EHR*). Some departments maintain specialized software to manage the needs specific to their workflow—for example Radiology departments using Picture Archiving and Communication Systems—that are interfaced into the EHR (i.e., to allow a report to be connected to the original CT scan). Similarly networked monitor data is made available by the use of a gateway interface device. *PACU*, Postanesthesia care unit

Common connections include monitoring devices that allow automatic transfer for measured parameters into the electronic chart, infusion pumps (recording programmed settings), laboratory instruments (blood gas machines, cell counters, biochemistry analyzers, point-of-care testing devices), or systems that manage patient admission, identification, and bed occupancy (admission, discharge, and transfer [ADT] system). All of these devices and systems need methods of communicating with the EHR (Fig. 4.2). Although in some situations it may be possible to use a proprietary standard for communication between systems, it can quickly become difficult to manage across an entire institution. As a consequence, a series of commonly used standards have been established that allow the communication of healthcare information.

The Health Level-7 (HL7) standard, originally developed in the late 1980s, is still used widely in the exchange of health information. HL7 allows the transmission of data in a standardized manner among devices and clinical systems. The information can be identified to a specific patient and organized into different data types, indicating laboratory results, monitor data, and billing information. It can also cause the receiving system to perform an action, such as update previously obtained data. The HL7 standard and subsequent derivatives that address the exchange of clinical documents in a structured and identified manner support communication among different clinical systems. However, this standard was based on data exchange within different software application systems within an institution and did not envisage the proliferation of Internet-connected devices remotely accessing shared resources across many healthcare organizations.

This new paradigm led to the development of Fast Health Interoperability Resources (FHIR). This communication standard is analogous to how modern Internet applications exchange data via simple standardized requests to a central resource. FHIR enables easier integration across different types of software and integrates security features necessary due to the proliferation of mobile devices. This standard is designed to facilitate the exchange of data regardless whether it is a single vital sign or a scanned document from a physical chart.

Regulation of Electronic Data Exchange

In the United States, the 1996 passage of the Health Insurance Portability and Accountability Act (HIPAA) established a common regulatory framework that defined health information and the processes by which it should be stored and transferred, and established powers to investigate concerns regarding noncompliance with these rules.

There are four major regulatory rules: the HIPAA Privacy Rule, Security Rule, Enforcement Rule, and the Breach Notification Rule. Each update is a complex regulatory document and professional advice should be sought on the applicability and relevance of each of these to a particular situation.

The HIPAA Privacy Rule details the allowable uses and disclosures of individually identifiable health information,

which is referred to as "protected health information" (PHI). Identifiers that are considered PHI are listed in Table 4.1. The privacy rule additionally defines the healthcare agencies covered by the rule. It defines processes that must be taken when working with business partners outside the healthcare agency through the creation of business associate agreements. Further, it establishes the concept of a limited data set, which is a set of identifiable healthcare information that is devoid of direct identifiers and can be shared with certain entities for research purposes, healthcare operations, and public health reasons; use of these is governed by "data use agreements."

The HIPAA Security Rule applies specifically to electronic PHI (e-PHI). The rule requires that e-PHI created, received, maintained, or transmitted by an organization should be done so confidentially and in a manner that ensures data integrity and availability. Additionally, the rule requires that threats to information security be monitored and measures be taken to mitigate these threats; this includes audits of computer systems to ensure unauthorized access has not occurred. The specification includes physical, technical, procedural, and administrative measures, all of which need to be undertaken for compliance. In general, the rule does not specify a particular set of computing resources that should be used, but instead specifies the standards to which they should be verified.

The HIPAA Enforcement Rule established the processes whereby a breach of the privacy rule could be investigated, and sanctions enforced. The Office of Civil Rights (OCR) within the Department of Health and Human Services (HHS) is responsible for receiving and investigating these complaints. Complaints may also be referred to the Department of Justice if it is believed that a criminal breach has occurred. Penalties for noncompliance can involve significant monetary fines or imprisonment in the context of criminal acts.

Finally, the HIPAA Breach Notification Rule defines what a breach of PHI data security is and obligates covered organizations to report to the OCR breaches of PHI that are discovered. Differing timelines for reporting apply, depending on if the breach involved greater or fewer than 500 individuals. Notification must also be provided to affected individuals and potentially to the media, depending on the number of individuals involved.

TABLE 4.1 Data Elements that Allow Patients to Be Identified

HIPAA IDENTIFIERS
Names
All geographic subdivisions smaller than a state, including street address, city, county, precinct, ZIP code
All elements of dates (except year) for dates that are directly related to an individual. Ages over 89 and all elements of dates (including year) indicative of such age
Telephone numbers
Vehicle identifiers and serial numbers, including license plate numbers
Fax numbers
Device identifiers and serial numbers
Email addresses
Web Universal Resource Locators (URLs)
Social security numbers
Internet Protocol (IP) addresses
Medical record numbers
Biometric identifiers, including finger and voice prints
Health plan beneficiary numbers
Full-face photographs and any comparable images
Account numbers
Any other unique identifying number, characteristic, or code
Certificate/license numbers

HIPAA, Health Insurance Portability and Accountability Act.
Adapted from https://www.hhs.gov/hipaa/for-professionals/privacy/special-topics/de-identification/index.html. Accessed March 3, 2019.

The Nature of Healthcare Information in the Anesthesia Encounter

In the conduct of anesthesia care, much of the information gathered could be considered as frequently-occurring structured data. That is, much of the information contained within the encounter can be categorized into one of a relatively small number of groups. This information is present commonly across anesthesia encounters. And the information itself can often be restricted to a small number of possible options—consider the example of an airway assessment.

This applies to information gathered in the preoperative phase of care (i.e., Mallampati classification from an airway examination) and the intraoperative phase of care (i.e., heart rate or systolic blood pressure). Furthermore, the intraoperative phase of care is marked by repetition of information at predefined intervals with measurements that may be taken in an automated manner (e.g., noninvasive blood pressure recordings every 3 minutes).

A majority of data gathered during an anesthesia case is structured, limited, and predictably repeated. However, the data are also voluminous with data generated and captured continuously on monitors, anesthesia machines, and medication pumps. More than 50 different parameters may describe a single minute of anesthesia care.

This is in contrast with the nature of the information captured in many medical specialties that are not easily constrained by content or structure. The documentation of a primary care visit may follow a standard format, however the number of variables captured may not be easily defined in advance or constrained to a standard structure; the range of possible issues to be documented may be too broad.

Anesthesia-derived data is well suited for capture into electronic charting systems. A number of mature commercially available systems are available for undertaking this task. These systems are often not standalone, and we will discuss how they are integrated in the next section.

Development and Deployment of Anesthesia Information Management Systems

Given the suitability for automated capture of recurring high-volume data, the concept of using computerized capture and storage for parts of the anesthesia record is not new. McKesson in 1934 described an early form of monitor that integrated with a vital signs data recorder (Fig. 4.3).[1] Early pioneering systems included the Duke Automatic Monitoring Equipment (DAME) System and its more compact successor, microDAME, which combined an internal monitoring platform with an integrated network architecture for central data recording.[2] Anesthesia Record Keeper Integrating Voice Recognition (ARKIVE) developed commercially in 1982 by Diatek included both a voice and touch screen interface.[3,4] Over time, other systems became available and these progressively morphed from being described as "anesthesia record keeping" (ARK) systems to "anesthesia information management systems" (AIMS) as the range of features and integration with other systems progressed.

Despite extensive development of a number of commercial systems, the use of AIMS was relatively limited in the early 2000s. Survey estimates suggest that by 2007 market penetration in academic medical centers increased from approximately 10% to approximately 75% by the end of 2014. By 2020, it is estimated that market penetration will reach 84% of all medical centers.[5-7] In the United States, the implementation of EHRs has been encouraged by federal government financial incentives including the American Reinvestment and Recovery Act of 2009, which authorized up to $11 million dollars per hospital to finance the adoption of health information technology.[8]

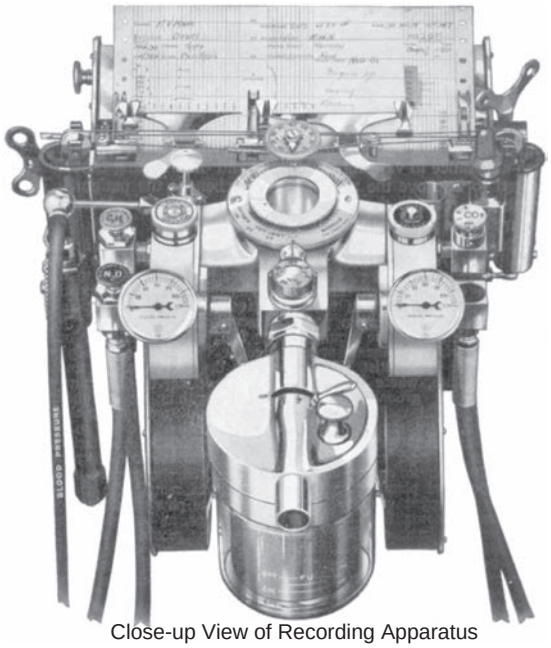

Fig. 4.3 McKesson's apparatus for the automated recording of physiologic recordings and gas mixtures. From 1934. (From McKesson EI. The technique of recording the effects of gas-oxygen mixtures, pressures, rebreathing and carbon-dioxide, with a summary of the effects. *Anesth-Analg.* 1934;13[1]:1–7 ["Apparatus" Page 2])

The adoption of health information technology has resulted in the increasing integration of the anesthesia record with other clinical systems. The American Society of Anesthesiologists (ASA) has produced a statement on the documentation of anesthesia care.[9] Such systems can be used to fulfill clinical documentation needs; however, much of the promise of these systems is in the potential for integration with the broader hospital environment and secondary uses of the data that they potentially facilitate.

ANATOMY OF AN ANESTHESIA INFORMATION MANAGEMENT SYSTEM

A mature AIMS must be capable of (1) recording all aspects of the anesthesia encounter (preoperative, intraoperative, and postanesthesia care unit [PACU]); (2) must automatically gather the high-fidelity physiologic data generated by monitoring platforms and anesthesia machines; and (3) must allow the anesthesia provider to record observations regarding the conduct of the anesthetic. These three simple requirements allow us to closely specify the anatomy of an AIMS.

The first requirement for access of the same patient record during multiple phases of a case suggests the use of a system organized on a computer network, where the computer record is maintained on a central server and accessed by multiple clients. This capability requires accessibility of computer workstations at each patient-care location to facilitate documentation. The computer must be accessible during the clinical interaction but in a way that does not interfere with this interaction, which is both an issue of ergonomics and of provider behavior. In the operating room (OR), the system should be directly accessible at the time of clinical care to allow contemporaneous documentation without the anesthesia provider physically moving away from the patient or care area. In many deployments, this is achieved with a computer mounted to the anesthesia workstation alongside the monitoring equipment. Because the computer hardware is located in clinical environments, these may become contaminated with pathogens and it is important that the hardware can be cleaned in a manner that is compatible with infection control policies.[10,11]

The second requirement for automated capture of data from OR monitors and anesthesia machines is some form of interface device between the computer hardware and the hemodynamic monitors, anesthesia machines, and other patient-connected equipment (infusion pumps or ventilators)—Table 4.2. In most AIMS implementations, this interface occurs at a central level, where a network of the physiologic monitors and the central server hosting the AIMS communicate via a gateway device. Typically, interfaces use standardized data formats, such as those described earlier that transmit communication among devices and software solutions from different manufacturers and developers. Interfacing these devices with a computer network may require specialized hardware and additional cost. However, the interface enables the automated capture of

TABLE 4.2 Examples of Parameters Commonly Included in the Anesthesia Record Gathered Automatically from Different Sources

FROM CORE PHYSIOLOGIC MONITOR
Arterial blood pressure (systolic, diastolic, mean)
Cardiac index
Cardiac output
Central venous pressure
End tidal CO_2
Heart rate (ECG monitoring and SpO_2)
Intracranial pressure (ICP)
Noninvasive blood pressure (systolic, diastolic, mean)
Pulmonary artery pressure (systolic, diastolic, mean)
Pulse pressure variation (PPV) and systolic pressure variation (SPV)
Saturation of peripheral oxygen (SpO_2)
ST segment analysis
Systemic vascular resistance
Temperature (all sources)
FROM STAND-ALONE DEVICES (MAY BE AVAILABLE WITHIN SOME CORE PHYSIOLOGIC MONITORS)
Acceleromyography value
Cerebral oximeter (NIRS)
Continuous cardiac output measurement devices
Level of consciousness monitors
Mixed venous oxygen saturation (SvO_2)
FROM ANESTHESIA WORKSTATION
Fraction of inspired oxygen (FiO_2)
Fresh gas flows: oxygen, air, nitrous oxide
Volatile anesthetic agents (inspired and expired concentrations)
Minute volume
Nitrous oxide (inspired and expired concentrations)
Oxygen (inspired and expired concentrations)
Peak inspiratory pressure (PIP)
Positive end-expiratory pressure (PEEP)
Respiratory rate (ventilator and $ETCO_2$)
Tidal volume
Ventilator mode

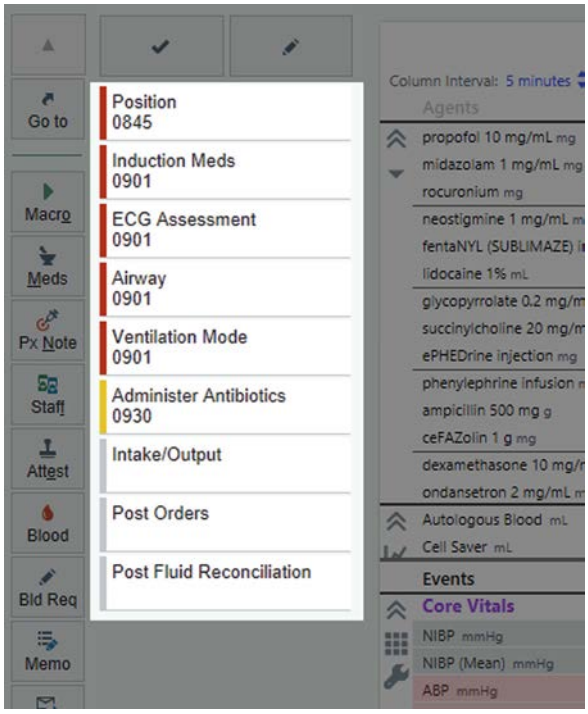

Fig. 4.4 A pre-defined set of charting elements for a given case. These may function as an example of passive decision support built into the EPIC Electronic Health Record Anesthesia Documentation (EPIC Systems, Verona, WI). The macro *(highlighted)* prompts the user to complete next documentation element. The "Administer Antibiotics" acts as an *aide-mémoire* reminding anesthesia providers that this is likely the next step in the process of care. (Image: © 2018 Epic System Corporation. Used with Permission.)

monitor and anesthesia machine data, freeing up clinical providers from the recording of these data elements. In light of the cost and practical challenges, some AIMS situated in low-resource settings (e.g., an office-based anesthesia location) may choose to eliminate the data interface feature.

Theoretically all electronically generated data can be recorded in the AIMS. As a consequence, the anesthesia provider must determine how much data should be incorporated into the system. Although some monitoring data is obtained with a defined frequency, such as a noninvasive blood pressure measurement taken every 3 minutes, most parameters are sampled from continuous data sources. In the OR, a pulse oximeter is not a single parameter checked at a discrete interval, but a continuous source of data. Continuous data sources (e.g., electrocardiogram [ECG], pulse oximeter, invasive blood pressure, or end-tidal carbon dioxide [$EtCO_2$] tracings) are transformed into measures that can be recorded with lower data intensity requirement, a process known as sampling. An ECG tracing may be sampled and interpreted to report heart rate and ST segment analysis results. Although it is technically possible to record continuous sources of data electronically for future review, this usually does not occur because the resulting data stream is difficult to present, archive, and review. Therefore, continuous data sources are usually reported as sampled values at a prespecified frequency.

The third requirement of an AIMS is to allow the user to annotate information (e.g., medications administered, descriptions of procedures performed, annotations to describe significant clinical events, or attestations for regulatory compliance) to the automatically collected data. Because of the similarity of one anesthesia encounter to another, some charting elements may be predefined to facilitate these documentation tasks and minimize the use of nonstructured or "free text" entries. Because of the possibility of similarity among cases, many systems use organized templates (sometimes referred to as "scripts," "templates," or "macros") that give the anesthesia provider easier access to charting elements required for a specific case type (Fig 4.4). For example, a cardiac anesthesia template may make charting elements regarding cardiopulmonary bypass

prominent and easily selectable. These charting elements and templates are typically customizable at each installed site, thus providing flexibility in documenting site-specific practices or procedures.

Although the three AIMS requirements described give some specifics about how a system may be constructed, they are minimum requisites. The AIMS that only provides these requirements is not one that would be considered high value. The major advantages of AIMS come from their integration into other clinical systems and healthcare processes, which will be explored in the coming sections.

ADVANTAGES OF IMPLEMENTATION OF AN ANESTHESIA INFORMATION MANAGEMENT SYSTEM

The shift to an AIMS is a key improvement in the quality of clinical documentation. Removing the task of manual documentation of physiologic parameters has not been shown to decrease vigilance to the clinical situation and may free up anesthesia providers to perform other tasks.[12-15] An AIMS also establishes an independent, unbiased record of monitoring and machine data. Finally, legibility issues noted in handwritten charting are resolved by the use of an electronically assembled record.

Early studies compared blood pressure values recorded in handwritten charts and those recorded by automated collection. The blood pressure recordings on handwritten charts had lower maximum systolic pressures and higher minimum diastolic pressures when compared with automated collected values in OR studies.[16-18] This variation has been termed the "smoothing effect" of handwritten charting and may result in loss of clinically meaningful data.[16,19] A subsequent study demonstrated that errors in handwritten charting were clustered during high-intensity periods; that is, induction, emergence, and significant clinical events.[20,21]

Although documentation of physiologic parameters may be more complete in AIMS-charted records compared with handwritten charts other data elements may remain incomplete.[22,23] As AIMS deployments have matured, it has become apparent that documentation quality varies among providers and important clinical fields can often be left incomplete, particularly when completion requires the entry of free text.[24] Medication administration has also been incompletely documented or omitted in the AIMS compared with observed practice with a similar effect of inaccuracies occurring during high intensity periods of care.[25] AIMS support degrees of customization, including designating certain data elements as mandatory prior to completion of the case, but the decision to add more mandatory elements must be traded off against risks of arbitrary data entry ("clicking through") or provider frustration, both of which detract from the aim of improved data quality.[26] It is clear that the system design and decisions made for default values or required data elements have significant influence on the quality of record created.

One solution to the challenge of excessively burdensome documentation requirements is to use an adaptive method that changes the required elements for documentation based on the clinical context—for example, requiring documentation of bilateral breath sounds in cases involving an endotracheal tube, but not with an laryngeal mask airway.[26]

In addition, to improve compliance with the capture of individual, high-priority data elements alternative strategies may be employed. Real-time provider notification by text page for allergy or procedural notes has demonstrated increases in completeness of this documentation.[27,28] Non-real-time feedback, via dashboards, email feedback, or informational campaigns may leverage AIMS data to improve data element completion.[29] These effects may be sustained past the interventional period.[27,29]

Integration with billing processes allows the automated capture of case elements necessary to facilitate anesthesia billing, such as care start and stop times, details of the surgical procedure for which anesthesia care is being provided, the nature of anesthesia care, any separately billable procedures, and the involved providers. This information can be extracted by reporting functions and integrated with the patient identifiers. Compared to solutions that require the manual review of copies of paper records, AIMS-based workflows offer significant overall process efficiency gains; although some designs unfortunately redistribute administrative tasks to point-of-care clinicians. The potential impact of AIMS use on anesthesia procedure includes improving capture of data elements needed for billing, improved documentation to support billing of anesthesia procedures, and billing capture at time of clinical care leading to more rapid processing.[27,28,30,31]

An advantage of an AIMS system is the ability to check concurrency of anesthesia providers across one entire organization in real time. In the United States, an "in-room" anesthesia provider must be physically present when anesthesia care is provided at all times. This is typically documented by "sign in" and "sign out" documentation times. An in-room provider may be supervised by a supervising provider who may supervise a number of ORs up to maximum specified by institutional or payer policy. The AIMS system can, at time of sign-in, check that no in-room provider is documented in more than one OR simultaneously and no supervising provider exceeds the prespecified supervision ratios. Checking at time of sign-in assures that these standards are not violated by documentation errors and prevents delays in the billing process. In certain billing environments, violation of the concurrency rules may cause rejection of claims at the time of billing.

Providing an anesthesia record that can be accessed concurrently by multiple users may facilitate remote monitoring of care being provided by the in-room anesthesia provider by a supervising anesthesia provider. This increased visibility of patient care being provided at each care location allows the supervising provider to maintain a better level of awareness on the course of the case and gives the supervising provider additional guidance on management decisions. OR managers benefit from similar insight and may be able to make decisions about resource utilization based on the documented care.

Integration of Anesthesia Care Information with Operating Room Information Systems

Given the necessity of maintaining information regarding locations of care, case, patient, staffing, and case progress, it is natural to integrate anesthesia information systems with OR

management systems. These systems are used in the scheduling of OR cases and assignment of staffing and supplies.

ORs are finite resources. There are a set number of available rooms, set number of available staff for these rooms, set times of availability of these staff, defined experience and specialization of these staff, and finite amount of specialist equipment for use in the rooms. As a result of these factors, ORs create enormous costs prior to any procedure being performed; efficient allocation and utilization of these resources are tied to financial outcomes of a hospital.

Each procedure performed requires allocation of procedural space, staff, and equipment that may be specific to the particular case. Therefore, it makes sense for this to be coordinated in a centralized manner. OR management systems are designed to accomplish this task controlling the allocation of these resources. These systems allow these resources to be allocated both generally (e.g., on Mondays OR 12 is dedicated for thoracic surgery cases [block scheduling]) and also specifically (e.g., John Smith is undergoing a right upper lobectomy by Dr. Jones from 11 AM to 1 PM on August 20), and further allocate staff and equipment to this procedure (case scheduling). Case scheduling may be enhanced by using historical procedural lengths to estimate future time needs stratified by proceduralist and specific procedure to be performed.

Scheduling of a case by a specific proceduralist allows the generation of a specific list of required equipment/instruments to be recalled based on anticipated requirements and proceduralist preferences. These "case pick lists" of "surgeons preference cards" can be used by supply teams to ensure that necessary equipment is available and predict future utilization.

The integration of OR management systems with AIMS provides the cases and procedures against which charting functions can be performed. Furthermore, communication between these systems can create common charting, such as phase of procedure (induction, procedure begun, procedure complete, etc.) which can be useful in understanding utilization of the OR environment for daily management and ascertaining longer-term trends. Given the enormous fixed expense incurred in the OR suite, an extensive literature has developed from the analysis of information derived from these systems regarding variability in procedure time, "turnover time" between sequentially scheduled procedures, and effect of variability of anesthesia-related case timings.[32-37]

A more recent trend is the integration of the AIMS and Operating Room Management Systems with the wider hospital-wide or "enterprise" EHR. This occurs via the development of specialized modules which account for the differences in workflow between the OR environment and the inpatient floor/ward units. These systems leverage common patient information—such as patient identification, demographics, registration, and location—then add specialization discussed above. Furthermore, this allows medical documentation, and laboratory and other diagnostic results to be made available to the perioperative providers on a single computer system.

One of the larger contrasts emerging from the OR workflow versus the rest of the inpatient environment is the process of medication documentation. When using an inpatient EHR, a provider enters a computer-based order for the routine administration of a medication. After pharmacy verification of the order, the medication is delivered to the appropriate unit for administration to the patient by a bedside nurse. In the OR environment, the medication administration decision making, selection of the medication from a pre-stocked cart, and administration is handled by an individual providing anesthesia care. This shortens the time from provider intent to patient administration. Therefore, the documentation needs to reflect the concept of care provided rather than care to be provided in the future (i.e., scheduling a medication to be administered). Given the high intensity of medication administrations, short time interval between administrations and supply from the bedside cart of the medications to be administered, the ideal documentation system should not be burdensome and allow rapid entry.

A number of features of the inpatient EHR are unavailable due to this mode of medication administration and documentation: positive identification of the patient and medication with a specified order—typically performed by "barcode" scanning of medications and patients at time of administration—is not performed as medications are typically documented retrospectively, although patients are positively identified at the beginning of each anesthesia care encounter. Additionally, automated medication interaction, dose, and allergy checking may not function in the context of perioperative administration due the practice of retrospective documentation. As the documentation of anesthesia care is quite different from that of most medical interactions. The differences in workflows must be accounted for in the development of modes of interaction and creation of documentation.

While most medications administered in the OR have a relatively short duration of action, there are important cases where medications which are administered in the OR have important consequences beyond the OR. Examples such as neuromuscular blockade, long-acting opioids, long-acting local anesthetic agents, and antibiotic administrations all may lead to important medication interactions well beyond the OR or need for modifications of postoperative care. Therefore, information regarding these administrations must be available to care providers working in the postoperative period. The use of "stand-alone" AIMS may contribute to a failure of communication of the use of these important medications. Interfaces between the stand-alone systems and enterprise EHRs allow this information to be communicated, however this poses additional development, maintenance, and deployment burden. Similarly, documentation of difficult airway management in the OR has impact beyond the OR as the patient may require emergent airway management in the intensive care unit or during future visits; information gleaned during the perioperative encounter may have enduring value to many other providers.

Development of Decision Support Tools

One of the most exciting promises of AIMS and enterprise EHRs is their ability to improve patient care by improving the decisions made by providers.[38] While medical decision making must be provided by responsible care providers, it is possible to aid decision making by providing default choices that support particular practice patterns, suggesting options which may be appropriate based on the type of care (see Fig 4.4), providing additional notification of important updated trends or results, and providing alerts based on the integration of multiple pieces of information. The former

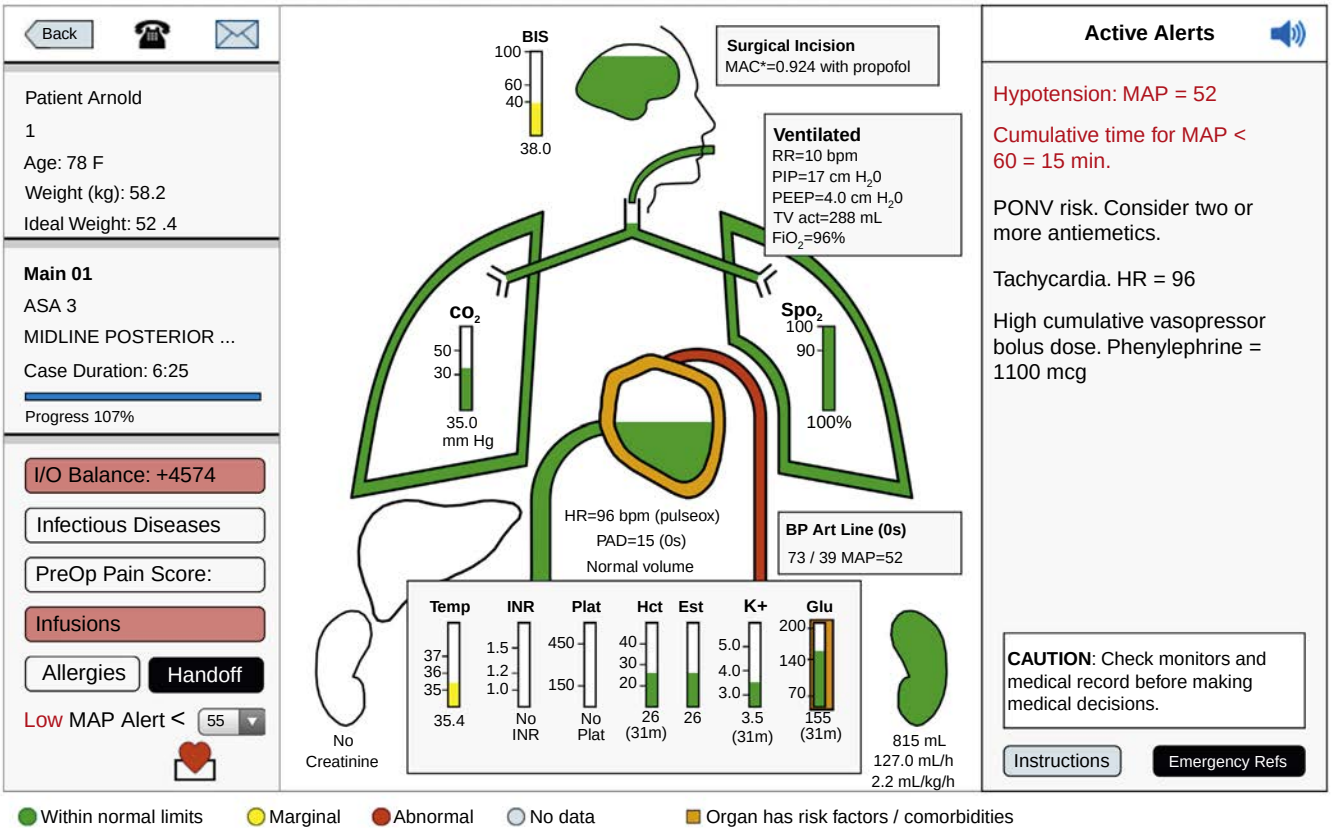

Fig. 4.5 The Alertwatch OR (Alertwatch, Ann Arbor, MI) multiparameter decision support system, illustrating the physiologic status of a patient under anesthetic care. This integrates data from physiologic monitors and electronic health record elements. Based on pre-specified rules it prompts providers to consider a specific course of action or indicates additional markers of patient state. * Indicates a calculated additive MAC value of inhaled agents and propofol and dexmedetomidine infusions.

two are examples of passive decision support, the latter two are examples of active decision support. Collectively these tools are referred to as decision support and are an integral part of the perioperative information system.[39]

PASSIVE DECISION SUPPORT SYSTEMS

In considering these tools it is helpful to move from the simplest to the most complex. At the simplest level in the configuration of the perioperative information system, decisions regarding the choices presented to users (default doses, units, and range checks) may act as prompts for users in their selections—the so-called anchoring effect. This is an example of passive decision support. Over time it is important to continue to assess how usage aligns with users' practice to ensure that the default options presented do indeed capture the typical usage at a particular institution.[40]

Systems for the documentation of anesthetic care typically feature methods for documentation of aspects of clinical care which cluster together based on aspects of the procedure, anesthetic technique employed, or location of service. For example, a template for cases performed via a spinal anesthetic would not be configured to require documentation of the endotracheal intubation technique as these do not frequently overlap. These can form the basis of decision prompts for providers; for example, in a cardiac case, the charting element available immediately after documentation of full cardiopulmonary bypass may be regarding discontinuation of mechanical ventilation. This may act as a reminder to the provider to perform this task. The level of sophistication of these prompts depends on the time devoted to their construction at the time of system installation and configuration.

One feature to improve documentation is the utilization of mandatory documentation elements that are required prior to the completion of case documentation. Extreme care needs should dictate what elements of documentation should be made mandatory. There are likely exceptions to even the most universal documentation element and forcing completion or entry of such items may undermine trust in the entirety of the clinical documentation.

ACTIVE DECISION SUPPORT SYSTEMS

In the intraoperative space, a number of more sophisticated approaches to decision support have been developed (Fig 4.5). These decision support tools continuously evaluate the medical record for incoming information and provide feedback to the user. These tools may be separate from the EHR but access the information being recorded by that software. These tools apply rules to alert providers to aspects of care which may have been overlooked or need to be addressed. This may guide users to re-evaluate patient status (if a blood pressure monitoring gap is detected), or consider additional interventions (prompts to treat extremely elevated blood glucose) or alternative management strategies (e.g., if large tidal volumes are being used).[41-46]

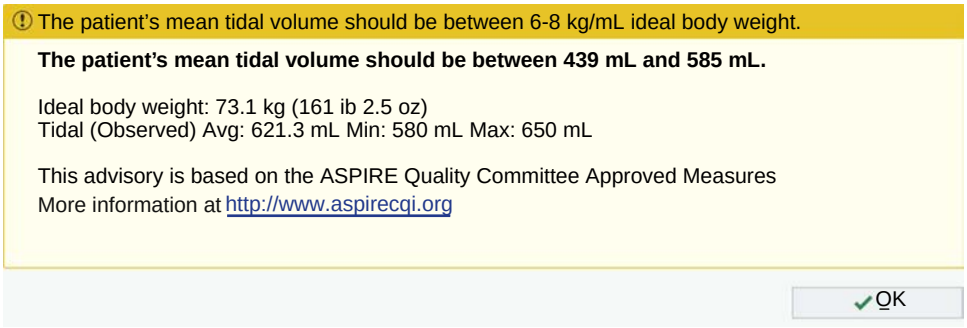

Fig. 4.6 An example of active decision support. Providers prompted to consider the tidal volume, with information which may allow them to consider change in clinical practice. This alert is triggered in the context of an averaged measured value which is above a predefined threshold. Image: © 2018 Epic System Corporation. Used with Permission.

In order to function, these more sophisticated forms of decision support are designed around a common architecture. They run in parallel with the clinical documentation functions of the EHR. They may be built into the EHR (Fig 4.6) or may run as separate software alongside the EHR (see Fig 4.5). Regardless of the specifics of the software implementation, it is best to consider the construction of these systems as being in components.[39] In addition to the modules which capture incoming device data and enable provider manual documentation, three additional modules are added.

The first module is a component which allows a user to define a series of rules against which the incoming information will be assessed. These rules should define the population to which the rule applies (i.e., patients aged over 18 undergoing surgeries in the main hospital operating rooms), the details of the rule (i.e., determine if blood glucose value is >300 mg/dL), and then the proposed action (i.e., notify provider of this finding by text page or display a pop-up window in the EHR software). The second component is the surveillance process which repeatedly assesses the patient status against the rules using newly updated laboratory results, charting elements, monitor or device data; the process determines when a rule has been triggered. The final component is the notification module; this is the method of interacting with the user. This may be within the EHR (as a pop-up message at the front of the patient's attention), separate to the EHR (in dedicated software running on the anesthesia workstation to display notifications regarding patient status), or alternatively may use a completely separate means of communication such as text paging, text messaging, or even phone calls.

Calibrating the alert to the clinical scenario is important and should take into account the lead time involved in data acquisition and notification. If an EHR obtains updated monitor information every minute, the rules require repeated values (to ensure non-artifact) and the output system has a 1-minute lag time, then this restricts the kinds of clinical events which are best addressed via this system. Second-to-second changes (such as in oxygen saturations) translate poorly through systems which have delays in the order minutes.[47] Therefore it is important in the design of decision support systems to target the correct events and recognize that extreme or rapidly occurring events may best be addressed via alternative notification systems or embedded into clinical monitors at the point of care.

The other key consideration is who is the intended recipient of the clinical decision support alert. In the US practice setting, there may be providers responsible for anesthesia care who are both within and outside the anesthetizing location. Alerts for providers in the OR may focus on supporting clinical decisions and selections, whereas those which are targeted at the supervising provider may be best focused on ensuring that the provider retains awareness of the current state of the OR cases being supervised. A provider in the role of OR anesthesia supervisor or manager may have additional concerns regarding allocation of anesthesia resources to support the anesthesia care being provided; notifications of significant deviations from schedules or occurrence of emergency events may be relevant to this group.

Various tools are available which incorporate these features. As discussed earlier, many passive decision support features are built into the EHR software natively. While more active decision support systems may be integrated into the EHR software it is also possible that this may come as part of stand-alone software which provides a mechanism for delivering these alerts to providers. More sophisticated implementations may additionally attempt to provide information about overall patient state drawing widely from EHR-derived data elements. This may be of use to providers in supervisory or OR manager roles seeking snapshots of the course of care.

IMPACT OF DECISION SUPPORT IN ANESTHESIA CARE

Evaluation of implementation of clinical decision support in anesthesia care has typically been focused around specific aspects of care, usually process measures. Examples include changes in ventilation parameters, perioperative β blockade, antibiotic administration, blood pressure management, administration of postoperative nausea and vomiting (PONV) prophylaxis and decreases in anesthesia agent usage (by reductions in fresh gas flow).[44,48-58] What is less well established is the relationship between clinical decision support and relevant patient outcomes. Perioperative decision support tools in the domain of perioperative glucose management in diabetic patients has been able to demonstrate differences in surgical site infection alongside improvements in perioperative glucose control in a single-center study.[59] It is likely that measurable changes in patient outcome do not come from use of a single decision rule in most

circumstances. Therefore, patient outcome impact is more likely in systems which include multiple elements in their decision support; this type of implementation is not widely implemented or studied. This is supported by a single-institution study which has demonstrated that deployment of a multiparameter perioperative decision support system may reduce hospital charges and therefore resources.[45]

Integration with the Enterprise Electronic Health Record

Given the substantial shared pool of information from which the AIMS and the enterprise EHR may draw on and contribute to, it is not surprising that these systems have become integrated at many institutions into a single system. It is important to note that this increases the complexity of the EHR. For organizations where the IT support for an OR or anesthesia information system was supported and maintained through an anesthesia or surgery department relationship, the migration to an enterprise EHR will result in these duties being transferred to the hospital or enterprise-wide support group. This may reduce the customizability of these systems as changes and alterations now become handled by groups with broader responsibilities and competing priorities.

An emerging feature of EHRs, which fulfills an early promise of their utility, is meaningful transmission of data from different EHR platforms across institutions. Typically, each institution maintains an EHR that is unique to that institution. As smaller medical practices have aggregated into larger health systems, providers come under the same umbrella EHR system. This has allowed records from more health interactions to be available in a single location; a satellite clinic in a physically separate location may use a health–systemwide common EHR for documentation, making it available to the anesthesiologist who sees the patient presenting for surgery at main campus. However, when a patient presents to a nonaffiliated practice or hospital, documentation from the other institutions are unavailable and have to be obtained as printed paper, or communicated by the patient manually.

To address this issue, healthcare information exchanges (HIE) have been developed. These exchanges facilitate the transfer of health information between multiple distinct healthcare system's EHRs. This can occur in a directed way: a user at one facility chooses to send imaging data to another and uses the EHR's HIE user interface to discover records available via the HIE. These come in multiple forms but are typically based on a geographic (i.e., at the state or regional level) or a shared EHR platform (i.e., EPIC Systems Care Everywhere functionality).

In order to function, HIEs must be able to correctly match the same patient across different hospitals or clinics. Failures of this process (both incorrectly matching two patients across institutions or failing to match the correct patient across institutions) could have potential for catastrophic consequences in clinical care. Matching must consider different identifiers used at each hospital; a medical record or registration number is usually unique to the institution so is not suitable for this task. Additionally, unique identification assigned for other reasons—such as social security numbers—may not be suitable for this task as their use may shift over time and the accuracy may not match the level of confidence required for medical care. Furthermore, social security numbers may pose risk to patient privacy as they are connected to multiple other datasets including financial records.

Typically, combinations of identifiers are used to uniquely identify patients. This is joined with logic that balances a degree of uncertainty to account for the challenges previously noted with the risks of failure to match and false matches. However, this may still lead to the exchange of patient identifiers. Cryptographic solutions may be employed to prevent the need to exchange patient identifiers.

In some situations, even acknowledging the existence of a record may be revealing and pose risk to patient privacy—for example a record existing in a clinic specializing in the treatment of a particular illness may cause an inference to be drawn about a particular diagnosis. One way to minimize this issue is to limit the links to another health system's records to patients in common at the source health system. Rather than allowing a user at one institution to search freely for patients at another institution, such an approach would allow users to access the "matched" patient records at another institution only. Access to remote systems could further be controlled to limit it to the context of an active patient-provider encounter. Each of these options contains trade-offs with maximizing information availability with patient privacy.

Billing System Interactions

Billing for hospital services involves capturing accurately the resources used in the delivery of care; for example, in the perioperative setting, OR and PACU times, or specific surgical supplies and equipment used. This is recorded via the OR management system and may be linked to a broader process which manages surgical supplies, resource utilization, and scheduling. In this manner, information captured as part of OR clinical care documentation may be reused for billing, supply, and utilization management. The management of information in a centralized EHR accessible by multiple users enables simultaneous use for clinical, operational, and administrative reasons. Automated export of documented parameters may form the basis of these other uses.

In the United States, professional charges for anesthesia care are based on the duration of the care provided and the procedure for which the care is provided. Additional charges may be possible for specialized monitoring, specialized vascular access, or pain management procedures provided for postoperative analgesia. Data necessary to aid the billing process can be extracted from the EHR: for example, basic case information such as duration of anesthesia care, ASA physical status classification, staff providing for anesthesia care, and procedure performed. Reports can be run at or near to the conclusion of the anesthesia care and allow a case to be rapidly

turned over to the billing staff for further processing. This may speed up the billing process and make it less dependent on paper billing sheets or other means. The implementation of automated billing alerts via text paging and email have been shown to increase prevention of documentation practices that may have been erroneous and alter reimbursement, reduce time to documentation being complete and ready to be billed, reduce time to correct errors, and increase capture of arterial line placement leading to increased reimbursement.[28,30,60]

Challenges in Anesthesia Information Management System Implementation

Just as the OR must be available for emergencies at all times, the underlying perioperative information systems which capture this activity must also be highly reliable. Despite architecting extensive EHR redundancy, backup processes must be available in cases where the system is unavailable due to hardware and software failures, or in times of planned maintenance. Typically, these result in reverting to a paper-based system for the limited periods of planned or unplanned downtime. Processes must be in place to determine how documentation captured during these downtimes is subsequently handled.

Due to the complexity of these systems it is possible that certain elements fail without the entire system becoming unavailable. For example, if the link between the monitoring platform and the AIMS system becomes unavailable, anesthesia providers may have to respond by manually entering monitoring data. Importantly, this data link failure has to be recognized. Unfortunately, it is unlikely that manual data entry will replicate the degree of completeness of the automatically gathered information. Concerns have been raised of the possibility of legal liability arising from such scenarios.[61]

In all situations where electronic records are created, a plan needs to be created to ensure that access in the future is preserved. Medical records retention requirements vary significantly by state. These typically extend for a period of time past the last contact with the health service, even up to 10 years beyond that period for adult patients. For minor patients, this period typically extends beyond the time in which the patient reaches the age of majority, even up until the patient turns 30 years old. These time periods may extend past the life expectancy of the software which created the records. Operators of EHRs, including those in the perioperative period, need to have a plan in place to ensure that data can be archived, retained, and remain accessible in line with these legal requirements.

Even with the most comprehensive of EHRs there may be a need for a physical medical record to be created as part of care—consent forms may be provided on paper, patients may write letters to their providers, and outside hospitals may send printed or paper records with a transferring patient. Decisions need to be made as to how these physical documents are retained and archived. This may involve making electronic copies which become available within the electronic record.

In situations in which separate systems are used in the perioperative process from the rest of the institution there may be situations where a paper record is printed and placed inside a patient's physical chart. When a paper record and an electronic record exist simultaneously at a given institution, then a decision needs to be made as to which has primacy. If a provider creates a paper record at the end of anesthesia care and then subsequently updates a documentation element at a later time, a process needs to be in place to ensure that this can be transferred to the patient's physical record for the paper record to maintain primacy.

Additionally, if differing systems are used in the perioperative period there may be failure of communication of important information to the entire healthcare team. While specific examples regarding medications with prolonged duration of action and challenges in airway management have been discussed above, the siloing of information in a separate system (potentially with different access requirements) contributes to the appearance of the perioperative period as being one which is completely distinct from the rest of the clinical encounter. This can contribute to failures of communication of events which occur during this important phase of care and thus potentially patient harm.

Ensuring coverage of all locations where an anesthetic may be performed can be challenging. There may be many sites where anesthesia care is provided infrequently. These are likely "non-operating room sites." In such cases the economic justification for the capital investment required to allow these sites to participate in electronic charting may not be justified. In such situations, cases performed in non-connected locations may require traditional paper charting. This creates a significant overhead as business processes need to be maintained to support the documentation of activity in these locations and ensure that the paper documentation is archived as the record of care, available for billing processes and quality assurance review.

Additional Uses for Collected Data

Secondary use of EHR data has become commonplace and is part of the value proposition of the transition to these systems. In addition to the primary purposes of clinical documentation, operational and support tasks, information contained within the EHR may find secondary uses including in the ascertainment of practice quality measures and research endeavors.

USE FOR MEDICAL RESEARCH

The rapid emergence of AIMS led to a proliferation of research into anesthesia care practices and outcomes. This proliferation has occurred because of the improved ease with which study data may be acquired. Queries of the underlying EHR databases are far quicker to perform and may be more extensive in scope than review of paper documentation in the same population. Collectively, this has led

to a rapid development of retrospective database research within anesthesiology. This work has allowed quantification and identification of risk factors for both rare events, such as difficult mask ventilation combined with difficult intubation or epidural hematoma after neuraxial anesthesia, and more common perioperative events, such as acute kidney injury.[62-67]

The use of an EHR as a data source for research initiatives has offered advantages of scale in study size but also allows a wide range of risk factors to be considered. It is now routine for observational research studies using EHR data to include thousands of patient records. Given the relatively infrequent occurrence of catastrophic complications or major adverse outcomes in modern anesthetic practice, extremely large sample sizes are necessary for quantification of risk factors and rates of occurrence of significant patient outcomes.

Despite the rarity of intraoperative complications, long-term complications of the surgical procedure remain common. The ability to utilize information drawn from the entire hospital record to characterize patient outcome is extremely important to the perioperative outcome researcher, as postoperative complications may have substantial impact on patient outcome.

It has become apparent that even the largest of single center studies may not be able to generalize well across sites. Substantial heterogeneity in clinical practice exists between institutions and across geographical regions. This has driven the development of multicenter studies, facilitated by the interchange of electronic data. The Multicenter Perioperative Outcomes Group (MPOG)* is one example of such an undertaking, bringing together investigators from over 50 institutions across the United States and Europe who have assembled, standardized, and identified over 10 million perioperative records for research and quality improvement.† By including data from many sites and seeking to include diverse practice locations, such efforts aim to develop generalizable knowledge.

One of the challenges in performing this work is the level of abstraction required to summarize the patient's clinical encounter into a small number of variables for inclusion in any analysis. For example, studies on the relationship of intraoperative hypotension and postoperative outcome need to consider how to develop a measure of hypotension which summarizes multiple hours of highly granular blood pressure information into a small number of variables for inclusion in the research study. A single 3-hour case may have 60 or more non-invasive blood pressure values recorded. To include in any analysis, these need to be summarized in a manner which remains biologically plausible. Many options are available, such as averages of all collected blood pressures or time or fraction of the case above (or below) absolute (i.e., mean arterial pressure [MAP] <65 mm Hg) or relative (<20% drop from baseline MAP) thresholds. Each approach would have very different output values and may alter the results and interpretation of a research finding. With any automatically collected information, methods for handling artifacts should be considered as artifactual values may have been propagated from the monitoring platform to the automated record without clinician intervention. Given the abundance of possible data to be included in any study, it is key that a clear hypothesis and approach be developed a-priori rather than post-hoc decisions that may evaluate particular statistically or clinically significant outcomes.

While most of the research thus far has been in the context of retrospective observational studies, an emerging theme in EHR-derived research is the use of this data in near real time (within days) for prospective interventional trials. These studies attempt to gather much of the information required for the trial as a byproduct of the clinical documentation created in the EHR. Additional information regarding patient progress in the study can be appended via traditional study management software. More novel methodologies such as embedded pragmatic clinical trials where hospitals or clinics choose to standardize their management in a coordinated manner for all patients (i.e., one class of antihypertensive or another as the usual first agent for adult patients without chronic kidney disease) are dependent on EHR data collection for patient follow up and perhaps even delivering the "usual choice" via decision support tools (see Chapter 89).[68]

MEASUREMENT OF QUALITY OF CARE

Information regarding the quality of care delivered and patient outcomes may be obtained from review of the EHR. Traditional models of quality management frequently depended on the use of trained abstractors reviewing medical records and applying standardized definitions. While these systems work well, they do not scale well into high volume clinical settings due to the time-consuming nature of detailed review and the resultant staffing costs. Interest has developed in the use of EHR data for the automated derivation of quality of care information. With careful design, both process of care (i.e., appropriate antibiotic prophylaxis administration) and outcome measures (i.e., surgical site infection) may be tracked using data derived from the EHR. Decision support tools may be used to aid in the alignment of the quality measures and the clinical practice which they seek to measure. Care needs to be taken to ensure the pattern of care which may be promoted is consistent with good clinical practice.

Using automatically derived measures, it is possible to provide feedback to medical providers near the time of clinical care. Automated data extraction and processing is well developed, with feedback being described across provider groups using email, provider and institutional specific "dashboard' reporting tools, and real-time paging alerts (Fig. 4.7).[38,49,51] Various groups have worked to make available tools to enable the widespread deployment of quality measures via submission of data from individual sites to a centralized database.[69] This approach is designed to limit the need for each site to develop the required technical architecture to build and deploy such tools—a significant hurdle for many organizations. However, this likely comes at the expense of flexibility of measurement offered at each site and some degree of delay in processing.

*Multicenter Perioperative Outcomes Group: http://www.mpog.org
†Personal communication, October 2018.

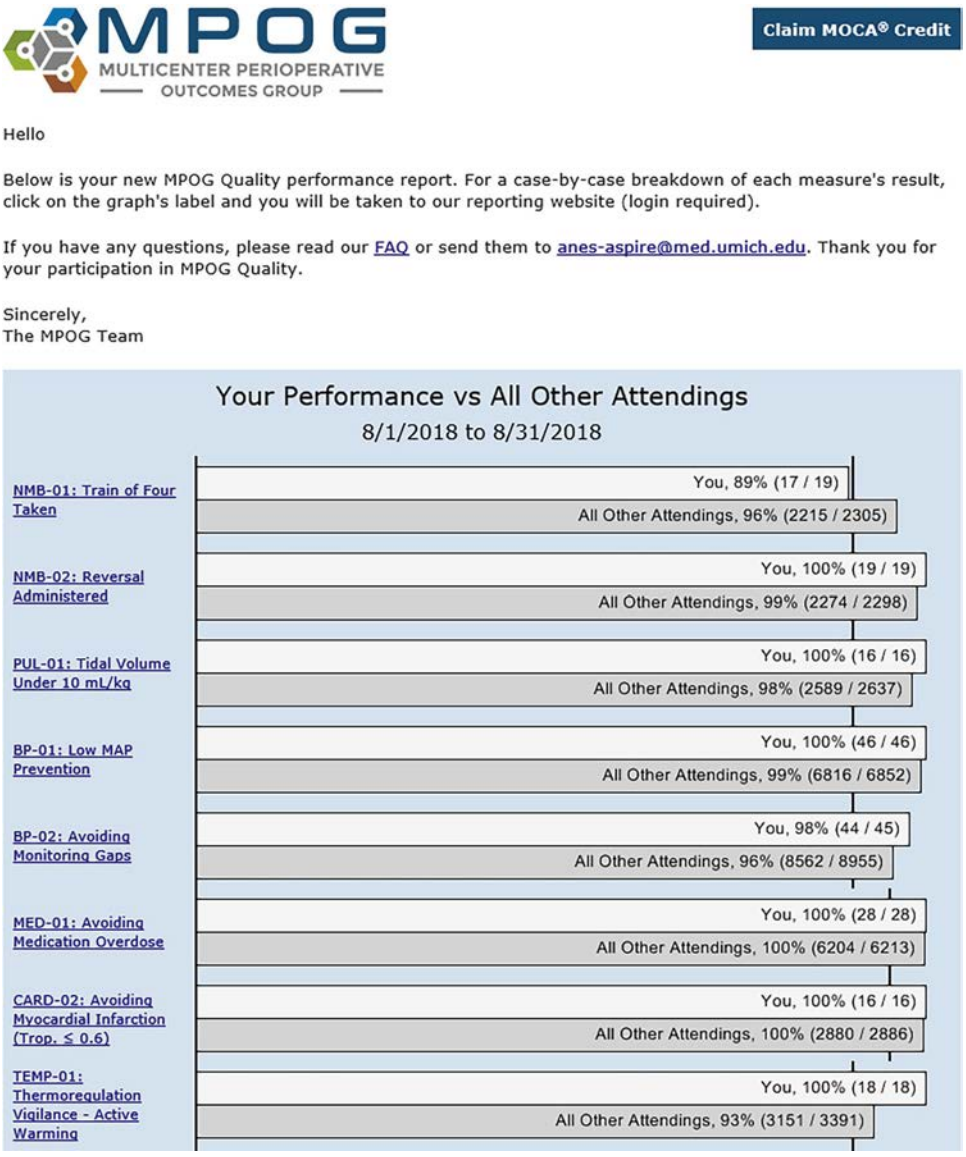

Fig. 4.7 Example of feedback email summarizing performance based on an automated assessment of compliance against predefined measurement instruments using data derived from the electronic health record. This figure has been lightly edited to remove identifying information of the recipient.

Interactions of Electronic Devices with the Delivery of Anesthesia Care

Safe anesthesia care requires the maintenance of a high degree of vigilance to multiple sources of information concurrently. When combined with required clinical tasks, estimates suggest that anesthesia care has high workload requirements.[70] Workload includes the factors related to the nature of the task, the situation in which it is performed, and the operator performing it.[71] In relation to phases of OR care, workload is clearly not uniformly distributed, clustering particularly in the induction and emergence phases of care.[70] The ability of providers to engage in tasks additional to patient care is debated.

Distractions from current patient care may include communication with other team members in the OR unrelated to patient care, preparation for subsequent patients, clinical reference lookup, pursuit of educational activities, and attention to personal issues. Attempts to quantify providers' attentiveness to the clinical situation or impact of a distracting event have been performed and note that distractions are a common feature of anesthesia care.[70,72-75] Given the common occurrence and diverse sources of possible distracting events during anesthesia care, mitigating the effects of distraction to maintain focus on patient care may be a required skill of an anesthesia provider.[74]

In particular, the proliferation of electronic devices in the OR including personally owned devices by providers (such as smartphone and tablet devices) and those that are part of the anesthesia workstation (frequently Internet-connected computers for accessing EHR and documentation purposes) has raised concern for the new sources of distraction in the OR.[76] A study from eight anesthesia workstations in one institution found that the computer attached to the anesthesia workstation was used for non-anesthesia documentation purposes for 16% of the procedure time. Importantly,

this study did not differentiate between time spent in this category that was related to patient care (i.e., accessing a separate lab or EHR system) or not.[77] Additional research has observed self-initiated distractions occurred in 54% of anesthesia cases.[78] Distractions related to personal matters were found in 49% of cases and related to educational activities in 24% of cases.[78]

Professional societies have issued guidelines on the role of distractions, including electronic devices, in the OR, some of which recommend the development of local policies to cover usage of electronic devices.[79-81] These policies may differentiate between clinical, educational, and personal usage of electronic devices and resources, and the appropriateness of each during patient care. It should be noted that many aspects of use of perioperative information technology, including use of personal devices, are subject to logging or recording. This may allow medicolegal review of activity performed on electronic devices contemporaneous to anesthesia care being provided in the future.

Conclusion

Information technology is very much part of the perioperative care process. It has significantly impacted clinical care, organizational performance, provider satisfaction, research, and assessment of quality of care. It is important that anesthesiologists understand the principles behind its use and be keenly aware of the benefits and potential shortcomings that applications of these tools may have. It seems likely that the future will hold a more connected perioperative environment with even more information available. The challenge, and the promise, of perioperative informatics still lies in ensuring the right people have access to the right information at the right time to enable them to make the right decision for the patient care they are providing.

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Complete references available online at expertconsult.com.

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5 Quality Improvement in Anesthesia Practice and Patient Safety

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KEY POINTS

- Quality needs to be an integral characteristic of the system in which care is delivered. Improving the quality of care often requires reorganization of the way we work. A challenge to the anesthesia team is to combine efficiency in perioperative care (especially the operating room) with safety and the best quality possible.
- The growing demand from patients, clinicians, insurers, regulators, accreditors, and purchasers for improved quality and safety in health care requires that anesthesiologists and members of the anesthesia team persistently evaluate the quality of care they provide.
- Improving quality of care requires measuring performance. Clinicians have an enhanced ability to obtain feedback regarding performance in their daily work, in part because of the increasing use of information systems. Unfortunately, consensus has not been reached on how to measure quality of care.
- The goal of measurement is to learn and improve. The measurement system must fit into an improvement system; clinicians must have the will to work cooperatively to improve, and they must have ideas or hypotheses about changes to the current system of care. Also, the clinical team must have a model for testing changes and implementing those that result in improvements.
- Outcome measures, including in-hospital mortality rates, have been the basis for evaluating performance and quality. However, hospital mortality alone provides an incomplete picture of quality, does not include all domains of quality, and does not measure the overall success of the full cycle of care for a specific medical condition. A balanced set of structures (how care is organized), processes (what we do), and outcome measures (results of care in terms of patient's health over time) is needed to evaluate the quality of care overall.
- Efforts to improve quality of care require development of valid, reliable, and practical measures of quality. Identification of clinical care that truly achieves excellence would be helpful not only to the administration of anesthesia, but also to health care overall.
- Developing a quality measure requires several steps: prioritizing the clinical area to evaluate; selecting the type of measure; writing definitions and designing specifications; developing data collection tools; pilot-testing data collection tools and evaluating the validity, reliability, and feasibility of measures; developing scoring and analytic specifications; and collecting baseline data.
- The best opportunities to improve quality of care and patient outcomes will most likely come not only from discovering new therapies, but also from discovering how to better deliver therapies that are already known to be effective.
- Safety is an integral part of quality that is focused on the prevention of error and patient harm. The airline industry is often lauded as an exemplar of safety because it has embraced important safety principles, including the standardization of routine tasks, the reduction of unnecessary complexity, and the creation of redundancies. Anesthesia care teams have also adopted these principles, although many opportunities remain to further bolster patient safety.
- Healthcare providers can organize their quality improvement and patient safety efforts around three key areas: (1) translating evidence into practice, (2) identifying and mitigating hazards, and (3) improving culture and communication. Although each of these areas requires different tools, they all help health care organizations evaluate progress in patient safety and quality.

The need for improving quality and reducing the cost of health care has been highlighted repeatedly in the scientific literature and lay press. Improving care, minimizing variation, and reducing costs have increasingly become national priorities in many countries. Quality improvement (QI) programs that address these issues not only improve delivery of care but also have a positive effect on practitioner job satisfaction and organizational commitment.[1]

The goal of this chapter is to present a practical framework for developing and implementing QI programs in anesthesiology and critical care medicine that are both scientifically sound and feasible. To accomplish this goal, we review the science and approaches to QI, present measures that help evaluate whether QI programs have resulted in improvements, and describe examples of successful QI efforts.

What Is Quality?

DEFINITION OF QUALITY

W. Edwards Deming, scholar, professor, author, lecturer, and consultant to business leaders, corporations, and governments defined quality as "a predictable degree of uniformity and dependability with a quality standard suited to the customer."[1] This early definition of quality, in the context of QI, stems from its application to industrial production. However, when the term *quality* is applied to health care, the subtleties and implications of treating a human being are of prime importance, as opposed to the concerns involved in producing consumer goods. Use of the term *quality* in the context of health care can sometimes lead to defensive attitudes, economic concerns, and even ethical debates.

In the healthcare sector, quality can have various meanings to different people. For example, a daughter may evaluate quality by the level of dignity and respect with which her elderly mother is treated by a nurse. A cardiac surgeon may see quality as a percentage of improvement in the function of a heart on which he or she has just operated. A business may judge quality by the timeliness and cost effectiveness of the care delivered to its employees and its effect on the bottom line. Finally, society may evaluate quality by the ability to deliver care to those who need it, regardless of their cultural or socioeconomic backgrounds.

Despite the numerous definitions of quality in both business and medicine, a unified definition of quality in the context of QI should exist in health care. This definition of quality may have implications for both its measurement and its improvement. In order to help standardize the definition of quality in health care, the Institute of Medicine (IOM) published its own definition in a 1990 report titled *Medicare: A Strategy for Quality Assurance.* The IOM, which has since been renamed the National Academy of Medicine (NAM), defined *quality* as "the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge."[2] Inherent in this definition are the elements of measurement, goal orientation, process and outcomes, individual and society preferences, and a dynamic state of professional knowledge. This definition of quality in health care has gained widespread acceptance. A similar definition is offered by the U.S. Government Department of Health and Human Services, which defines quality in public health as "the degree to which policies, programs, services, and research for the population increase desired health outcomes and conditions in which the population can be healthy."

AIMS OF QUALITY IN HEALTH CARE

In the 2001 report, *Crossing the Quality Chasm,* six aims for quality in health care were outlined.[3] These aims of safety, effectiveness, patient-centeredness, timeliness, efficiency, and equity included and extended the issues of patient safety described in their earlier report *To Err Is Human.*[4] The aims have been adopted by many organizations, including the Institute for Healthcare Improvement (IHI), a United States nongovernmental agency devoted to advancing QI and patient safety in health care. These aims serve as a basis on which quality is evaluated and improved and are described as follows.

1. Safety. No patient or healthcare worker should be harmed by the healthcare system at any time, including during transitions of care and "off hours," such as nights or weekends. Errors may be categorized as either failure of an action to occur as planned, such as the administration of a wrong medication to a patient, or having the wrong plan altogether, such as misdiagnosing and subsequently mistreating a patient.[4] As much as possible, patients should be informed about the risks and benefits of medical care in advance. If a complication does occur, medical staff should make full disclosure, provide assistance to the patient and family, and exercise due diligence in preventing any recurrences of the error.
2. Effectiveness. Effective medicine requires evidence-based decisions about treatment for individual patients, when such evidence exists. The best available evidence should be combined with clinical expertise and patient values in forming a treatment plan. With effective care, medical practitioners avoid underuse by providing a treatment to all who will benefit and avoid overuse by refraining from giving treatment to those unlikely to benefit.
3. Patient-centeredness. Patient-centered care is respectful of individual patient preferences, needs, and values and uses these factors to guide clinical decisions.[4] More specifically, according to Gerteis and colleagues,[6] patient-centered care encompasses respect for patients' values; coordination and integration of care; information, communication, and education; physical comfort; emotional support that relieves fear and anxiety; and involvement of family and friends. The dramatic increase in access to health information on the Internet has resulted in more patients who are well informed and proactive in their care. Patient-centered care embraces this trend and shifts more of the power and control to patients and their families. Examples of patient-centered care include shared decision making, patient and family participation in rounds, patient ownership of medical records, schedules that minimize patient inconvenience, and unrestricted visitation hours.[7]
4. Timeliness. Reduced wait time is important to both patients and healthcare practitioners. Long waits signal a lack of respect for a patient's time. Furthermore, delays may not only affect patient satisfaction, but may impair timely diagnosis and treatment. For healthcare workers, delays in availability of equipment or information may decrease job satisfaction and the ability to perform their jobs adequately.
5. Efficiency. Rising costs have increased scrutiny of waste in health care; this includes waste in labor, capital, equipment, supplies, ideas, and energy.[8] Improved efficiency reduces waste and results in an increased output for a given cost. Examples of efficiency measures include mean length of hospital stay, readmission rate, and mean cost of treatment for a diagnosis. The elimination of waste can result in better quality of care for patients at the same or lower cost.
6. Equity. Equitable care does not vary in quality based on personnel. The NAM defines equitable care at two levels. At the population level, equitable care means

reducing or eliminating disparities between subgroups. At the individual level, it means absence of discrimination based on factors such as age, gender, race, ethnicity, nationality, religion, educational attainment, sexual orientation, disability, or geographic location.[3]

Another framing of quality is the "quadruple aim" proposed by Bodenheimer and Sinsky[5] and adopted by the IHI. These four aims include better care, better outcomes, lower cost, and better work life for the healthcare workforce. This last aim was added to the IHI's previous "Triple Aim" in recognition that increasing clinician burnout represents a threat to high-quality care.[5]

DEMING'S SYSTEM OF PROFOUND KNOWLEDGE

Before learning about frameworks and tools for improvement, it helps to have an understanding of the theory behind improvement work. W. Edwards Deming wrote about two different types of knowledge: subject matter knowledge and profound knowledge. Subject matter knowledge is professional expertise, such as expertise in anesthesiology. Profound knowledge is the knowledge of improvement. The most significant improvement occurs where these two types of knowledge overlap. Deming divides profound knowledge into four different categories: appreciation of a system, the theory of knowledge, understanding variation, and psychology.

The first area of profound knowledge is appreciation of a system. A system is a network of interdependent components working together for a common aim.[6] It is often said that "Every system is perfectly designed to get the results it gets." If a system is underperforming, it is because it has unintentionally been designed to underperform. If this is the case, it is our responsibility to manage the system to get the results we want.

The second part of Deming's profound knowledge is the idea that knowledge requires a theory. Information by itself is not knowledge. For example, a dictionary contains information, but it is not knowledge. We must have a theory behind our improvement work, not just data, if we are going to learn.[6]

In order to learn, we must additionally understand variation and how to react to it. Deming says that "life is variation."[6] Common cause variation is variation that is inherent to the process. Special cause variation is variation from causes that are not inherent to the process but arise from specific circumstances. A process which only has common cause variation is in statistical "control." On the other hand, a process that has both common cause and special cause variation is an unstable process.[7] Two common errors in improvement work are acting upon common cause variation as if it were special cause, and acting upon special cause variation as if it were common cause.

The last area of profound knowledge is psychology. This is often the most challenging part of improvement work. Deming believed in intrinsic motivation, and the need to nurture people's joy in work and intrinsic motivation to learn.[6] More recently John P. Kotter describes eight steps to change in his book *The Heart of Change*. These are increase urgency, build the guiding team, get the vision right, communicate for buy-in, empower action, create short-term wins, don't let up, and make change stick.[8]

Approaches to Quality Assessment

QUALITY ASSURANCE VERSUS CONTINUOUS QUALITY IMPROVEMENT

Although the terms *continuous quality improvement (CQI)* and *quality assurance (QA)* were used interchangeably in the past, substantial differences existed between the two. Most medical CQI systems were built on the foundation of a traditional QA system that used *standards* to define quality.[9] Standards can be defined as an "acceptable" level of performance. For example, a standard for overall mortality after cardiac surgery is less than 3%; however, is 3% (vs. 4% or 2%) mortality after cardiac surgery acceptable? Similarly, a standard for head injury evaluation is a computerized tomography (CT) brain scan within 4 hours of admission, but in certain circumstances, patients with head injury may warrant a CT scan sooner than that.

Most standards are inherently arbitrary and often lack consensus among medical professionals.[9] Additionally, QA systems typically react only when a standard is not met. Examples of traditional standard-based QA systems were peer review systems and morbidity and mortality reviews. These systems often exist to flag certain cases or practitioners for intense review. Practitioners may regard this intense review as a punishment because only "failures" or "bad apples" are identified, and process failures are not connected with the outcome on every case. Thus, QA systems are inherently judgmental and, if not carefully administered, can hold practitioners responsible for random causes over which they have no control. CQI systems, on the other hand, recognize that errors occur and require different responses. Often excellence in health care is not identified by analysis of QA systems. Excellence is sometimes defined by the lack of failure. Is there a difference between good (acceptable) and excellent health care?

Systems within health care are a series of interlinked processes, each of which results in one or more outputs. CQI systems, as opposed to QA systems, include an explicit approach to process and the use of specifications to improve a process or outcome. A specification is an explicit, measurable statement regarding an important attribute of a process or the outcome it produces.[9] Specifications identify variables that need to be measured, but typically do not set acceptable limits or standards. Once specifications have been defined in a CQI system, all outputs or cases, not just failures, are evaluated against these specifications. The system then attempts to correct errors by fixing the process rather than the people. Thus, CQI aims to change the process and prevent quality failures before they happen by building improvements into the process. To quote Philip Crosby, "The system for causing quality is prevention, not appraisal."[10]

FRAMEWORKS FOR IMPROVEMENT

Model for Improvement

The journey toward improvement can be made more efficient and more effective with a systematic approach. The Model for Improvement, developed by the training and management consulting company Associates in Process Improvement (http://www.apiweb.org), is one such

TABLE 5.1 Steps of a Plan, Do, Study, Act (PDSA) Cycle

Step	Description
Plan	Make a plan for the test of change. Include predictions of results and how data will be collected.
Do	Test change on a small scale. Document data, observations, and problems that occur.
Study	Use data gathered from previous stages to build new knowledge and make predictions. Knowledge is gained from both successful and unsuccessful changes.
Act	Adopt the change, or use knowledge gained to plan or modify the next test of action.

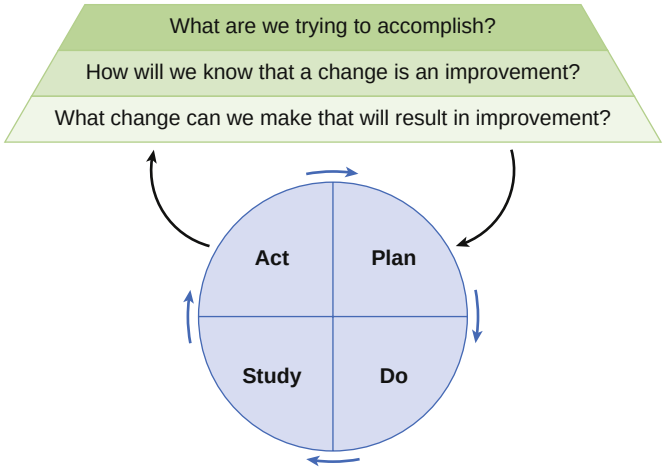

Fig. 5.1 Diagram of model for improvement. (From Langley GJ, Moen RD, Nolan KM, et al. *The Improvement Guide: A Practical Approach to Enhancing Organizational Performance.* San Francisco: Jossey-Bass; 2009. With permission from John Wiley & Sons.)

approach adopted by organizations across varied disciplines and is currently the approach used by IHI. It is a structured, dynamic model that applies the scientific method to testing and implementing a change.[7] In 1939, Walter A. Shewhart, a physicist, engineer, and statistician, introduced the science of modern QI.[11] He introduced a three-step scientific process of specification, production, and inspection, stating that "these three steps must go in a circle instead of in a straight line."[12] In the 1940s, his protégé, W. Edwards Deming, applied these concepts to government and industry and developed the Plan, Do, Study, Act (PDSA) cycle (Table 5.1).[13] A modification of the PDSA by the addition of three fundamental questions (as explained in the next paragraph) resulted in the Model for Improvement (Fig. 5.1).[12]

Beginning an improvement project with the three fundamental questions for improvement helps set a clear direction for the project, define what success will look like, and hypothesize successful interventions. The three fundamental questions for improvement are:

1. Aim: "What are we trying to accomplish?" The aim (or objective) for improvement should be specific, measurable, actionable, relevant, and time-specific (also referred to as a SMART aim). Ideas for improvements may come from interviewing those involved or affected by the process, such as staff or patients. Ideas may also come from examining previous data on operational, clinical, or financial processes.
2. Measure: "How will we know if change is an improvement?" Ideally, measures should be linked directly to the aim or goal of the project and should ensure that the interests of the stakeholders of the process are represented.[7] Quantitative measures should be used when possible to measure change over time. These measures provide the feedback that enables one to know whether or not the change is an improvement. However, not all projects have an easily quantifiable outcome and the outcome may be more qualitative. It is worth the time and effort to identify opportunities to translate goals into quantifiable outcomes if possible. These can be easier to use to communicate success.
3. Changes: "What changes can we make that will result in improvement?" Ideas for changes that result in improvement often start with observations, modeling the success of others, and brainstorming. The more intimate the understanding of a process and its key drivers, the higher the likelihood of generating successful changes.

The three fundamental questions are followed by a PDSA cycle, which is the framework for testing and implementing previously generated ideas for change. Improvement may require multiple cycles of preferably small tests of change over time. By testing changes on a small scale before implementation, risk is mitigated. Small tests of change may also help overcome individuals' resistance to change. Through repeated cycles, increased knowledge is acquired, and actions are continuously modified or changed. Measures defined in the first part of the model help determine whether or not a change is a success. These measures are often plotted over time on run charts or control charts (Figs. 5.2 and 5.3). Knowledge can be gained from both successful and unsuccessful tests! Finally, PDSA cycles both test a change and implement a successful change on a larger scale or in diverse clinical areas.

Lean Methodology and Six Sigma

In addition to the Model for Improvement, CQI initiatives have many other frameworks. Two of these frameworks, Lean Production and Six Sigma, are briefly discussed here. These frameworks are sometimes combined, as in "Lean Six Sigma." Regardless of which framework is employed, benefits are gained by retaining a structured and consistent approach to CQI.

Lean methodology has its roots in Japanese manufacturing, particularly in the Toyota Production System.[14] More recently, Lean has found success in the healthcare industry. Two notable examples of its use are Virginia Mason Medical Center and ThedaCare, Inc., both of which have transformed their organizations through the application of Lean principles. In fact, ThedaCare reported $3.3 million in savings in 2004 with reduced accounts receivable, redeployed staff, reduced phone triage times, reduced time spent on paperwork, and decreased medication distribution time.[14]

Lean methodology is focused on creating more value for the customer (i.e., the patient) with fewer resources. Every step in a process is evaluated to differentiate those steps that add value from those that do not. The ultimate goal is to eliminate all waste so that every step adds value

TABLE 5.2 Steps in the Lean or Six Sigma Process

Step	Description
Define	Define the goals of the improvement project. Obtain necessary support and resources and put together a project team.
Measure	Establish appropriate metrics. Measure baseline performance of the current system.
Analyze	Examine the system for possible areas of improvement.
Improve	Improve the system through implementation of ideas. Statistically validate improvements.
Control	Institutionalize the new system and monitor its stability over time.

to a process. Other key components of Lean include reducing unevenness of workflow—for instance, what we might find in intensive care unit (ICU) admissions or emergency cases—and eliminating the overburdening of people and equipment. Five principles govern Lean improvement:[7]

1. *Define the value* that the customer is seeking. Virginia Mason Medical Center has a "patient-first" focus for all its processes.[14]
2. *Identify and map* the value stream. If evaluating preoperative assessment, map the physical flow of a patient from the scheduling of a procedure through the day of surgery (history and physical, preoperative counseling, laboratory tests, imaging, consultations). In this process, all of the steps are accounted for, including the back-and-forth flow of the patient to the front desk, to the laboratory, and so on. Time spent during each step of the process should be documented.
3. *Smooth the flow* between value-added steps. Eliminate steps that do not add value to the overall process and are likely a poor use of time or effort on the part of the caregivers or the patient. An example of this process might be eliminating unnecessary tests or consultations in a patient's preoperative evaluation and reducing excess wait times that are the result of correctable inefficiencies.
4. *Create pull* between steps. Customer demand should trigger the start of a downstream process. Examples include opening operating rooms (ORs) or increasing staffing based on surgical demand, as opposed to having a fixed amount of time for each surgeon or surgical division.
5. *Pursue perfection* by continuing the process until you have achieved ultimate value with no waste.

The transformation of Motorola in the 1980s from a struggling company to a high-quality, high-profit organization helped give rise to the Six Sigma methodology. Two key fundamental objectives of Six Sigma are a virtually error-free process and a large focus on reducing variation.[15] In fact, a Six Sigma process, or a process whose frequency falls six deviations from the mean, corresponds to just 3.4 errors per million.

Health care often falls far short of this standard. In a 1998 report, Chassin[16] reported that hospitalized patients harmed by negligence were at a four sigma level (10,000/million), patients inadequately treated for depression were at a two sigma level (580,000/million), and eligible heart attack survivors who failed to receive β-adrenergic blockers were at a one sigma level (790,000/million). In contrast, Chassin found that anesthesiology was the one healthcare specialty that approached the six sigma level, with deaths caused by anesthesia as low as 5.4/million.[16] In comparison with health care, airline fatalities were a two sigma process (230/million) and a traditional company operated around four sigma, the equivalent of 6200 errors/million.[16] Considering that errors are often tied directly to cost, this error rate has significant financial implications.

Six Sigma is similar to the Model for Improvement in that it makes use of a simple framework to guide improvement, in this case using Define, Measure, Analyze, Improve, Control (DMAIC).[15] The DMAIC steps are described in Table 5.2. As mentioned earlier, many organizations have found the greatest benefit by combining elements of different methodologies in their CQI work. One popular example of this is Lean Six Sigma, which combines improvements in flow and value with reduction in error and variation. Furthermore, individual tools from these strategies, such as PDSA cycles or DMAIC processes, can be applied where appropriate.

The Value Framework in Health Care

Since quality in health care is focused on patient outcomes, another approach to quality is the value framework. Quality relative to cost determines value. Hence, in health care, value is defined as the patient health outcomes achieved per dollar spent.[17] Value should define the framework for performance improvement in health care. Value includes goals already embraced by health care such as quality, safety, patient centeredness, and cost containment; the value framework allows for a way to integrate these goals.

Because value is always defined around the customer, in the healthcare industry it is what matters most to patients, and unites the interests of all the stakeholders in the healthcare system. Thus, when value improves, not only do patients, payers, providers, and suppliers all benefit, but the economic sustainability of the healthcare system also improves. As such, value should be the overarching goal of healthcare delivery. According to Porter, the failure to adopt value as the central goal in health care and the failure to measure it, are the most serious failures of the medical community.[18]

Value measurement today is limited and highly imperfect. Value should be measured by outputs not inputs. Thus, value is dependent on patient health outcomes and not the volume of services delivered. The only way to accurately measure value is to track individual patient outcomes and costs longitudinally over the full cycle of care, which can vary from 30 to 90 days for hospital care and 1 year for chronic care.

Value is not measured by processes of care utilized by a patient. While process measurement is an important component of improvement, it should not be substituted for measurement of patient outcomes. Outcomes and cost should be measured separately. Outcomes, the numerator of the value equation, refer to the actual results of care in terms of patient health and should consist of a set of multidimensional outcomes that, when considered together, constitute patient benefit. Cost, the denominator of the value equation, should include total costs involved in the full cycle