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Miller's Basics of ANESTHESIA

EIGHTH EDITION

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To my wife, Susan, and daughter, Allison, for their support and encouragement while I was working on this book throughout the pandemic; to Dr. Ronald D. Miller for his mentorship, especially regarding textbooks; and to all students of this wondrous specialty of anesthesiology.

Manuel C. Pardo, Jr.

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PREFACE

Basics of Anesthesia was first published in 1984 with the editorial leadership of Robert K. Stoelting and Ronald D. Miller. Their goal was to provide a concise source of information for the entire community of anesthesia learners, including students, residents, fellows, and other trainees. This eighth edition—the first without Dr. Miller as an editor—continues the pursuit of that goal while acknowledging how the specialty has evolved. The total number of chapters (49) is two fewer than the prior edition. Separate chapters on topics such as congenital heart disease and awareness were removed, but these subjects are now covered in other chapters. New chapters focus on clinician well-being, point-of-care ultrasound, perioperative medicine, and the environmental impact of anesthetics. The title "basics" belies the fact that chapters have more references than prior editions, consistent with the growth in knowledge and scholarly publications in the field.

This eighth edition is the first to be called *Miller's Basics of Anesthesia*, in recognition of Dr. Miller's leadership of the book throughout his career. It was an honor to collaborate with Dr. Miller on the sixth and seventh editions of this book, and I look forward to the challenge of maintaining its excellence as a learning resource.

I am thankful to the authors who contributed to this edition—an international group that includes over 35 new authors. My experience with the pandemic has only increased the gratitude I feel for all who contributed despite the impact on our personal and professional lives. Finally, I would like to acknowledge our publisher, Elsevier, and the dedication of their staff, including publisher Sarah Barth, senior content strategist Kayla Wolfe, senior content development specialist Ann Ruzycka Anderson, and senior project manager Beula Christopher—I appreciated our many Zoom calls to keep the book on track for publication.

Manuel C. Pardo, Jr.

FOREWORD

As an anesthesia resident at the University of California, San Francisco (UCSF), the first edition of *Basics of Anesthesia*, edited by Robert K. Stoelting and Ronald D. Miller, was my first textbook of anesthesia. My fellow residents and I used *Basics of Anesthesia* (which we fondly called "Baby Miller" or "Miller Light") as a concise source of foundational knowledge in our field, supplemented by more in-depth reading in the multivolume textbook *Anesthesia*, also edited by Dr. Miller.

Since then, under Dr. Miller's editorial leadership, both *Basics of Anesthesia* and *Anesthesia* have been regularly revised with the same goals. *Basics of Anesthesia* is oriented to the community of new anesthesia learners, while *Anesthesia's* intention is to be the most complete and thorough resource on the global scope and practice of contemporary anesthesiology.

In 2004, the sixth edition of *Anesthesia* was named *Miller's Anesthesia* in recognition of Dr. Miller's stewardship of the book. It is entirely fitting that this eighth edition of *Basics of Anesthesia* is now titled *Miller's Basics of Anesthesia*. Dr. Miller served as a coeditor for all seven prior editions—the first five with Dr. Stoelting and the last two with Dr. Manuel C. Pardo, Jr., who continues as the sole editor for this edition. The objective of *Miller's Basics of Anesthesia* remains the same: to provide updated and concise information for the entire anesthesia community. I encourage all learners of anesthesia to read and enjoy this book, including those new to the field as well as experienced clinicians who want to refresh and expand their knowledge of the specialty.

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I

INTRODUCTION

Chapter

1 SCOPE OF ANESTHESIA PRACTICE

Manuel C. Pardo, Jr., Neal H. Cohen

Surgery preceded the development of anesthesia as a medical specialty, with significant implications. Surgery has been performed for thousands of years. Archaeologists have discovered human skulls from prehistoric times with evidence of trephination, a surgical procedure involving drilling or scraping a hole in the skull to expose the brain. However, the brutality of surgery without anesthesia limited the types of surgery that could be performed and the disease processes that could be treated. Advances in surgery could only be accomplished as a result of improved ability to relieve pain during a procedure and manage the physiologic changes taking place both during surgery and thereafter. The first use of an anesthetic agent occurred in 1842 when the use of ether as a surgical anesthetic was administered by Crawford Long in Georgia. Although acknowledged as the first anesthetic administered to a human, it was not documented until Dr. Long published his experience in 1849. The first public demonstration of administration of ether anesthesia was provided by dentist William T.G. Morton at Massachusetts General Hospital on October 16, 1846. Since this initial administration of an inhaled anesthetic to reduce pain during a surgical procedure, the specialty of anesthesiology has advanced beyond the surgical suite to encompass the entire course of perioperative care in addition to associated subspecialties, including pain medicine, critical care medicine, palliative care, and sleep medicine.

ANESTHESIOLOGY AS A MULTIDISCIPLINARY SPECIALTY

Although anesthesia is understood to encompass administration of medications to facilitate surgical procedures, as the specialty has evolved, the scope of practice and expertise expected of an anesthesiologist have been formally defined by the American Board of Anesthesiology (ABA), a member of the American Board of Medical

Box 1.1 American Board of Anesthesiology Definition of Anesthesiology

The ABA defines anesthesiology as the practice of medicine dealing with but not limited to:

1. Assessment of, consultation for, and preparation of patients for anesthesia.
2. Relief and prevention of pain during and after surgical, obstetric, therapeutic, and diagnostic procedures.
3. Monitoring and maintenance of normal physiology during the perioperative or periprocedural period.
4. Management of critically ill patients.
5. Diagnosis and treatment of acute, chronic, and cancer-related pain.
6. Management of hospice and palliative care.
7. Clinical management and teaching of cardiac, pulmonary, and neurologic resuscitation.
8. Evaluation of respiratory function and application of respiratory therapy.
9. Conduct of clinical, translational, and basic science research.
10. Supervision, teaching, and evaluation of performance of both medical and allied health personnel involved in perioperative or periprocedural care, hospice and palliative care, critical care, and pain management.
11. Administrative involvement in health care facilities and organizations and medical schools as appropriate to our mission.

From Policy Book 2021. Raleigh: The American Board of Anesthesiology.

Specialties (ABMS) (Box 1.1). The ABA establishes and maintains criteria for board certification in anesthesiology and for subspecialty certification or special qualifications in the United States. Similar professional certification boards exist in many other countries. Currently, formal subspecialty certification is offered in anesthesiology and a number of subspecialties by the ABA, including critical care medicine (also see Chapter 41), pain medicine (also see Chapters 40 and 44), hospice and palliative medicine (also see Chapter 47), sleep medicine (also see Chapter 48), pediatric anesthesiology (also see Chapter 34), and neurocritical care (also see Chapter 30). Other ABMS boards also provide subspecialty qualifications in some of the same subspecialties, allowing providers to collaborate in the care of complex patients requiring specialized services.

The American Society of Anesthesiologists (ASA), founded in 1905 as the Long Island Society of Anesthetists, is the largest professional society for anesthesiologists. The ASA has over 100 committees and editorial boards dedicated to all anesthesia subspecialties and aspects of anesthesia practice. In addition to supporting the practice of anesthesiology and its subspecialties, the ASA advocates on behalf of anesthesiologists with other organizations, including Centers for Medicare & Medicaid Services (CMS), other medical specialties, hospital organizations, and payors. The International Anesthesia Research Society (IARS) and subspecialty societies also provide support for advancing clinical care and research in anesthesia and its subspecialties, reflecting the multidisciplinary growth of anesthesiology (Table 1.1).

PERIOPERATIVE PATIENT CARE

Although the specialty of anesthesiology began in the operating room, the scope of anesthesia practice has evolved as anesthesiologists and surgeons recognized that management of each patient before, during, and after surgery improved outcomes and quality of care. The preoperative evaluation of patients has become critical to the preparation for anesthesia and surgical management. For selected patients, perioperative management for those with underlying medical conditions has also improved outcomes and quality of care.[1] Similarly, postoperative assessment and management related to sequelae of anesthesia is an important component of perioperative care.

Based on this broader definition of anesthesia care, new drugs, monitoring capabilities, and documented improved outcomes in the surgical suite, anesthesia care has expanded to many locations within the health care system, including hospital-based locations, freestanding ambulatory care centers, and office practices (Table 1.2). Several other factors are contributing to the evolution of anesthesiology practice, including the advances in anesthesia care allowing patients with significant comorbidities to undergo complex procedures; the extremes of age of the surgical patient, including the expanding elderly population (also see Chapter 35); increasing importance of quality, safety, and value of health care delivery (also see Chapter 46); changing composition and expectations of the anesthesia workforce; increasing fragmentation of perioperative care with multiple handoffs and transitions of care; and changing payment methods for physicians that increasingly emphasize value-based approaches.[2]

In addition to the factors that affect the clinical practice of anesthesiology, anesthesiologists have assumed broader roles in health system leadership, including perioperative medical directors, chief quality officers, and other administrative and leadership positions related to both perioperative care and broader health system management.[3]

ANESTHESIA WORKFORCE

Anesthesia care is provided by physician anesthesiologists and other providers with various levels of training both in the United States and throughout the world. In the United States the anesthesia workforce includes physician anesthesiologists, certified registered nurse anesthetists (CRNAs), and anesthesia assistants (AAs). Although each state has different

Table 1.1 Selected Anesthesiology Professional Societies

Society	Year Founded	Mission
American Society of Anesthesiologists (ASA)	1905	Advancing the practice and securing the future. Strategic pillars include advocacy, educational resources, leadership and professional development, member engagement, quality and practice advancement, research, and scientific discovery.
International Anesthesia Research Society (IARS)	1922	To encourage, stimulate, and fund ongoing anesthesia-related research projects that will enhance and advance the specialty and to disseminate current, state-of-the-art, basic, and clinical research data in all areas of clinical anesthesia, including perioperative medicine, critical care, and pain management.
World Federation of Societies of Anaesthesiologists (WFSA)	1955	To unite anesthesiologists around the world to improve patient care and access to safe anesthesia and perioperative medicine.
Society for Obstetric Anesthesia and Perinatology (SOAP)	1968	To advance and advocate for the health of pregnant women and their babies through research, education, and best practices in obstetric anesthesia care.
Society for Neuroscience in Anesthesiology and Critical Care (SNACC)	1973	Organization dedicated to the neurologically impaired patient.
International Association for the Study of Pain (IASP)	1974	IASP brings together scientists, clinicians, health care providers, and policy makers to stimulate and support the study of pain and to translate that knowledge into improved pain relief worldwide.
American Society of Regional Anesthesia (ASRA)	1975	To advance the science and practice of regional anesthesia and pain medicine to improve patient outcomes through research, education, and advocacy.
Society for Education in Anesthesia (SEA)	1985	Support, enrich, and advance anesthesia education and those who teach.
Society for Ambulatory Anesthesia (SAMBA)	1985	To be the resource for providers who practice in settings outside of hospital-based operating rooms.
Society for Pediatric Anesthesia (SPA)	1986	SPA advances the safety and quality of anesthesia care, perioperative care, and pain management in children by educating clinicians; supporting research; and fostering collaboration among clinicians, patient families, and professional organizations worldwide.
Society of Critical Care Anesthesiologists (SOCCA)	1987	Dedicated to the support and development of anesthesiologists who care for critically ill patients of all types.
Society for Technology in Anesthesia (STA)	1988	To improve the quality of patient care by improving technology and its application.
Society of Cardiovascular Anesthesiologists (SCA)	1989	International organization of physicians that promotes excellence in patient care through education and research in perioperative care for patients undergoing cardiothoracic and vascular procedures.
International Society for Anaesthetic Pharmacology (ISAP)	1990	Dedicated to teaching and research about clinical pharmacology in anesthesia, with particular reference to anesthetic drugs.
Society for Airway Management (SAM)	1995	Dedicated to the practice, teaching, and scientific advancements of the field of airway management.
Society of Anesthesia and Sleep Medicine (SASM)	2011	To advance standards of care for clinical problems shared by anesthesiology and sleep medicine, including perioperative management of sleep-disordered breathing, and to promote interdisciplinary communication, education, and research in matters common to anesthesia and sleep.
Trauma Anesthesiology Society	2014	To advance the art and science of trauma anesthesiology and all related fields through education and research.

Table 1.2 Locations of Anesthesia Care

Hospital					Outpatient		
Operating Room	Nonoperating Room Location	Preoperative Unit Regional Anesthesia Service Postanesthesia Care Unit	Intensive Care Unit	Hospital Ward - Acute Pain Service - Perioperative Medicine Service - Palliative Care Service - POCUS Service (including TEE/TTE)	Ambulatory Surgery Center	Preoperative Evaluation Clinic	Pain Medicine Clinic

POCUS, Point-of-care ultrasound; *TEE*, transesophageal echocardiography; *TTE*, transthoracic echocardiography.

requirements for delivery of care, scope of practice, and supervision, and some states have allowed CRNAs independent practice, most states currently require nonphysician anesthesia providers to be supervised by a physician. Those states that license AAs require that they be directly supervised by a physician. Dental anesthesia is provided by a physician anesthesiologist or a dentist who has received specialty training in anesthesia care. A 2017 global survey reported that the United States had 67,000 physician anesthesiologists, 49,000 nurse anesthesia providers, and 1960 nonphysician/nonnurse providers.[4]

The "care team" model that includes CRNAs and physician anesthesiologists is the most common practice model in most states. For most U.S. anesthesia groups, the working relationship between physician anesthesiologists and CRNAs is highly collaborative, benefiting patients by providing a coordinated approach to clinical management and immediate availability of a provider with the skills and background required to address emergencies or unforeseen clinical problems. In other countries anesthesia care is provided in a variety of different models. For most European and Asian countries, anesthesia services are provided exclusively by physician anesthesiologists or other physicians with additional training in anesthesiology. In other countries with limited numbers of physicians to provide all aspects of clinical management, alternative models are required to meet the clinical needs of the surgical patient populations. In some cases, depending on clinical needs and regulatory issues, other providers—often with limited formal educational experiences—deliver anesthesia services.

As a result of the expansion of surgical services and need for anesthesia care in nonoperating room environments, the breadth of anesthesia services has expanded dramatically over the past decade. Each of the surgical subspecialties prefers having a dedicated pool of subspecialty trained anesthesiologists; at the same time, the roles for other anesthesia subspecialists in critical care, pain medicine, preoperative management programs, and palliative care and sleep medicine have created significant workforce challenges. Despite the increasing need for anesthesia providers, the United States has had only a modest growth in the number of anesthesia providers; the demand for anesthesia services far exceeds the current supply. The Association of American Medical Colleges (AAMC) commissions annual reports to project future supply and demand for U.S. physicians. A 2021 AAMC report predicts that by 2034 the demand for physicians in the "Other Specialties" category, which includes anesthesiologists and seven other specialties, will exceed supply by 10,300 to 35,600, even with growth in advanced practice providers.[5] The main drivers of the increased physician demand include both population growth (approximately 10% growth during this time) and aging of the population (proportion of the population aged 65 or older is estimated to grow by 42%). CRNA programs have expanded to address the increasing need; in states that license AA programs these programs have also had increasing enrollment. Despite the increase in nonphysician anesthesia providers, the number of providers is not keeping pace with the increasing clinical demands.

The models of anesthesia practice have also changed considerably, as has the relationship with health systems and anesthesia practices.[2] Many community practices have consolidated, often through acquisition into regional and national anesthesia or multispecialty groups. In some parts of the country physicians, including anesthesiologists, have become employees of medical foundations or are directly employed by hospitals. Most academic

practices are managed within the academic departments with varying financial models for managing both professional and technical fees with the academic health system. Although the primary motivation for some of these new business models is financial, the most critical value to the integrated models of care is the ability of the physicians, anesthesiologists and their medical colleagues, and the health systems to optimize clinical care, reduce complications, and more effectively manage resources. In addition, payors, including Medicare and private payors, are transitioning to "value-based" care, so this collaboration has been critical.

TRAINING AND CERTIFICATION IN ANESTHESIOLOGY

Training of anesthesia providers is based on background education, clinical knowledge and experience, and scope of practice. As a result, the training of anesthesia providers in the United States differs for physician anesthesiologists, CRNAs, and certified anesthesiologist assistants (CAAs).

For U.S. physician anesthesiologists, training in anesthesiology consists of 4 years of supervised experience in an approved program after the degree of Doctor of Medicine or Doctor of Osteopathy has been obtained. The first year of postgraduate training consists of education in the fundamental clinical skills of medicine. The second, third, and fourth postgraduate years (clinical anesthesia years 1 to 3) are spent learning about all aspects of clinical anesthesia, including subspecialty experience in obstetric anesthesia, pediatric anesthesia, cardiothoracic anesthesia, neuroanesthesia, preoperative medicine, postanesthesia care, regional anesthesia, and pain management. In addition to these subspecialty experiences, 4 months of training in critical care medicine is required as part of this core curriculum. The ABA is responsible for initial certification after completion of a training program accredited by the Accreditation Council for Graduate Medical Education (ACGME), in addition to subspecialty certification and maintenance of certification. The duration and structure of anesthesiology education differ in other countries, although most countries require 4 years or more of training in anesthesia care, often including critical care medicine within the core curriculum.[4]

The admission requirements for training as a CRNA include a bachelor's degree, registration as a professional nurse in the United States or its territories, and at least 1 year of full-time equivalent experience as a critical care registered nurse. Nurse anesthesia programs are accredited by the Council on Accreditation of Nurse Anesthesia Educational Programs (COA). All accredited nurse anesthesia programs offered master's-level education by late 1998; by 2022 all programs must offer doctoral degrees.[6] The minimum duration of a master's-level program is 24 months of full-time study (or its part-time equivalent), whereas the curriculum for a practice-oriented doctoral degree is typically a minimum of 36 months of full-time study. After completion of an accredited program, a CRNA is eligible to take the National Certification Examination of the National Board of Certification and Recertification for Nurse Anesthetists.

AA education programs require that students have a bachelor's degree and premedical course work. After receiving 27 months of master's degree–level education in an accredited program, they are eligible for the Certifying Examination for Anesthesiologist Assistants, administered by the National Commission for Certification of Anesthesiologist Assistants (NCCAA) in collaboration with the National Board of Medical Examiners (NBME). CAAs must practice under the supervision of a physician anesthesiologist as part of the anesthesia care team model. Currently, CAAs may practice in 18 U.S. jurisdictions.

QUALITY AND SAFETY

For many years, clinical anesthesia practice has been recognized as a model for quality and safety in medicine. The 1999 Institute of Medicine (now the National Academy of Medicine) report, "To Err Is Human," specifically identified anesthesia as "an area in which very impressive improvements in safety have been made."[7] The ASA has been a leader within organized medicine in the development and implementation of formal, published standards of practice. ASA standards, practice guidelines, practice advisories, and alerts have significantly influenced how anesthesia is practiced in the United States.[8] Anesthesiologists have also formed patient safety–focused societies, such as the Anesthesia Patient Safety Foundation (APSF), an independent nonprofit corporation begun in 1985 with the vision "that no patient shall be harmed by anesthesia." The APSF is supported by the ASA and corporate sponsors, with members that include physician anesthesiologists, nurse anesthetists, manufacturers of equipment and drugs, engineers, and insurers. The APSF Newsletter is dedicated solely to safety and has become one of the most widely circulated anesthesia publications in the world.[9] The APSF has highlighted diverse issues such as anesthesia machine checkout, opioid-induced respiratory depression, residual neuromuscular blockade, postoperative visual loss, emergency manual use, and COVID-19 airway management. In 2018 the APSF board of directors generated a list of the top perioperative patient safety priorities; these priorities are reviewed on an annual basis. The 2021 top patient safety priorities are listed in Box 1.2. Although these

Box 1.2 APSF 2021 Perioperative Patient Safety Priorities

1. Culture of safety, inclusion, and diversity
2. Teamwork, collegial communication, and multidisciplinary collaboration
3. Preventing, detecting, and determining pathogenesis and mitigating clinical deterioration in the perioperative period
4. Safety in nonoperating room locations such as endoscopy, cardiac catheterization, and interventional radiology suites
5. Perioperative delirium, cognitive dysfunction, and brain health
6. Prevention and mitigation of opioid-related harm in surgical patients
7. Medication safety
8. Emerging infectious diseases (including but not limited to COVID-19), including patient management, guideline development, equipment modification, and determination of operative risk
9. Clinician safety: occupational health and wellness
10. Airway management difficulties, skills, and equipment

APSF, Anesthesia Patient Safety Foundation.
From APSF Newsletter. 2021;36(2):53.

advances in patient safety are significant, clinical challenges and complications still occur. Anesthesiology practices must maintain robust quality assessment and improvement programs to continue the leadership role of the specialty in advancing patient care. Many of the advances in perioperative care made by anesthesiologists have emphasized outcomes during a surgical procedure to reduce intraoperative adverse events. To continue to improve patient safety and quality of care will require more focused assessment of the entire perioperative period, including identifying postoperative outcomes for which anesthesia management might have contributed and developing strategies to minimize the likelihood of these adverse events prospectively, including the potential need for readmission.

VALUE-BASED CARE

U.S. health care spending continues to grow, reaching $4.1 trillion in 2020, approximately $12,530 per person, this represents 19.7% of the gross domestic product.[10] The high cost of health care has been challenging for clinicians and health systems to manage. As a result of the increasing costs of care, often without evidence of improved outcome, government (Medicare and Medicaid) and private insurance companies have implemented various types of alternative payment models (APMs) designed to incentivize "value." For these payment models, value is defined as outcome (or quality) divided by cost. A more complete description of quality includes six domains identified by the Institute of Medicine: safety, efficacy, patient-centered, timely, efficient, and equitable.[11] Table 1.3 lists some drivers of value-based health care.[12] In a value-based payment model services are compensated based on improved patient health outcomes rather than specific services provided.

The value-based payment models, particularly for perioperative surgical services, have significant implications for anesthesia practices. A variety of approaches have been used to improve quality and value and create opportunities for providers to benefit from efforts to optimize care and reduce costs. Medicare has implemented the Merit-Based Incentive Payment System (MIPS) requiring anesthesia practices to report quality measures as part of the Quality Payment Program (QPP) from which payments will be adjusted based on performance. Although the MIPS program continues to be refined, the transition to a payment model for anesthesia services that is at least partly based on quality metrics will continue to have financial impact on anesthesia practices.

In addition to the MIPS program and other merit-based payment models, APMs that provide payment to all providers and a health system for a course of care are transforming how care is provided and requiring those participating in care to document their value. For anesthesia practices, the APMs have significant implications and provide opportunities for practices to assume a greater role in perioperative care, to manage costs, and to improve quality, all of which can allow the practices to receive financial benefit based on the value provided. Most important, the APMs represent a significant opportunity to expand the scope of practice across the continuum of the perioperative period to optimize management, reduce costs, and improve patient safety. Some examples in which anesthesia providers have transformed their practice to benefit patients and the health systems include participation in the Perioperative Surgical Home (PSH)[13] and leadership roles in the implementation of Enhanced Recovery After Surgery (ERAS) protocols designed to optimize perioperative care, reduce complications, costs, and lengths of stay.[14] As a result of these efforts, the role for anesthesiologists expanded and provided opportunities to work collaboratively with a more diverse group of providers and health system leaders to improve care for patients beyond the specific needs of the surgical patient population.[3]

Many anesthesia groups are adapting their practices to these new models of care and payment; however, the transition is challenging. The emphasis on value represents an opportunity for anesthesiologists to redefine their role and the scope of anesthesia practice. To do so will require that they develop new skills related to quality, safety, and management beyond what was a part of the core curriculum of anesthesia training.

Table 1.3 Drivers of Value-Based Health Care

Program	Description	Cost Savings	Advantages	Disadvantages
Centers of Excellence	Multidisciplinary, comprehensive program for patient care in a highly focused area (e.g., orthopedics, bariatric surgery).	Standardized approach to equipment; reduction in complications, readmissions, and discharge to facility.	Potentially improved patient outcomes and financial performance.	May lead to decreased access to care. Some studies indicate no improvement in care.
Accountable Care Organizations	Group of physicians, hospitals, and other health care providers joining together to coordinate care among Medicare patients.	Health care teams meet specific quality benchmarks, increasing efficiency of care and reducing costs.	Streamlined communication, reduced medical errors, and reduced duplication of services and cost of care.	May not demonstrate mortality reduction in surgical patients.
Insurance specialty programs (e.g., bundled payments, shared cost savings, population-based payments, merit-based incentive payment)	Engages physicians and health care systems to coordinate care and reduce cost. Fosters competition among providers to create value. Hospital administration negotiates with department chairs or practice managers for reimbursement, including anesthesiology/ perioperative medicine.	Hospital retains more money from bundle if there is a reduction in complications, readmissions, or discharge to facility.	Total allowable expenditures for an episode of care are predetermined. Merit-based incentive payments tie payment to quality, cost, and use of health care information.	May penalize physicians caring for the sickest patients. May not really improve quality or cost.

Adapted from Table 1 in Mahajan A, Esper SA, Cole DJ, et al. Anesthesiologists' role in value-based perioperative care and healthcare transformation. Anesthesiology. 2021;134(4):526–540.

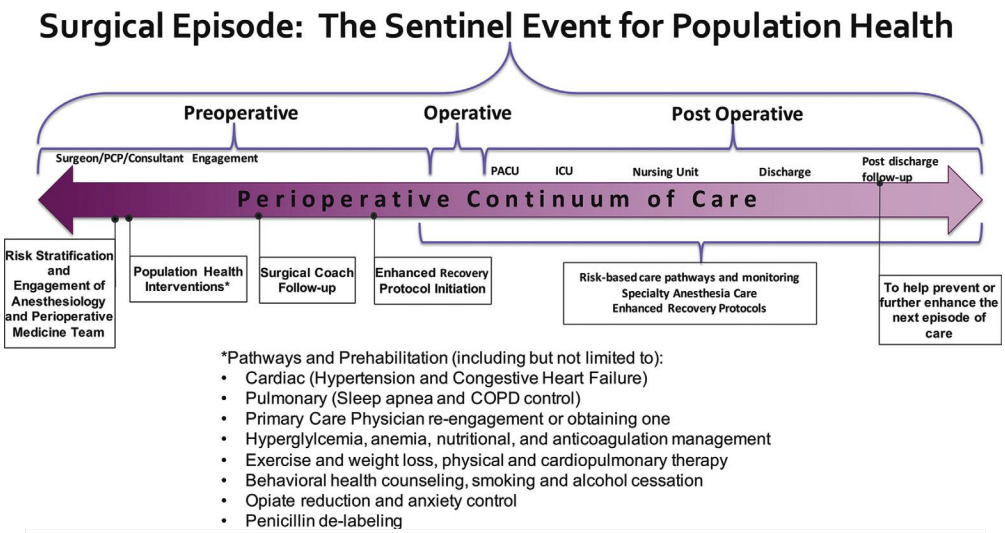

Fig. 1.1 An approach to coordinated perioperative patient care with targeted population health interventions and risk-based care pathways designed to improve patient outcomes.
(From Mahajan A, Esper SA, Cole DJ, et al. Anesthesiologists' role in value-based perioperative care and healthcare transformation. *Anesthesiology*. 2021;134[4]:526–540, Fig. 4.)

Residency programs are refining the curriculum to meet these new needs. Practicing anesthesiologists are also acquiring these additional skills needed to succeed in this new model of care and payment. Fig. 1.1 describes an approach to proactively improving population health in the perioperative setting.[12]

FUTURE OF ANESTHESIA CARE

Anesthesiology is a vibrant and exciting specialty that has undergone dramatic changes over the past few decades. Advances in clinical management and new drugs and technologies have transformed clinical practice and significantly improved patient outcomes. New models of care, including the PSH, and an expanded scope of practice represent major advances for the specialty. At the same time, anesthesia practices must continue to evolve, to reassess traditional approaches to clinical care and identify opportunities to improve quality and safety across the entire continuum of care. Many have taken a broader role in the health care system in order to continue to improve value for the populations served, implement patient-centered care, and manage the financial burdens confronting the health care system. Anesthesiologists, along with their colleagues, must also contribute to efforts to improve access and address health disparities faced by those of low socioeconomic status and for racial and ethnic minorities. Although health care is undergoing significant change and new models of care will continue to evolve, for learners just entering the field of anesthesiology, the opportunities are exciting and diverse and provide the foundation for a rewarding career.

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Chapter

2 LEARNING ANESTHESIA

Kristina R. Sullivan, Manuel C. Pardo, Jr.

The challenges of learning perioperative anesthesia care have grown considerably as the specialty has evolved. The beginning anesthesia trainee is faced with an ever-increasing quantity of literature and the need for increased knowledge and adequate patient care experiences. Healthcare systems increasingly focus on improving the patient experience of care (including quality and satisfaction), improving population health, reducing the cost of healthcare,[1] and improving environmental sustainability.[2]

Most training programs begin with close clinical supervision by an attending anesthesiologist. More experienced trainees may also offer their perspectives, coaching, and practical advice to junior trainees. Programs use a variety of teaching modalities to facilitate learning, including problem-based learning, various forms of e-learning, hands-on task training, mannequin-based patient simulation, and standardized patient sessions.[3] The practice of anesthesia involves the development of flexible patient care routines, factual and theoretical knowledge, manual and procedural skills, and the mental abilities to adapt to changing situations.[4]

COMPETENCIES, MILESTONES, AND ENTRUSTABLE PROFESSIONAL ACTIVITIES

Physician anesthesiologists must attain a broad fund of knowledge and skills. Over the past few decades, the Accreditation Council for Graduate Medical Education (ACGME) has carefully considered how to ensure physician competence. In the late 1990s it launched the Outcome Project, which includes a focus on six core competencies: patient care, medical knowledge, professionalism, interpersonal and communication skills, systems-based practice, and practice-based learning and improvement. The ACGME then advanced the core competencies approach by adopting the Dreyfus model of skill acquisition to create a framework of "milestones." Milestones specific to anesthesiology, published in 2014, defined the development

Table 2.1 Example of Anesthesia Resident Milestones: Patient Care Competency, Perioperative Care, and Management

Level 1	Level 2	Level 3	Level 4	Level 5
Identifies the components of an anesthetic plan	Develops an anesthetic plan for a healthy patient undergoing uncomplicated procedures	Develops an anesthetic plan for patients with well-controlled comorbidities or undergoing complicated procedures	Develops an anesthetic plan for patients with multiple, uncontrolled comorbidities and undergoing complicated procedures	
Identifies the components of a pain management plan	Implements simple perioperative pain management plan	Identifies patients with a history of chronic pain who require a modified perioperative pain management plan	Implements the anesthetic plan for patients with complex pain history and polypharmacy	In collaboration with other specialists, develops protocols for multimodal analgesia plan for patients with a complex pain history and substance use disorder
Identifies potential impact of anesthesia beyond intraoperative period	Identifies patient-specific risks factors for long-term anesthetic effects	Develops the anesthetic plan based on risk factors to mitigate the long-term impact of anesthesia	Implements the anesthetic plan to mitigate the long-term impact of anesthesia	Develops departmental or institutional protocols for reduction of the long-term impact of anesthesia

Milestones are arranged into levels from 1 to 5. These levels do not correspond with postgraduate year of education. Level 4 is designed as a graduation goal (but not a graduation requirement).
From Anesthesiology Milestones 2.0. Accreditation Council for Graduate Medical Education (ACGME), 2020. Available at https://www.acgme.org/globalassets/PDFs/Milestones/AnesthesiologyMilestones2.0.pdf. Accessed December 17, 2021.

of anesthesia residents during 4 years of training.[5] These milestones were updated in 2020 to account for advancements in the field of anesthesiology.[6] For example, an entire milestone devoted to point-of-care ultrasound was added in the 2020 revisions. Table 2.1 shows an example of a milestone in the patient care competency. The milestones incorporate several aspects of residency training, including a description of expected behavior, the complexity of the patient and the surgical procedure, and the level of supervision needed by the resident.

Over the last decade, Entrustable Professional Activities (EPAs) have gained traction as a tool to advance competency-based assessment.[7,8] EPAs are defined as tasks or responsibilities that trainees are entrusted to perform without supervision once relevant competencies are attained.[7,9] An EPA, or task, can be mapped to multiple milestones and competencies and thus provide a framework for assessment. Entrustment decisions by supervisors are documented along a continuum (Box 2.1). Feedback related to these decisions can help trainees form individualized learning plans that will help inform future goals.

Box 2.1 Example of Entrustable Professional Activity (EPA) in Anesthesiology

Task: Induction of anesthesia for a fasted ASA 1/2 patient without a known difficult airway
Competencies involved: medical knowledge, patient care, interpersonal and communication skills
Milestones addressed: perioperative care and management, application and interpretation of monitors, intraoperative care, airway management
Entrustment decisions by supervisors: observed, performed under supervision, performed independently

ASA, American Society of Anesthesiologists.

STRUCTURED APPROACH TO ANESTHESIA CARE

Anesthesia providers care for the surgical patient in the preoperative, intraoperative, and postoperative periods (Box 2.2). Important patient care decisions involve assessing the preoperative evaluation; creating the anesthesia plan; preparing the operating room; and managing the intraoperative anesthetic, postoperative care, and outcome. An understanding of this framework will facilitate the learning process.

Preoperative Evaluation

The goals of preoperative evaluation include assessing the risk of coexisting diseases, modifying risks, addressing patients' concerns, and discussing options for anesthesia care (see Chapters 13 and 14). The beginning

Table 2.2 Questions to Consider in Preoperative Evaluation

Question	Anesthetic Considerations
What is the indication for the proposed surgery?	The indication for surgery may have anesthetic implications. For example, a patient requiring esophageal fundoplication will likely have severe gastroesophageal reflux disease, which may require modification of the anesthesia plan (e.g., preoperative nonparticulate antacid, intraoperative rapid-sequence induction of anesthesia).
What is the proposed surgery?	A given procedure may have implications for anesthetic choice. Anesthesia for hand surgery, for example, can be accomplished with local anesthesia, peripheral nerve blockade, general anesthesia, or sometimes a combination of techniques.
Is the procedure elective, urgent, or an emergency?	The urgency of a given procedure (e.g., acute appendicitis) may preclude lengthy delay of the surgery for additional testing, without increasing the risk of complications (e.g., appendiceal rupture, peritonitis). Surgical procedures related to a cancer diagnosis may also present a degree of urgency depending on the risk of metastasis.
What are the inherent risks of this surgery?	Surgical procedures have different inherent risks. For example, a patient undergoing coronary artery bypass graft has a significant risk of problems such as death, stroke, or myocardial infarction. A patient undergoing cataract extraction is unlikely to sustain perioperative morbidity.
Does the patient have coexisting medical conditions? Does the surgery or anesthesia care plan need to be modified because of them?	The anesthesia provider must understand the physiologic effects of the surgery and anesthetic and the potential interaction with the medical condition. For example, a patient with poorly controlled systemic hypertension is more likely to have an exaggerated hypertensive response to direct laryngoscopy. The anesthetic plan may be modified to increase the induction dose of intravenously administered anesthetic (e.g., propofol) and administer a short-acting beta-adrenergic blocker (e.g., esmolol) before instrumentation of the airway.
Has the patient had anesthesia before? Were there complications such as difficult airway management? Does the patient have risk factors for difficult airway management?	Anesthesia records from previous surgery can yield much useful information. The most important fact is the ease of airway management techniques such as direct laryngoscopy. If physical examination reveals some risk factors for difficult tracheal intubation but the patient had a clearly documented uncomplicated direct laryngoscopy for recent surgery, the anesthesia provider may choose to proceed with routine laryngoscopy. Other useful historical information includes intraoperative hemodynamic and respiratory instability and occurrence of postoperative nausea.

trainee should learn the types of questions that are the most important to understanding the patient and the proposed surgery (Table 2.2).

Box 2.2 Phases of Anesthesia Care

Preoperative Phase
Preoperative evaluation
Choice of anesthesia
Premedication

Intraoperative Phase
Physiologic monitoring and vascular access
General anesthesia (i.e., plan for induction, maintenance, and emergence)
Regional anesthesia (i.e., plan for type of block, needle, local anesthetic)

Postoperative Phase
Postoperative pain control method
Special monitoring or treatment based on surgery or anesthetic course
Disposition (e.g., home, postanesthesia care unit, ward, monitored ward, step-down unit, intensive care unit)
Follow-up (anesthesia complications, patient outcome)

Creating the Anesthesia Plan

After the preoperative evaluation, the anesthesia plan can be completed. The plan should list drug choices and doses in detail, in addition to anticipated problems (Boxes 2.3 and 2.4). Many alternatives to a given plan may be acceptable, but the trainee and the supervising anesthesia provider should agree in advance on the details.

Preparing the Operating Room

After determining the anesthesia plan, the trainee must prepare the operating room. Routine operating room preparation includes tasks such as checking the anesthesia workstation (see Chapter 15). The specific anesthesia plan may have implications for preparing additional equipment. For example, fiber-optic tracheal intubation requires special equipment that may be kept in a cart dedicated to difficult airway management.

Managing the Intraoperative Anesthetic

Intraoperative anesthesia management generally follows the anesthesia plan but should be adjusted based

Box 2.3 Sample General Anesthesia Plan

Case
A 47-year-old, 75-kg female with biliary colic and well-controlled asthma requires anesthesia for laparoscopic cholecystectomy.

Preoperative Phase
Premedication:
Midazolam 1–2 mg intravenous (IV) to reduce anxiety
Albuterol, two puffs, to prevent bronchospasm

Intraoperative Phase

Vascular Access and Monitoring
Vascular access: one peripheral IV catheter
Monitors: pulse oximetry, capnography, electrocardiogram, noninvasive blood pressure with standard adult cuff size, temperature

Induction
Propofol 2 mg/kg (150 mg) IV (preceded by lidocaine 60 mg IV to reduce propofol injection pain)
Neuromuscular blocking drug to facilitate tracheal intubation: rocuronium 0.6 mg/kg (50 mg) IV
Airway management
Facemask: adult medium size
Direct laryngoscopy: Macintosh 3 blade, 7.0-mm internal diameter (ID) endotracheal tube

Maintenance
Inhaled anesthetic: sevoflurane
Opioid: fentanyl, anticipate 2–4 μg/kg IV total during procedure
Neuromuscular blocking drug titrated to train-of-four monitor (peripheral nerve stimulator) at the ulnar nerve

Emergence
Antagonize effects of nondepolarizing neuromuscular blocking drug: sugammadex 2–4 mg/kg based on train-of-four monitoring
Antiemetic: dexamethasone 4 mg IV at start of procedure; ondansetron 4 mg IV at end of procedure
Tracheal extubation: when patient is awake, breathing, and following commands
Possible intraoperative problem and approach: bronchospasm: increase inspired oxygen and inhaled anesthetic concentrations, decrease surgical stimulation if possible, administer albuterol through endotracheal tube (5–10 puffs), adjust ventilator to maximize expiratory flow

Postoperative Phase
Postanesthesia care unit (PACU) orders to include fentanyl IV prn for postoperative analgesia, in addition to oxycodone 5 mg PO before PACU discharge; prn antiemetics include prochlorperazine, because antiemetics of two different drug classes were administered intraoperatively
Disposition: PACU, then hospital ward once PACU discharge criteria are met

Box 2.4 Sample Regional Anesthesia Plan

Case
A 27-year-old, 80-kg male requires diagnostic right shoulder arthroscopy for chronic pain. He has no known medical problems.

Preoperative Phase
Premedication: midazolam 1–2 mg intravenous (IV) to reduce anxiety
Nerve block placed in preoperative area with electrocardiogram (ECG), blood pressure, and pulse oximetry monitoring
Type of block: interscalene
Needle: 22-gauge short-bevel, 5 cm long, echogenic
Local anesthetic: 0.5% ropivacaine, 20 mL
Ancillary equipment: ultrasound machine with linear transducer, sterile sheath, ultrasound gel
Technique: chlorhexidine skin preparation, localize nerve in posterior triangle of neck, use ultrasound to guide in-plane needle insertion, inject local anesthetic
Precautions: because of the risk of local anesthetic systemic toxicity (LAST), the location of 20% intralipid is confirmed before block placement

Intraoperative Phase
Intraoperative sedation and analgesia:
Midazolam 0.5–1 mg IV given every 5–10 minutes as indicated
Fentanyl 25–50 μg IV given every 5–10 minutes as indicated

Postoperative Phase
Postanesthesia care unit (PACU) orders will include prn IV fentanyl for analgesia, but will most likely not be required because of the long-acting local anesthetic used for the nerve block
Disposition: PACU, then home once PACU discharge criteria are met

on the patient's responses to anesthesia and surgery. The anesthesia provider must evaluate several different information pathways from which a decision on whether to change the patient's management can be made. The trainee must learn to process these different information sources and attend to multiple tasks simultaneously. The general cycle of mental activity involves observation, decision making, action, and repeat evaluation[10] (Fig. 2.1). Vigilance, being watchful and alert, is necessary for safe patient care, but vigilance alone is not enough. The anesthesia provider must weigh the significance of each observation and can become overwhelmed by the amount of information or by rapidly changing information. Intraoperative clinical events can stimulate thinking and promote an interactive discussion between the trainee and supervisor (Table 2.3).

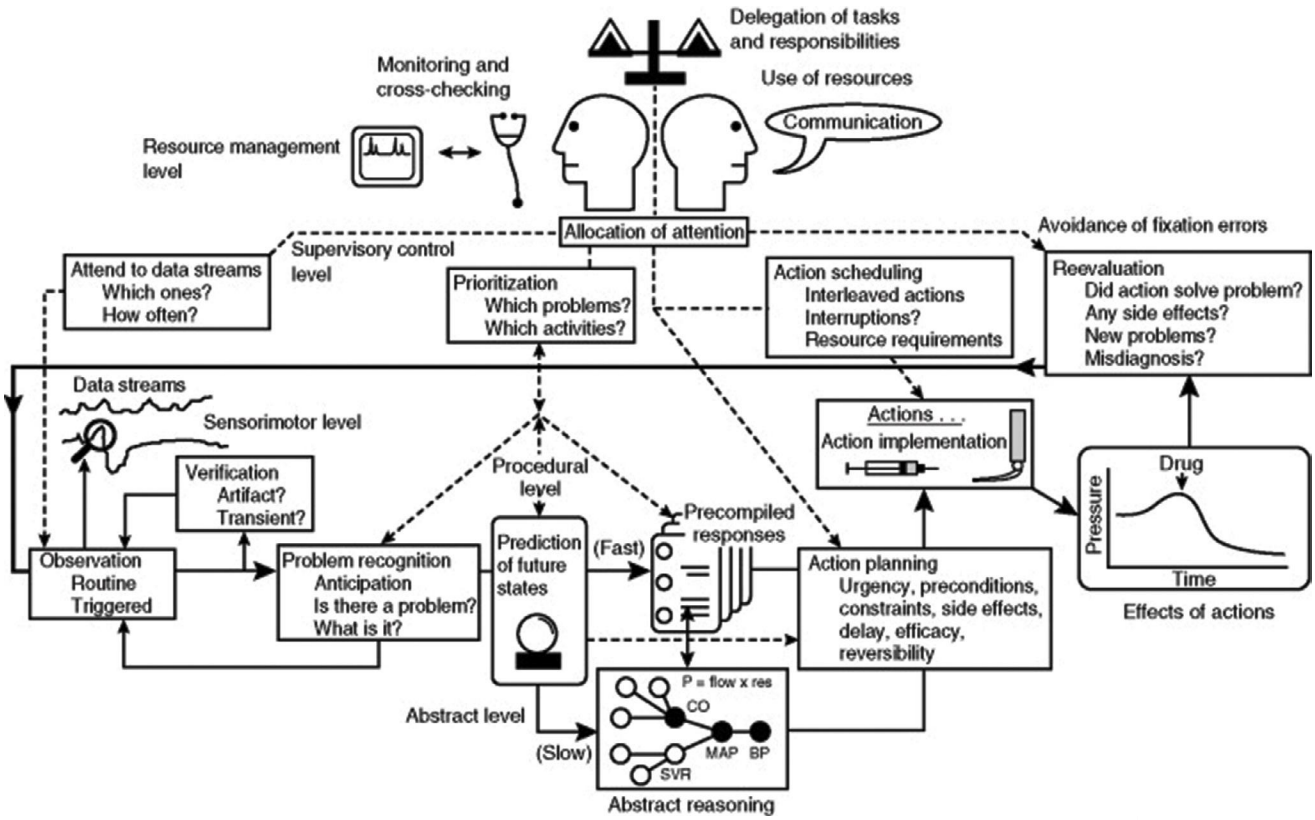

Fig. 2.1 Model of the anesthesia professional's complex process of intraoperative decision making. There is a primary loop (*heavy black arrows*) of observation, decision, action, and reevaluation. This loop is controlled by higher levels of supervisory control (allocation of attention) and resource management. *BP*, Blood pressure; *CO*, cardiac output; *MAP*, mean arterial pressure; *P*, pressure; *res*, resistance; *SVR*, systemic vascular resistance. (From Gaba DM, Fish KJ, Howard SK, et al. Crisis Management in Anesthesiology, 2nd ed. Philadelphia: Saunders; 2014, Figure 1.4.)

Patient Follow-up

The patient should be reassessed after recovery from anesthesia. This follow-up includes assessing general satisfaction with the anesthetic; postoperative pain; and a review for complications such as dental injury, nausea, nerve injury, and intraoperative recall.

LEARNING STRATEGIES

Learning during supervised direct patient care is the foundation of clinical training. Because the scope of anesthesia practice is so broad (see Chapter 1) and the competencies trainees are required to master are diverse, direct patient care cannot be the only component of the teaching program. Other modalities include independent reading, in-person or synchronous virtual lectures or small-group discussions, simulations, and various forms of e-learning.[3] Independent reading should include basic textbooks and selected portions of comprehensive textbooks in addition to anesthesia specialty journals and general medical journals. In-person or synchronous virtual lectures can be efficient methods for transmitting large amounts of information. However, the large group lecture format is not conducive to audience interaction. In-person or synchronous virtual group discussions are most effective when they are small (fewer than 12 participants) and interactive. Journal clubs, quality assurance conferences, and problem-based case discussions lend themselves to this format.

A teaching method termed *the flipped classroom* can combine aspects of asynchronous e-learning and in-person or synchronous group discussions.[11] One popular approach to the flipped classroom involves the use of an asynchronous video lecture that must be viewed before the class session. Interactive class time involves discussions or other active learning modalities that are only effective if the trainee has viewed the material beforehand.

Table 2.3 Examples of Intraoperative Events to Discuss

Event	Questions to Consider	Possible Discussion Topics
Tachycardia after increase in surgical stimulation	Is the depth of anesthesia adequate? Could there be another cause for the tachycardia? Is the patient in sinus rhythm, or could this be a primary arrhythmia?	Assessment of anesthetic depth Approaches to increasing depth of anesthesia Diagnosis of tachycardia
End-tidal CO_2 increases after laparoscopic insufflation	Is the patient having a potentially life-threatening complication of laparoscopy such as CO_2 embolism? What is the expected rise in end-tidal CO_2 with laparoscopic procedures? How should the mechanical ventilator settings be adjusted?	Complications of laparoscopy Mechanical ventilation modes Causes of intraoperative hypercarbia
Peripheral nerve stimulator indicates train-of-four 0/4 15 minutes before the end of surgery	Is the nerve stimulator functioning properly? Is there a reason for prolonged neuromuscular blockade? Can the blockade be reversed safely?	Neuromuscular stimulation patterns Clinical implications of residual neuromuscular blockade Pharmacology of neuromuscular blockade reversal

Simulations can take several forms: task-based simulators to practice discrete procedures such as laryngoscopy or intravenous catheter placement, mannequin-based simulators to recreate an intraoperative crisis such as malignant hyperthermia or cardiac arrest, and computer-based simulators designed to repetitively manage advanced cardiac life support algorithms. The wide variety of web-based material that is readily accessible to trainees includes podcasts and videocasts, ultrasound learning modules, and other procedure-based instructional videos.[3]

The beginning trainee is typically focused on learning to care for one patient at a time, that is, case-based learning. When developing an individual anesthesia plan, the trainee should also set learning goals for a case (Box 2.5). Trainees should regularly reflect on their practice and on how they can improve their individual patient care and their institution's systems of patient care.

Box 2.5 Sample Learning Goals for Operating Room Case

A 47-year-old, 75-kg female with biliary colic and well-controlled asthma requires anesthesia for laparoscopic cholecystectomy. Possible learning goals to be addressed by directed reading before the case or discussion during the case include the following:

What complications of laparoscopic surgery can present intraoperatively?
What are the manifestations?
How should these complications be treated?
How will the severity of the patient's asthma be assessed?
What if the patient had wheezing and dyspnea in the preoperative area?

Learning Orientation

The trainee's approach to a learning challenge can be described as a "performance orientation" or a "learning orientation."[12] Trainees with a performance orientation have a goal of validating their abilities, whereas trainees with a learning orientation have the goal of increasing their mastery of the situation. Feedback is more likely to be viewed as beneficial for trainees with a learning orientation, whereas a trainee with a performance orientation is likely to view feedback as merely a mechanism to highlight an area of weakness. If the training setting is challenging and demanding, an individual with a strong learning orientation is more likely to thrive.

The growth mindset theory suggests that performance versus learning orientation is influenced by an individual's beliefs about their intelligence and abilities. People with a growth mindset believe that intelligence and abilities are not fixed and can be developed. Other features of a growth mindset include embracing challenges, viewing effort as necessary for success, and considering feedback as important for ongoing learning.[13] Individuals with a growth mindset focus on mastery of learning goals rather than performance (either performing more poorly than others or trying to outperform others). Although growth mindset theory has been studied in primary and secondary schools for decades, the theory as it relates to health professions education is in its early phase of exploration. Although more research is warranted, potential benefits of the growth mindset include helping health professions learners be more receptive to feedback, which can support the relationship between learners and educators.[13]

Cognitive Load

Providing anesthesia in the operating room is a complex process that requires processing and using enormous amounts of information. Anesthesia trainees, especially those in the beginning of their training, encounter an enormous cognitive load as they learn new information. In brief, cognitive load theory suggests that new information must be processed by the working memory, which has a limited capacity.[14] The working memory faces three types of cognitive load: intrinsic load, extraneous load, and germane load.[15] Intrinsic load is related to the degree of difficulty of the material and the expertise of the person processing the information (i.e., load associated with the task). Extraneous load is the load imposed that is not necessary to learning the information (i.e., load *not* essential to the task). Germane load is the load imposed by the learner's use of strategies to organize and process information and may be viewed as a learner's level of concentration devoted to learning. Optimizing germane load allows learners to organize knowledge into schemas or scripts. These act as a single element in working memory and therefore reduce intrinsic load. Extensive practice allows for schemas and scripts to become automated and performed with ease and without effort. This opens space in the working memory to process and learn more information.

Using cognitive load theory, instructors can facilitate learning in one of three ways: (1) teach at the level and expertise of the learner (decrease intrinsic load); (2) remove content or other interruptions not pertinent to the task or subject (decrease extraneous load); and (3) encourage strategies that allow for processing of information (optimize germane load).[14,16] If intrinsic and extraneous load are too high, a learner will not have enough working memory to allow for the germane load needed to develop schemas and scripts. Trainees who understand these processes, including the importance of practice, are more likely to excel in their learning and grow as clinicians.

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Chapter

3 CLINICIAN WELL-BEING

Laura Berenstain, Jina Sinskey

Clinician well-being has emerged as a critical issue because of widespread clinician burnout. There is growing recognition that a combination of individual strategies and systems-level solutions is required to successfully promote clinician well-being. Interventions to prevent burnout are more effective than those that address burnout after it has occurred.

DEFINING TERMS

Burnout

In its 11 revision of the International Classification of Diseases (ICD-11) the World Health Organization (WHO) defines burnout as an occupational phenomenon rather than an individual mental health diagnosis (e.g., depression).[1] The term burnout was initially coined by Freudenberger in the 1970s, who described 12 progressive stages of burnout experienced by individuals in the helping professions in response to severe stress: (1) compulsion to prove oneself, (2) working harder, (3) neglecting of needs, (4) displacement of conflicts, (5) revision of values, (6) denial of emerging problems, (7) withdrawal, (8) obvious behavioral changes, (9) depersonalization, (10) inner emptiness, (11) depression, and (12) burnout.[2] Three key dimensions of burnout are commonly evaluated: emotional exhaustion, depersonalization, and a diminished sense of personal accomplishment.[3] Burnout rates in U.S. anesthesiologists and anesthesiology trainees range from 14% to 51%.[4,5] Clinician burnout is associated with negative consequences for (1) patient care, (2) the clinician workforce and health care system costs, and (3) clinicians' own health and safety.[1] Both work environment and individual factors can influence the risk of burnout in anesthesiology (Table 3.1).

Table 3.1 Work Environment and Individual Factors as Risk Factors for Burnout in Anesthesiology

Anesthesia Work Environment Factors	Individual Factors
• Front-line providers of acute care • Work associated with time pressure • Rapid pace of work • Need for sustained vigilance • Chaotic setting • Limited control over schedule • Lack of respect as a consulting clinician	• Perceived lack of support at work • Perceived lack of support at home • Working more than 40 hours per week • Lesbian, gay, transgender/transsexual, queer/questioning, intersex, asexual status • Perceived staffing shortages

From Pinyavat T, Mulaikal TA. Fostering physician well-being in anesthesiology. *Int Anesthesiol Clin*. 2020;58(4):36–40 and Afonso AM, Cadwell JB, Staffa SJ, et al. Burnout rate and risk factors among anesthesiologists in the United States. *Anesthesiology*. 2021;134(5):683–696.

Resilience

Resilience refers to the ability of both individuals and social groups to withstand, adapt, recover, or even grow from adversity, stress, or trauma; in other words, the ability to bounce back from challenging life experiences. Traditionally, resilience in the context of clinician well-being has focused on individual personality traits, behaviors, and attitudes. Resilience is a continuous, dynamic state that can be nurtured and trained.[1]

Moral Injury

Moral injury was first described in war veterans. It refers to the lasting negative effects on an individual's conscience or moral compass when that person perpetrates, fails to prevent, or witnesses acts that transgress one's own deeply held moral beliefs and expectations.[6] Emotions of guilt, shame, and remorse are frequently associated with moral injury. In medicine moral injury describes the distress that clinicians experience when they are unable to provide high-quality patient care because of factors beyond their control. During the coronavirus disease 2019 (COVID-19) pandemic, concerns about adequate personal protective equipment (PPE), witnessing patients dying alone in isolation, and the need to make allocation decisions to ration scarce medical resources were among numerous factors that contributed to clinician moral injury.

Well-Being

Well-being is not simply the absence of burnout. It also includes the presence of positive emotions (e.g., contentment and happiness), the absence of negative emotions, satisfaction with life, fulfillment, engagement, and positive functioning. Professional well-being allows clinicians to thrive and achieve their full potential through the experience of positive perceptions and an environment that supports a high quality of life at work.[1] The terms *wellness* and *well-being* are often used interchangeably. Efforts to promote wellness have traditionally focused on physical and emotional health and maintaining a healthy lifestyle. Although physical and emotional health are critical to overall well-being, they are only part of the equation. In addition to these two domains, well-being encompasses several distinctive, interdependent dimensions that can be internal or external to the individual (Fig. 3.1). Drivers of clinician well-being can be organized into a hierarchy of needs, starting with basic needs at the lowest level and leading to self-actualization at the highest level (Fig. 3.2).

WHY WELL-BEING IS IMPORTANT

Physicians with high levels of well-being generally have enthusiasm for life and work, along with a sense of accomplishment and belonging. However, personal characteristics such as perfectionism, self-doubt, inability to delegate, and high levels of commitment despite adversity can contribute to emotional exhaustion. Maslach and colleagues suggested that the best workers are more predisposed to burnout because they will continue to expend significant energy to meet their goals even in the face of barriers.[7] Not surprisingly, the prevalence of burnout observed among physicians compared with other U.S. workers is significantly higher even after adjustment for work hours, age, and gender.[1]

Chronic occupational stress is linked to neurobiologic findings. High levels of norepinephrine and dopamine are released in the brain during episodes of uncontrollable stress, weakening the abilities of the prefrontal cortex and impairing higher-order functions, including reasoning, social cognition, attention regulation, and complex decision making. In contrast, controllable stressors (such as a meaningful challenge) do not result in the same chemical changes.[8] Structural magnetic resonance imaging (MRI) findings obtained longitudinally in both a control population and a group with occupational exhaustion syndrome strongly suggested links between chronic occupational stress and thinning of the prefrontal cortex, enlargement of the amygdala, and caudate reduction. These findings were gender-specific, with women affected to a greater degree than men.

Professionalism, teamwork, and patient safety can all suffer as a result of burnout. Multiple studies have suggested a relationship between physician burnout and an increased incidence of both self-perceived medical errors and suboptimal care. Anesthesia residents at greater

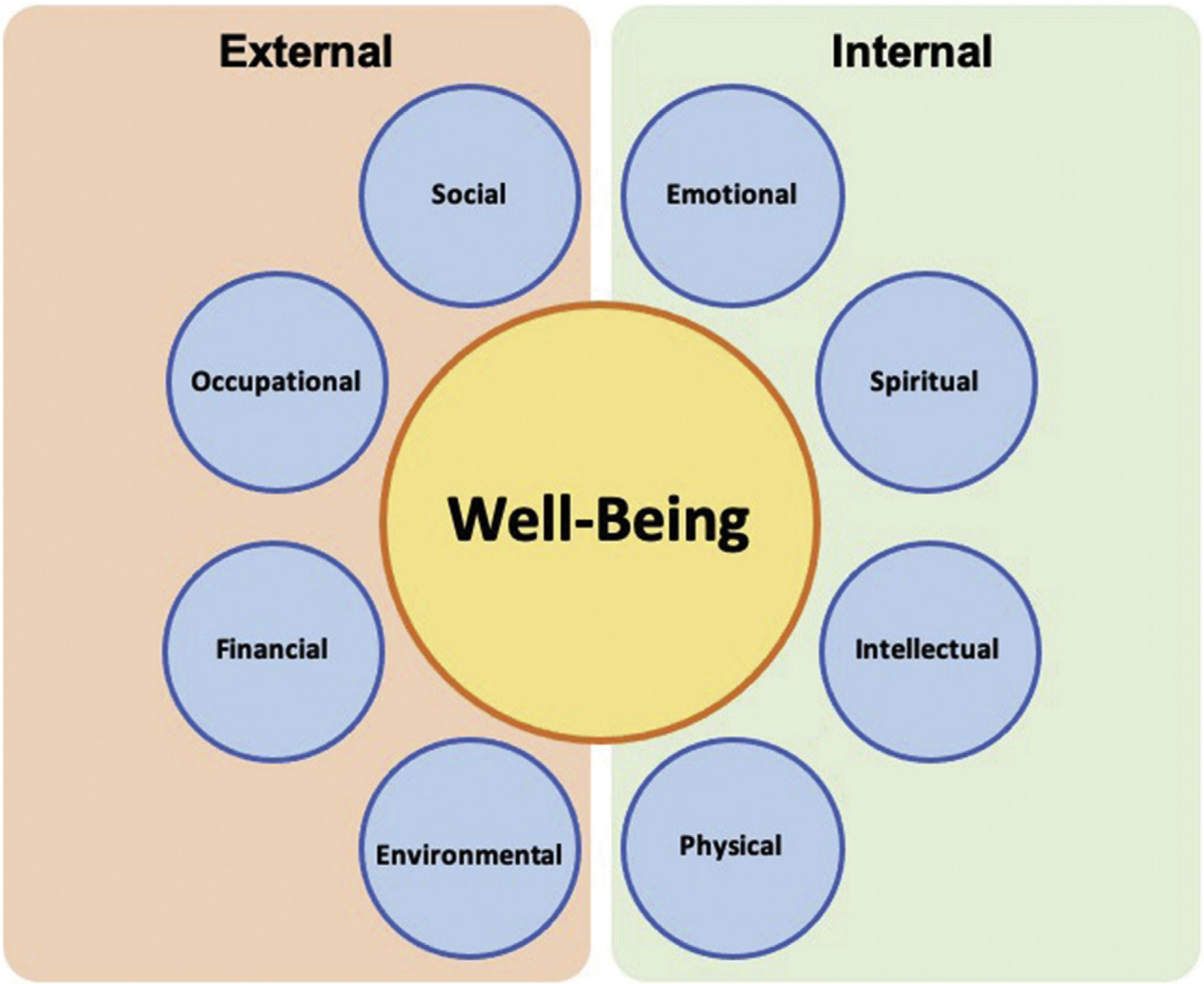

Fig. 3.1 The eight dimensions of well-being. (Adapted from Substance Abuse and Mental Health Services Administration [SAMHSA]. *Creating a Healthier Life: A Step-by-Step Guide to Wellness.* Washington, DC: SAMSHA; 2016.)

risk for burnout and depression reported more medication errors and mistakes with negative consequences for patients than residents with lesser risk.[9] Perhaps most concerning is the finding that emotional distress demonstrated during residency can have implications for future burnout as a practicing physician. In a longitudinal study of internal medicine physicians with early signs of emotional distress the persistence of emotional distress along with an association with depersonalization was identified 10 years after residency.[10]

The negative financial impact of burnout on health care systems is considerable. Studies have found that physicians with self-reported burnout were approximately twice as likely to leave the institution; the societal cost of turnover and reduced productivity caused by physician burnout in the United States is estimated to be greater than $4 billion annually.[1] Clinicians may also elect to reduce their work hours or retire early, resulting in decreased system productivity and reduced access to care for patients. Physician turnover also adversely affects colleagues and increases the risk of burnout for other health care team members.

The provision of optimal health care is the end product of a successful relationship between those providing care and those seeking care. Recognizing the negative impact of clinician burnout on health care organizations, the American Medical Association (AMA) has outlined five critical arguments for supporting well-being: (1) moral and ethical, (2) business, (3) recognition, (4) regulatory, and (5) tragedy.[11] The moral and ethical case may be the most important, as clinician burnout may contribute to excessive alcohol use and suicide.[1]

Fig. 3.2 Health professional wellness hierarchy. (*From Shapiro DE, Duquette C, Abbott LM, et al. Beyond burnout: A physician wellness hierarchy designed to prioritize interventions at the systems level. Am J Med. 2019;132[5]:556-563.*)

FACTORS AFFECTING CLINICIAN WELL-BEING

Autonomy, competence, and relatedness (or belonging) are basic psychological needs recognized as critical for achieving life satisfaction and supporting well-being.[12] Motivation also plays a critical role in well-being. Intrinsic motivators such as honoring one's values and finding meaning in one's work and life are associated with increased satisfaction.[12] The Charter on Physician Well-Being acknowledges the need for commitment on the individual, organizational, and societal levels to improve clinician well-being.[13]

Individual Factors

The incidence of burnout symptoms varies across medical specialties and practice settings. Professional characteristics correlated with a higher risk of burnout or dissatisfaction with work–life integration include medical specialty,[14] hours worked per week, and the number of call nights per week.[15] Factors unique to the practice of anesthesiology have been shown to result in a higher practitioner risk for burnout than seen in other specialties. Within the specialty itself, anesthesiology residents show the highest risk of developing burnout.[16] A National Aeronautics and Space Administration (NASA) Task Load Index assessing mental, physical, and time demands and perceived effort by the physician was used to determine physician task load. Higher task load scores were strongly correlated with burnout independent of other variables, with anesthesiology demonstrating one of the highest task load scores.[14]

Overall, physicians have a lower rate of satisfaction with work–life integration than the general U.S. working population, even after adjusting for age, sex, relationship status, and hours worked per week.[1] A 2021 survey of over 4000 American Society of Anesthesiologists (ASA)

members evaluated the presence of burnout with the Maslach Burnout Inventory Human Services Survey.[4] Of the respondents, 59% were at high risk of burnout and 14% met criteria for burnout syndrome. The risk factors independently associated with a high risk of burnout included perceived lack of support at work; working more than 40 hours per week; lesbian, gay, bisexual, transgender/transsexual, queer/questioning, intersex, or asexual status; and perceived staffing shortages.

In a 2021 cross-sectional study of over 4000 U.S. physicians lower work–life integration scores were independently associated with female gender; age between 35 and 44 years; working more hours per week; and certain medical specialties, including anesthesiology, general surgery, and emergency medicine. The relationship status of "single" was also associated with lower work–life integration. Among females, the most significant adverse effect on work–life integration was seen in women identifying as Black/African American.[15] Compared with other physician mothers, physician mothers carrying additional caregiving responsibilities (e.g., caring for ill parents or other relatives) had significantly higher rates of mood or anxiety disorders.[17]

An overdeveloped sense of responsibility to others coupled with a culture that deprioritizes personal needs can consistently lead to difficulty finding adequate time for self-care and a lack of self-compassion. Impostor syndrome, or feelings of not being "enough," can contribute as well. A multicenter study suggested a strong association and dose–response relationship between physician self-valuation and both sleep deprivation and burnout, with self-valuation accounting for nearly 27% of the variability in physician burnout. Differences in self-valuation also accounted for most of the observed differences between male and female physicians in burnout rates.[18]

Organizational Level

Although individual factors influence clinician well-being, most clinicians already tend to exhibit high levels of resilience, underscoring the importance of organizational factors in promoting well-being.[1] A supportive work environment can profoundly affect clinician engagement. A 2021 study found that perceived lack of support at work is strongly associated with a high risk for burnout in practicing anesthesiologists.[4] A survey of anesthesiology trainees found that factors associated with a lower risk of burnout include perceived workplace resource availability, perceived ability to maintain work–life balance, and having a strong social support system.[5]

Numerous factors at the organizational level influence clinician well-being. The areas of the work–life model proposed by Maslach and Leiter provide an organizational context of burnout by looking at six areas: workload, control, reward, community, fairness, and values.[19] The degree of mismatch existing in these six areas is predictive of burnout, representing opportunities to develop specific strategies targeted to each area to improve matches between people and their work.

Culture refers to the collective norms, values, and beliefs of members of a particular group or society. By encouraging behaviors such as the compulsion to prove oneself, working harder, and neglecting one's needs, the culture of medical training often drives clinicians toward the initial stages of burnout described previously in this chapter.[20] Historically, the culture of medicine has upheld the idea that the responsibility for clinician well-being belongs to the individual rather than the organization or society. Organizational culture permeates the work experience and can affect and intensify factors perceived to be individual in nature. For example, work–life integration is typically considered to vary by individual. However, clinicians feel comfortable tending to nonwork needs only when cultural norms in the workplace also demonstrate a commitment to work–life integration.[21]

Societal Level

The practice of medicine happens within, and is strongly influenced by, the broader context of society. In 2019 the National Academy of Medicine (NAM) advocated for a systems approach to clinician well-being, with recommendations to reduce stigma and eliminate barriers associated with obtaining mental health support (Table 3.2).[1] Clinicians are often reluctant to seek help for mental health conditions because mental health–related stigma and structural issues such as medical licensure can have serious repercussions for clinicians' ability to practice medicine. This is especially concerning because failure to seek professional mental help is thought to contribute to a higher risk of suicide among physicians versus the general population. Although the Federation of State Medical Boards (FSMB) published recommendations for physician well-being in 2018, a review of initial medical license applications from 54 states and territories and Washington, DC in 2021 found that only 1 state was consistent with all recommendations and 5 states were consistent with none.[22]

The rapidly changing and stressful environment created by the COVID-19 pandemic exacerbated existing clinician burnout. Health care professionals' experiences during COVID-19 compromised the foundation of clinician well-being by threatening not only their basic needs but also their safety (physical safety and job security). Anesthesia care team members and other individuals participating in endotracheal intubation procedures experienced an even greater threat to their physical safety and mental health because of the heightened risk of exposure to, and transmission of, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The surge of physical and mental health issues in clinicians has

Table 3.2 National Academy of Medicine Goals for Eliminating Clinician Burnout and Enhancing Professional Well-Being

Goal	Description
Create positive work environments	Transform health care work systems by creating positive work environments that prevent and reduce burnout, foster professional well-being, and support quality care
Create positive learning environments	Transform health professions education and training to optimize learning environments that prevent and reduce burnout and foster professional well-being
Reduce administrative burden	Prevent and reduce the negative consequences on clinicians' professional well-being that result from laws, regulations, policies, and standards promulgated by health care policy, regulatory, and standards-setting entities, including government agencies (federal, state, and local), professional organizations, and accreditors
Enable technology solutions	Optimize the use of health information technologies to support clinicians in providing high-quality patient care
Provide support to clinicians and learners	Reduce the stigma and eliminate the barriers associated with obtaining the support and services needed to prevent and alleviate burnout symptoms, facilitate recovery from burnout, and foster professional well-being among learners and practicing clinicians
Invest in research	Provide dedicated funding for research on clinician professional well-being

From National Academies of Sciences, Engineering, and Medicine. National Academy of Medicine: Taking Action Against Clinician Burnout: A Systems Approach to Professional Well - Being. 2019.

accentuated the need for a national strategy to protect their well-being.

The NAM recommends creating positive work and learning environments to foster professional well-being in medicine,[1] underscoring the importance of inclusive environments that allow all clinicians to thrive. The recognition that structural racism and health inequities exist in medicine and the medical community must be acknowledged and addressed. Bias and discrimination occur regularly in medicine and can create a harsh work environment that can lead to burnout and suicidality.[23] Microaggressions refer to everyday slights, insults, putdowns, invalidations, and offensive behaviors experienced by members of a marginalized group. Microaggressions may be intentional or unintentional.[24] In medicine microaggressions often take the form of verbal and nonverbal reminders of how an individual, such as a member of an underrepresented minority or a woman, differs from the traditional image of someone in their field. This can lead to attrition, continuing and perpetuating inequities that ultimately hurt the entire medical community. In contrast, *microinterventions* can be a powerful tool to nurture an environment of diversity, equity, and inclusion by providing support and affirmation to individuals targeted by microaggressions.

MENTAL HEALTH

Fatigue Mitigation

Fatigue is defined as mental and physical exhaustion and tiredness. Practicing anesthesiologists and anesthesiology residents often work 24-hour or overnight shifts, which can lead to sleep deprivation and disruption of their circadian rhythm. Sleep-related impairment is associated with decreased professional fulfillment, increased burnout, and increased self-reported medical errors.[25] The Accreditation Council for Graduate Medical Education (ACGME) includes guidelines for fatigue mitigation as part of its common program requirements for anesthesiology residents.[26] Potential strategies for fatigue mitigation include scheduling interventions (e.g., 16-hour vs. 24-hour shifts), strategic naps, and the use of bright lights in clinical settings if feasible.

Substance Use Disorders

Substance use disorders are a serious issue in the anesthesia workplace with potentially devastating consequences for the involved clinician and their patients. Ease of access to venous cannulation equipment and potent drugs with abuse potential, and proficiency with both, create a unique risk for substance use disorders. The incidence of substance use disorders in practicing anesthesiologists and anesthesiology residents ranges between 1% and 2%,[27] with a high risk of relapse in both groups.[28,29] The risk of substance use disorder in certified registered nurse anesthetists (CRNAs) appears similar.[30] Substance use disorders can prove fatal, and one study of practicing anesthesiologists demonstrated that nearly 20% of physicians with a substance use disorder died of a substance use disorder–related cause.[28]

Behavioral changes described in affected anesthesiologists include withdrawal from family and friends; mood swings; increased episodes of anger, irritability, and

hostility; spending more time at the hospital (even when off duty); volunteering for extra calls; refusing relief for lunch or coffee breaks; requesting frequent bathroom breaks; and signing out increasing amounts of opioids or quantities inappropriate for the given case.[31] Treatment generally involves referral to an inpatient facility that specializes in the treatment of health care professionals and includes detoxification, monitored abstinence, intensive education, exposure to self-help groups, and psychotherapy.[31] Substance use disorder prevention programs composed of education, strict substance control practices, structured interventions, and testing have been proposed as a potential strategy to reduce substance use disorders.[27] Reentry into clinical practice must be carefully planned with appropriate staging and monitoring to mitigate the risk of relapse.

Depression

Physicians with a high level of distress, whether because of burnout, depression, or both, can potentially enter a downward cycle that can result in tragic consequences. Burnout can be conceptualized as a process that proceeds through stages beginning with exhaustion and potentially culminating in physical symptoms and despair. As a clinician progresses through the various stages, patient care is often maintained at the expense of the clinician's own well-being and mental health. This perspective also aids in determining the most appropriate and helpful interventions for the clinician who is suffering.

Burnout and major depressive disorder (MDD) can share many of the same symptoms, including anhedonia, fatigue, impaired concentration and cognition, and changes in appetite and sleep. Burnout is described as a workplace phenomenon, whereas MDD is a clinical disorder with well-defined diagnostic criteria published by the American Psychiatric Association. Consideration for the distinction is essential in order not to prevent or delay treatment for clinicians with MDD.

The proportion of physicians screening positive for MDD showed a modest but steady increase between 2011 and 2017, reaching 42%.[32] Burnout, depression, and suicidal ideation are frequent among anesthesiology residents. A 22% incidence of depression risk has been described in anesthesiology residents, with a rate of suicidal ideation more than twice the age-adjusted rate observed in developed countries.[9] In a repeated cross-sectional study approximately half of residents were at high risk for burnout, and one in eight screened positive for depression.[5] These estimates may be low because of underreporting and undertreatment of depression as a result of the stigmatization in medical culture.

Depression is linked to patient safety. Physicians with depression are more likely to experience suboptimal functioning and report medical errors. In a study of anesthesiology residents those at high risk for burnout and depression reported more medical errors and less vigilant patient monitoring than their fellow residents.[9]

Suicide

Physicians have the highest suicide rate of any profession, twice that of the general population, with female physicians at greater risk than males.[33] Although female physicians attempt suicide less often than women in the general population, their completion rate equals male physicians and is estimated to be 2.5 to 4 times that of the general population. A 2020 meta analysis evaluated physician suicide rates since 1980.[34] Although the age-standardized suicide mortality ratio (SMR) for male physicians was significantly lower than the SMR of the general male population, female physicians' SMR remained substantially greater than the SMR for the general female population. Career-associated factors were the most prominent risk factor, and physician specialties associated with a greater risk of suicide included psychiatry and anesthesiology.[34] Although overall rates of suicide were lower than the rates for the age- and gender-matched general population, suicide is the leading cause of death among male residents and the second leading cause among female residents.

Physicians are more likely to commit suicide because of a job-related problem than the general population.[35] Risk factors for suicide in the medical profession include fatigue, social or professional isolation, stress resulting from complaints of bullying, the effects of aging, a perfectionist personality type, and reluctance to seek medical help.[33] Depression, substance abuse, impaired relationships, and self-destructive tendency have also been associated with physician suicide.[34] Early recognition of warning signs, continued efforts to enhance access to mental health resources, and the availability of a national suicide hotline (National Suicide Prevention Lifeline: 1-800-273-8255) will hopefully decrease the risk and promote emotional wellness for all.

INTERVENTIONS TO IMPROVE WELL-BEING

Personal Strategies

Anesthesiology poses more complex challenges to well-being than most medical specialties, ranging from constant scheduling changes to the frequency of exposure to stressful patient care situations. In concert with fatigue and duty to others practice-related challenges can complicate developing reliable personal strategies to enhance well-being and resiliency. Individual factors related to resilience include self-monitoring, setting limits, promotion of social engagement, and the capacity for mindfulness. Choosing the best personal strategies to promote well-being and how and when to implement them is an

individual process, with success related to the sustainability of one's choices. One size does not fit all.

Adequate nutrition, hydration, exercise, and sleep are the cornerstones of self-care and fit into the "basics" level of the health professional wellness hierarchy (see Fig 3.2). Yet even these can prove difficult to achieve consistently, as most clinicians become conditioned to ignore or defer their own needs in response to work demands. Although meeting basic needs can be considered personal strategies, they should also remain departmental and institutional priorities. The individual's ability to consistently fill these human needs is greatly facilitated by providing adequate breaks, accessibility to nutritional food, and conveniently located exercise facilities. Seeking social support and having trusted confidants are also crucial for regenerating energy.

Clinicians with burnout often experience an inability to be "present" and are obsessed with thoughts of the past or anxiety about the future. The practice of mindfulness provides a path to allow the mind respite by fully engaging in the present moment. By creating intentional and nonjudgmental awareness of the moment, mindfulness can be practiced during hand hygiene and while washing the dishes, eating, walking, or sitting. Meditation is a way of cultivating and facilitating mindfulness through the self-regulation of attention and awareness. In mindfulness meditation an anchor, usually the breath, is used as a focus to return to when the mind wanders. Recognizing it as a "practice" helps one remember that perfection is not the goal. Instead, the aim is to return to the present moment as many times as necessary, with nonjudgment and acceptance. A greater level of mindfulness has been shown to facilitate self-reflection, decrease anxiety, and promote emotional self-regulation, with less reactivity to stressful situations and emotional triggers.[36]

As humans, we constantly judge our thoughts, feelings, and experiences, many times harshly. Self-compassion is defined as being open and sensitive to one's own suffering, experiencing feelings of care and kindness to oneself, and not judging one's own inadequacies and failures. Self-compassion allows us to recognize and accept our common humanity and is also associated with compassion towards others.[37] Loving-kindness ("metta") or compassion meditations use the self as the object of practice, cultivating compassion for oneself and spreading it to others. Multiple studies have suggested a complementary effect between mindfulness and compassion practices, with mindfulness practices reducing negative affect system activity (amygdala) and compassion increasing positive emotion brain systems.[38]

Clinicians often find it hard to permit themselves to spend time on self-care. We must shift our mindset and learn to choose ourselves, understanding that self-care is not selfish and that if we do not care for ourselves, we will not be able to care for others effectively. The sustained effort necessary to implement and continue self-care strategies is not easy, and recognizing this may necessitate self-compassion.

Systemic Approaches

The NAM has put forth recommendations for health care organizations to address clinician well-being using a systems approach (see Table 3.2).[1] To address trainee well-being, the ACGME includes well-being requirements for all accredited residency and fellowship programs.[26] Professional societies, including the ASA, are supporting clinician well-being by providing open, accessible, and practical resources and websites for clinician well-being.

Most anesthesia providers will be involved in a medical error or adverse event during their career. A survey of anesthesiologists showed that 84% of respondents were involved in an unanticipated death or serious injury of a perioperative patient, and most were emotionally affected by the event with feelings of guilt, anxiety, and reliving of the episode.[39] Sixty-seven percent stated that their ability to provide patient care was compromised immediately after the event, and 19% acknowledged that they had never fully recovered. The term "second victim" refers to health care professionals who are injured by the same errors as their patients who are harmed. Second victims tend to migrate toward one of three paths: dropping out, surviving, or thriving.[40] Many institutions have formal peer support programs in place to provide social support after critical events. Peer support can and should also be made available outside of specific critical events.

There is a growing emphasis on well-being education for trainees and practicing clinicians, with an increasing number of anesthesiology programs developing formal well-being curricula. Published well-being curricula for anesthesiology residency programs incorporate a combination of education modalities beyond the traditional lecture format, including facilitated small-group discussions and simulation.[41] A study comparing facilitated small-group discussions with providing the same amount of free time found that a facilitated small-group curriculum aimed at promoting collegiality and community reduced depersonalization and increased meaning and engagement in work, with sustained results at 12 months.[42]

Coaching can be defined as "partnering with a client in a thought-provoking and creative process that inspires the client to maximize their personal and professional well-being."[43] Coaching is distinct from other workplace interventions, as it addresses the whole person and can explore both professional and personal issues to facilitate well-being. Through an ongoing trusting and confidential relationship, coaching encourages the development of self-awareness and recognition of individual strengths, enabling the coachee to question self-defeating beliefs and assumptions and focus on future possibilities. Unlike a traditional mentoring relationship, coach and client work as equals, with the client presumed to have the resources

and wisdom to tackle life's challenges. Mindfulness and self-reflection are encouraged. Coaching can also be used for leadership or career development and to enhance team performance. In a randomized study of physicians a 6-month coaching intervention decreased overall burnout by 17.1% in the intervention group, whereas burnout in the control group during the same period increased by 4.9%. Improvements in emotional exhaustion, resiliency, and quality of life were also noted.[44] Coaching is not psychological treatment, however, and clinicians suffering from depression or substance abuse should be referred to appropriate sources for help.

Extensive evidence supports the fact that organizational culture and work environment are crucial elements in whether clinicians remain engaged or enter the burnout cascade. When individual strategies to combat burnout are placed at the center of leadership's efforts, there may be skepticism regarding leadership's commitment to the problem. The NAM has advocated for a systemic approach to promoting engagement and reducing burnout.[1] An organizational infrastructure to support well-being can potentially include a chief well-being officer, well-being committees, and associate/vice chair positions for well-being.

A 2021 report proposed a new integrative model for wellness-centered leadership (WCL) that has three key elements. The first and foremost element requires that leaders *care about people always,* seeking to understand the complex needs and contributions of both individuals and teams.[45] The importance of practicing self-care should also be emphasized for leaders, as a leader's personal level of burnout and self-valuation has been shown to predict their leadership behavior scores.[46] Flexibility and work–life integration should be encouraged. The second element of WCL requires the *cultivation of individual and team relationships*. This involves articulating a vision, creating a shared sense of alignment, and nurturing individualized professional development for team members. Building community at work leads to increased engagement and decreases in burnout. The final component for WCL is transformational: *to inspire change* by empowering teams and encouraging innovative thinking. Intrinsic motivators, including meaning, purpose, alignment in values, and professional development, are emphasized. Leadership is transformational rather than transactional, and the psychological needs of autonomy, competence, and belonging are honored.

Policies to Support Well-Being

The NAM Action Collaborative on Clinician Well-Being and Resilience was created in 2017 in response to the rising rates of clinician burnout and its consequences. Its mission is to improve the understanding of clinician well-being challenges and seek and elevate evidence-based, multidisciplinary solutions. Sponsors of the Action Collaborative on Clinician Well-Being and Resilience include the ACGME, the AMA, the ASA, and multiple academic medical centers.

Several national policies are currently in progress to advocate for clinician well-being. The Dr. Lorna Breen Health Care Provider Protection Act (HR1667) was passed by both the U.S. House of Representatives and the U.S. Senate in 2021 after the death by suicide of Dr. Lorna Breen.[47] The bill specifies that the secretary of Health and Human Services will establish evidence-based education and awareness campaigns encouraging health care professionals to seek support and treatment for mental health concerns. It will further establish grants to health professions schools and academic health centers for training in evidence-informed strategies to reduce and prevent suicide, burnout, and behavioral health conditions among health care professionals and provide funding for evidence-informed strategies to improve clinician well-being and job satisfaction. Currently, in early 2022, HR1667 is awaiting resolution of technical differences between the two bills before being signed into law by President Biden.

Challenges related to well-being exist in a spectrum across all stages of a health care professional's career. The results of burnout are detrimental to clinicians, patients, colleagues, and the health care system. Efforts to enhance clinician well-being must occur at all levels: individual, organizational, and societal.

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Section II

PHARMACOLOGY AND PHYSIOLOGY

Chapter

4 BASIC PHARMACOLOGIC PRINCIPLES

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The basic principles of pharmacology are a fundamental element of an anesthesia provider's knowledge base. This chapter provides an overview of key principles in clinical pharmacology used to describe anesthetic drug behavior. Box 4.1 lists definitions of some basic pharmacologic terms. Pharmacokinetic concepts include volumes of distribution, drug clearance, transfer of drugs between plasma and tissues, and binding of drugs to circulating plasma proteins. The section on pharmacokinetics introduces both the physiologic processes that determine pharmacokinetics and the mathematical models used to relate dose to concentration. Pharmacodynamic concepts include the concentration–drug effect relationship and drug–drug interactions for selected anesthetic interactions for selected anesthetic effects. Anesthesia providers rarely administer just one drug. Most anesthetics are a combination of several drugs with specific goals in analgesia, sedation, and muscle relaxation. Thus pharmacodynamic interactions can profoundly influence anesthetic effect. Formulating the *right dose* of an anesthetic requires consideration of many patient factors: age; body habitus; sex; chronic exposure to opioids, benzodiazepines, or alcohol; presence of heart, lung, kidney, or liver disease; and the extent of blood loss or dehydration, among others. Two of these factors, body habitus and age, will be discussed as examples of patient factors influencing anesthetic drug pharmacology.

PHARMACOKINETIC PRINCIPLES

Pharmacokinetics describes the relationship between drug dose and drug concentration in plasma or at the site of drug effect over time. The processes of absorption, distribution, and elimination (metabolism and excretion) govern this relationship. Absorption is not relevant to intravenously administered drugs but is relevant to all other routes of drug delivery. The time course of intravenously administered drugs is a function of distribution