CURRENT OPINION

Nonoperating room anesthesia education: preparing our residents for the future

Steven D. Boggs[a] and Markus M. Luedi[b]

Purpose of review

Nonoperating room anesthesia (NORA) is the fastest growing segment of anesthetic practice. This review provides an overview of knowledge and trends that will need to be introduced to residents as part of their education.

Recent findings

Topics for the future include, but are not limited to, new medications, artificial intelligence and big data, monitoring depth of hypnosis, translational innovation and collaboration, demographic changes, financial driving forces, destination hubs, medical tourism, and new approaches to education training and self-management.

Summary

Implementing new medical technologies for anesthesia outside the operating room will help to successfully master this ever evolving subspecialty. Anesthesiologists require specific preparation for the diverse settings that they will encounter during their training. In this rapidly changing field, cognitive fitness must be factored into teaching and evaluation of residents. We describe the most important topics to consider when educating anesthesiology residents, and highlight research that addresses upcoming challenges.

Keywords

clinical training, education, nonoperating room anesthesia

INTRODUCTION

Nonoperating room anesthesia (NORA) is the fastest growing segment of anesthetic practice [1■■]. With the development of minimally invasive procedures and advanced diagnostic methods, the demand for anesthetic services outside of traditional operating rooms will continue to increase. Residents in anesthesiology programs must learn how to manage patients in diverse settings [2,3] utilizing new techniques. In the future, new medications as well as developments in both artificial intelligence and monitoring will require residents to continually assimilate new skills. Resident education must address methods of teaching (pedagogy) and focus on psychological adaptability.

ADAPTING TO DIVERSE SETTINGS

Providing anesthesia for the cardiologist doing a catheter ablation is strikingly different from caring for a gastrointestinal patient with an ejection fraction of 15% who needs a colonoscopy prior to receiving a heart transplant. The problems confronting the anesthesiologist differ depending on the NORA location, leading to centers being established for disciplines such as cardiology, gastroenterology, psychiatry, pulmonology, radiology (diagnostic and interventional), radiotherapy, sleep medicine, and urology [4].

Anesthetic objectives for diagnostic and therapeutic NORA procedures are to provide optimal care to the patient in the least amount of time, with the fewest resources, and at minimal cost [5,6].

NEW MEDICATIONS

Although there may never be an 'ideal agent', medications with rapid onset, rapid elimination, minimal hemodynamic and respiratory effects, low cost, and a nontoxic clinical profile [7] are currently in

[a]Department of Anesthesiology, The University of Tennessee School of Health Sciences, Memphis, Tennessee, USA and [b]Department of Anaesthesiology and Pain Medicine, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland

Correspondence to Steven D. Boggs, MD, MBA, Department of Anesthesiology, The University of Tennessee School of Health Sciences Memphis, Chandler Building, Suite 600, 877 Jefferson Avenue, Memphis, TN 38103, USA. Tel: +1 901 448 5988; e-mail: sboggs6@uthsc.edu

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KEY POINTS

- Nonoperating room anesthesia (NORA) is the fastest growing segment of anesthetic practice.
- As NORA evolves and changes take place at an ever-faster pace, cognitive fitness must be factored into teaching and evaluation of residents.
- Industry, hospitals, and academic medical centers are working together to develop new medical technologies for use outside the operating room.

development (see Table 1). These newer agents will increase the options for anesthesia and sedation in NORA locations. Anesthesiologists and clinical pharmacologists must help their residents understand when to apply new medications in their daily practice.

MONITORING

Hypnosis is a prime objective of anesthesia. Depth of hypnosis (DOH) has not been quantifiable in the past. Now, however, there is increasing public concern about awareness under anesthesia [18,19]. The anesthesia literature suggests that we want our patients to be anesthetized but 'not too deep' [20–22].

DOH monitors will be seen in NORA locations more frequently in the coming years. DOH systems may also be combined with closed-loop delivery anesthesia systems to modulate anesthetic delivery. [23,24]. In the future, residents will have to understand the attributes and limitations of DOH monitoring devices, understand the theory behind target-controlled infusions and closed-loop infusion systems, and be comfortable using all of them.

ARTIFICIAL INTELLIGENCE, MACHINE LEARNING, AND BIG DATA

Big data may be defined as new infrastructures capable of dealing with large volumes of heterogeneous data [25,26]. Big data, artificial intelligence, machine learning, and deep learning will all have a profound effect on the ways that medical information is processed. To consider the implications for anesthesiology, we need to consider general

Table 1. New medications under development

Remimazolam [8–11]	Combination of midazolam and remifentanil In Phase III clinical trials in the USA Short-acting anesthetic eliminated by tissue esterases (carboxylesterases) Independent of renal or hepatic metabolism More rapid onset and offset than midazolam Developed for procedural sedation but may find utility in the OR setting
ADV6209 [12,13]	New formulation of oral midazolam Phase I and II clinical trials Longer shelf life More palatable (sweeter when combined with citric acid solution)
MOC-etomidate [14]	Methoxycarbonyl etomidate Ester bond that is rapidly hydrolyzed to form carboxylic acid metabolite No adrenal suppression in rats, human studies in progress
Carboetomidate [14]	Etomidate analog that does not inhibit steroid production
MOC-carboetomidate [14]	Combination of the two agents Combines rapid onset of MOC-etomidate with lower steroid inhibition of carboetomidate Slower onset than MOC-etomidate
AZD-3043 [14–16]	Water-insoluble Rapid hypnosis and rapid recovery, within 3 min Metabolism occurs because of plasma and tissue esterases to inactive metabolite No pain on injection Problems are: chest discomfort, dyspnea, involuntary muscle movements
Phaxan [14,17]	Combination of alphaxalone and 7-sulfobutylether β-cyclodextrin in aqueous solution Similar to propofol Less cardiovascular depression No pain on injection

OR, operating room.

characteristics of data collated by IBM, the world's largest computer company [27]:

(1) 2.3 trillion gigabytes (1000^3 bytes) of data are created each day.
(2) Most US companies have 100 terabytes (1000^4 bytes) of data.
(3) The New York Stock Exchange captures 1 terabyte of data during each trading day.
(4) As of 2011, the global size of data in healthcare was 150 exabytes (1000^6 bytes).
(5) Thirty billion pieces of content are shared on Facebook each month.
(6) Poor data quality costs the US $3.1 trillion a year.
(7) Forty zettabytes (1000^7) of data will be created by 2020, a 300-fold increase over 2005.

The amount of data currently generated in the field of anesthesiology [28] is very small in comparison to the amount produced by business and industry. For example, the amount of data generated if you have a 120-minute procedure and sample the heart rate at various frequencies is shown in Table 2.

What can be said about our data is that it is quite heterogeneous, with information coming from multiple data streams: physiologic, demographic, medication, event data (timestamps), imaging (video laryngoscope, transesophageal echocardiography), billing databases, closed-claim databases and content management system data, among others.

Machine learning is an iterative process in which data is selected and 'trained' [29], validated and tested, after which the model is deployed with further tuning to refine performance. This decreases the error of prediction and improves the accuracy of prediction [30,31,32▪].

Deep learning is a machine learning technique with which a computer learns to perform classification tasks based on images, text, or sound. Deep learning models can achieve state-of-the-art accuracy, sometimes exceeding human-level performance [33,34,35▪▪]. The advantage of deep learning is that it performs very well as the quantities of data increase [36,37] (Fig. 1).

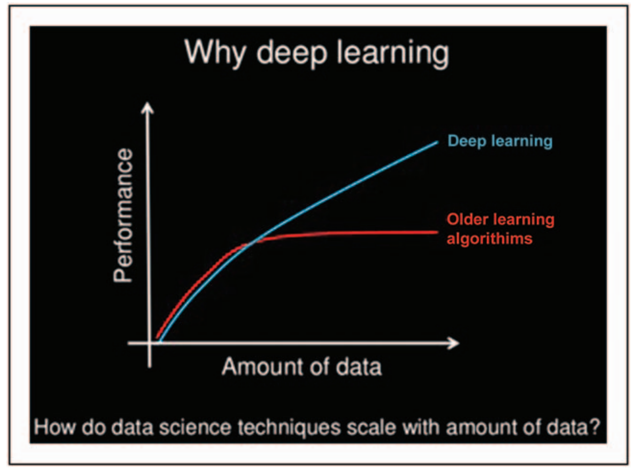

FIGURE 1. In the future, deep learning may be applied to help deal with increasing amounts of healthcare data. Reproduced with permission of Andrew Ng, Stanford University.

This has implications for NORA and resident education. First, as artificial intelligence techniques improve, imaging capabilities will become better and better [38▪]. With better imaging, performance of procedures in all NORA locations, including pulmonary, cardiology and gastrointestinal sites, will be enhanced. Better imaging combined with smaller and less invasive equipment will reduce the physiologic burden on patients [39,40]. Second, artificial reality and artificial intelligence will enable enhanced education with training models before the actual procedure is performed [41]. Third, predictive analytics will allow anesthesiologists to treat hypotension and other physiologic variables before they become significantly disordered and clinically significant [42,43]. And fourth, big data will allow associations to be seen in large numbers of cases, permitting investigation of hypotheses concerning causes for outcomes [44,45].

The result: residents will not be expected to become expert coders, but they will have to be capable of working within a system featuring a human/machine interface in which changes occur rapidly.

Table 2. Anesthesiology data

Sample rate	Data points
5 min	24
1 min	120
15 s	480
250 Hz (every 0.004 s)	1.8 million
Anesthesia cases in general	
Single case	1 MB
200 cases/day	200 MB
50 000 cases/year	50 GB
51.4 million cases/year in the USA	51 TB
Anesthesia Quality Institute (AQI)/National Anesthesia Clinical Outcomes Registry (NACOR) cases	13 million since 2010
1 million AQI/NACOR entries contain Anesthesia Information Management System (AIMS) data	1 TB

TB, terabytes. Data from [28].

PARTNERSHIPS BETWEEN INDUSTRY, HOSPITALS, AND ACADEMIA

Translational innovation is leading to new relationships between industry, hospitals and academic medical centers worldwide. The results of these collaborations can already be seen in multiple NORA sites.

(1) The Norwegian center for Minimally invasive Image-guided Therapy and medical technologies (NorMIT) was created in 2014 to leverage the capabilities of several Norwegian institutions doing research in high-tech medicine [46]. The goal was for Norwegian universities, health institutions, and industrial partners to work collaboratively on the development of medical technologies [47].

(2) In Japan, Kyushu University Center for Clinical and Translational Research (CCTR) is a collaboration between industry and academia. This consortium involves 11 universities in Kyushu, 5 in Chugoku and 4 in Shikoku [48].

(3) In New York, the Weill Cornell Minimally Invasive New Technologies (MINT) Program is exploring technologies to treat complex gastrointestinal and vascular conditions. The MINT program's mission is the development and marketing of 'medical devices and technology that will revolutionize the way minimally invasive surgery is performed' [49].

These three examples reflect the growing interest that academic centers have in partnering with industry to accelerate the development of new technologies.

DEMOGRAPHIC CHANGES

Major demographic changes are occurring worldwide [50]. Fertility and mortality are both decreasing, which is leading to a trend known as population aging. The percentage of older adults in the world population increased from 5% in 1960 to 9% in 2018, and is projected to reach 16% in 2050. Children's percentage of the global population, on the other hand, is decreasing, from 37% in 1960 to 26% in 2018, with 21% projected for 2050 [51]. Over the next three decades, the United States and Europe will transition from having a significant population of older and younger patients to having mainly older patients. Western Europe, China, and India will also transition to having older patients, whereas sub-Saharan Africa will be the only region of the world with a high child dependency ratio.

Because of these demographic changes, medical residents will increasingly be called on to provide care for patients in two different circumstances. Especially in high-income countries, they will have to master techniques for anesthesia in NORA locations, which can ameliorate chronic disease in older adults. In low-income and middle-income countries, conversely, residents will have to learn how to treat critically ill children with minimal resources.

FINANCIAL DRIVING FORCES

The past century saw the centralization of medical care in hospitals in almost every healthcare system in the developed world. Hospitalization in the United States, for example, peaked in 1981 with 171 admissions per 1000 Americans [52], with similar dynamics reported for European countries [53]. There were 6933 hospitals in the United States at that time. Between 1981 and 2013, the occupancy rate in hospitals decreased from 77% to 60%, and it continues to fall. In 1980, there were 4.0 beds for every 1000 Americans, and 140 physicians per 100 000 Americans. In 1996, there were fewer beds (3.5 beds), but the number of physicians had doubled to 280, and in 2018, the numbers were 2.4 beds and 265 physicians [52]. Although the number of providers has not decreased substantially, the number of inpatient beds continues to decrease. This change is consistent with the significant increases seen in this period in ambulatory surgery as well as the number of patients treated outside of the operating rooms using NORA procedures [1▪▪].

Destination hubs

Globally and independent of the healthcare settings, hospitals are facing financial pressure in their local markets, and the definition of a healthcare market itself is changing. Previously, hospitals and providers were in competition within strictly defined geographic areas – cities, states, and perhaps regions. Now, certain procedures have extraordinary requirements for specialized equipment, physical plant, and personnel, and because of this some centers have become destination hubs for specific conditions in the United States (Table 3).

Medical tourism

A related trend, gaining importance in countries such as Thailand and Singapore, is medical tourism [56]. In 2017, 1.4 million United States adults traveled outside of the United States for care [52]. Although such dynamics might threaten access to resources for local patients in emerging markets, these developments have only just started in other regions, such as Europe, which have more regulated

Table 3. Examples of destination hubs for cancer care and cardiac care in the United States

Cancer care [54]	University of Texas MD Anderson Cancer Center
	Memorial Sloan-Kettering Cancer Institute
	Mayo Clinic
	Dana-Farber/Brigham and Women's Cancer Center
	Cleveland Clinic
	Johns Hopkins Hospital
	Seattle Cancer Alliance/University of Washington Medical Center
	H. Lee Moffitt Cancer Center and Research Institute
Cardiac care [55]	Cleveland Clinic
	Mayo Clinic
	Smidt Heart Institute at Cedars-Sinai
	New York Presbyterian – Columbia and Cornell
	Massachusetts General Hospital
	Northwestern Memorial Hospital
	Hospitals of the University of Pennsylvania-Penn Presbyterian
	Brigham and Women's Hospital

heathcare markets. In Canada, medical tourism is seen as a threat by some because it allows patients to circumvent domestic regulation of care [57].

Employer-organized medical care

In a different approach, large corporations, such as Boeing, Wal-Mart, and Whole Foods, are contracting directly with hospitals [58–60] for medical care of employees, so the concentration of highly specialized procedures will accelerate in certain centers, and the trend toward sending patients to centers of excellence will accelerate as well. These trends indicate that many US trainees will be practicing in extremely specialized NORA referral locations, such as the destination hubs listed above.

HOW TO PREPARE RESIDENTS FOR THE FUTURE

Education and training

Residents learning to practice anesthesia outside of the operating room must receive a good foundation in anesthetic training [61,62▪▪,63]. Interestingly, Millennials have many ways of acquiring knowledge, none of which seems to be superior [64▪]. Evidence-based medicine, patient safety, and physiologic monitoring are pillars of anesthesia care. Their role in anesthesia is communicated through mentoring in well supervised surgical operating rooms. Traditional teaching will retain its spot in resident education. Currently, popular training methods include the flipped classroom [65▪,66▪▪,67▪▪], problem-based [68] and competency-based learning [68–72], and simulation training [73]. When anesthesia residents themselves are asked what is important for their education, there are multiple factors that they consider significant, not just a single factor [62▪▪].

Intellectual knowledge, a sound scientific grounding, and technical skills will continue to be the basic requirements for selecting residents [74▪,75▪]. As NORA evolves and changes take place at an ever-faster pace, cognitive fitness must also be factored into teaching and evaluation of residents.

Cognitive fitness

Gilkey *et al.* [76] describe a four-step approach to cognitive fitness. First, individuals must 'understand that experience makes the brain grow'. This means that faculty must model the behaviors (clinical and professional) that the resident must learn. Second, the learner needs to 'work hard at play'. If the resident is subjected to continuous, unrelenting pressure, conditions are not ripe for learning. Within structured parameters, the resident must be allowed the autonomy to take risks and push boundaries. Third, faculty must challenge the resident with patterns and scenarios that are outside of the norm. In the NORA environment, it is not difficult to create challenging scenarios. Finally, it must be impressed upon the resident that learning is continuous. One does not 'graduate', but rather, accumulates experience.

Burnout and adverse settings

The burnout rates in anesthesia residents are high [77▪,78▪,79–85]. Thus personality traits such as adaptive coordination and emotional intelligence will be essential for the next generation of anesthesiologists [86,87]. Resilience will be vital, especially in settings such as NORA, with high production pressure and difficulties in standardizing complex procedures [88].

Graham Jones says that 'elite performers are not born but made' [89]. In industries as diverse as business, music, and sports, winners excel under pressure. A central task in teaching residents will be helping them develop coping skills. Residents must learn how to remain functional under extreme pressure, focusing on themselves and what they can control, and not allow job stress to interfere with their personal lives. Furthermore, training with other specialties will become more important in the future [90▪].

Leadership

In interviews with more than 40 leaders, Bennis and Thomas [91] came to the conclusion that 'positive adaptive capacity' is an essential quality that allows leaders to learn from intense, often traumatic experiences, or 'crucibles'. In dealing with negative experiences, integrity and the retention of personality traits such as passion and curiosity are essential [91]. Residents should know that exposure to adverse settings, such as high-throughput NORA, can be transformative. How we teach these skills remains to be determined [92■]. A strong interpersonal network, psychological fitness, and optimism are essential for building resilience [89].

CONCLUSION

In summary, this fastest growing segment of anesthetic practice requires specific preparation of anesthesiologists during their training. Reliable practical and scientific education covering techniques used to safely anesthetize high-risk patients in these complex, nonstandardized settings is essential. In response to current evidence and trends, we must also focus on supporting trainees' cognitive fitness and psychological adaptability. This will ensure that they are successfully and sustainably prepared to practice in this rapidly evolving area.

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Conflicts of interest

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This article underscores that situational awareness is commonly agreed to be a necessary attribute of anesthesia residents. However, methodologies for teaching situational awareness still are more tacit than formal.