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Anesthesia Quality Improvement: Current State and Future Opportunities

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ABSTRACT

Continuous improvement of quality and safety is a professional obligation of anesthesiologists and an ongoing activity of all academic departments and private practices. Quality improvement is an infinite process that is never fully complete but that instead evolves over time in response to emerging threats to patient safety from new medications, new surgical procedures, and increased recognition of systematic threats. This review discusses current definitions and thinking in anesthesia quality improvement, outlines recommended efforts at the local department level, and makes suggestions for the projects and activities most likely to benefit the anesthesia patients and clinicians of the future.

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Anesthesiology is rightfully praised as the medical specialty with the best record for ongoing improvement in patient outcomes. Although clinical anesthesia was once considered a high-risk activity, our current "defect-free production rate"—electively scheduled cases completed as planned without a perioperative death—is better than 99.9%.[1,2] Although risk is higher in emergency cases, even the highest-risk patients are very unlikely to die in the operating room. This laudable performance is the result of decades of research focused on quality and safety combined with technological advances in anesthesia delivery and patient monitoring.

Most practicing anesthesiologists are familiar with the many contributions of our specialty to patient safety and quality improvement. Among these are widespread adoption of monitoring standards,[3] review of closed claims events,[4] widely promulgated results of national event-reporting systems,[5] use of simulation to hone event responses,[6] and higher level "systems" and "human error" analysis of adverse events.[7] Safety culture is built into the daily working environment of anesthesiologists, from knobs discernable by feel to gas conduits that only fit a specific source.[8]

Anesthesiologists have also been early adopters of new models of thinking about patient safety. These include not only "Safety 1" perspectives focusing on how identifiable system failures cause accidents but also more modern 'Safety 2" perspectives that recognize the inherent variability in system function and the need for human adaptability[9] and the emerging "Safety 3" model that expands to involve hazard and variance management.[10]

Although the generic strategies described above contribute considerably to anesthesia quality and safety, each anesthesia department exists in a local environment with a unique complement of nurses, surgeons, patients, support services, operating rooms, and other infrastructure. For best results, quality and safety strategies for individual practices should be tailored to the specific working environment including multidisciplinary outreach to surgeons and hospital departments. This review will suggest an operational definition of quality, recommend department-level practices for ongoing quality improvement, and identify future opportunities for improving practice both within groups and across the healthcare ecosystem. The descriptions and recommendations in this review are largely drawn from practices in the United States but may apply to anesthesia clinicians in any part of the world.

Definition

Quality is inherently difficult to define. Oxford Languages define it as "the degree of excellence of something." When applied to medicine, the definition might best be described by performance in six domains: effective, equitable, timely, efficient, safe, and patient centered.[11] Quality is thus multidimensional, and because specific definitions of these domains may vary, quality in anesthesia care is best thought of as an asymptotic limit that can be approached but never fully achieved. In addition, improving performance in one domain may not improve performance in others. *Safety*, for example, is defined as "the condition of being protected from or unlikely to cause danger, risk, or injury." *Adverse events* are the opposite of safety: the undesired occurrence of patient harm or risk of harm. *Sentinel events* are those adverse events so severe as to merit a formal review and response. Because complete safety is also an unattainable asymptote, quality improvement cannot be focused on safety alone and requires thoughtful application of available

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resources to those activities promising the greatest margin for improvement. For example, anesthetic care can be made safer by providing cardiac bypass capability in all anesthetizing locations but doing so would consume resources that could be applied elsewhere at a higher return.

Another example of the multidimensional nature of anesthesia quality is the concept of perioperative mortality, defined in the 1940s as the death rate within 30 days in patients admitted for elective surgery.[12] This rate hovers between 2 and 4% in developed countries worldwide and has not changed substantially in the seven decades since it was first described.[13,14] However, a closer look reveals considerable progress in that more complex operations are performed on increasingly older and sicker patients. A typical surgical patient in the 1950s could anticipate a 10-day stay after their open cholecystectomy, with substantial potential for morbidity and mortality.[15] Today, that patient would likely not be included in an inpatient mortality study because the procedure would be carried out laparoscopically, and the patient would go home within 23 h, with an expected mortality rate close to zero. Inpatient surgery 70 yr ago thus encompassed a vastly different population of patients and procedures than today, and anesthesiologists should be justly proud of our contributions to this progress. When applied to anesthesia, then, a meaningful definition of quality focuses not only on clinical outcomes but also the scope of what can be accomplished and the range of patients that can benefit.

Quality is an evolving concept. In addition to the six domains identified by the Institute of Medicine,[11] other relevant quality goals for any specialty include the wellness of the healthcare workforce, the advancement of science, preservation of the environment, preserving public respect for healthcare facilities and workers, and advancement of healthcare equity for all populations. These goals apply to anesthesiology as well,[16] as exemplified by contemporary efforts to reduce the release of greenhouse gases, meet a growing demand for out-of-operating room sedation services, and promote equitable access to high-level care.

Local Examples of Quality Improvement

Improvement in anesthesia quality requires the ability to measure and evaluate past and present performance in domains of interest. In the anesthesia realm, measurement may be applied to care processes such as the timing of antibiotic administration or to outcomes such as the rate of postoperative respiratory failure. Because anesthesiologists typically have extremely accurate, granular data regarding the former, it is tempting to focus on the intraoperative period postanesthesia care unit (PACU). However, the vast majority of perioperative adverse events occur after PACU discharge. Without the ability to measure post-PACU patient outcomes, the ability to link intraoperative behavior to the effectiveness of care is limited. In his 2023 Rovenstine address to the American Society of Anesthesiologists (ASA; Schaumburg, Illinois),[17] Daniel Sessler, M.D. (University of Texas Health Science Center, Houston, Texas), highlighted the common but incorrect assumption that safe arrival to the PACU means the period of highest perioperative risk is over, noting instead that the risk of 30-day mortality is 140 times higher than during surgery, and commented that, statistically, the 30 days after surgery is the third-leading cause of death in the United States.[18]

Unfortunately, for many anesthesia departments, the ability to track postoperative patient outcomes is limited. The day-of-surgery anesthesiologist is rarely included in post-PACU decision-making, and most operating room anesthesiologists receive little feedback on the post-PACU outcomes of their patients. This quality improvement "blind spot" makes it difficult to recognize and address issues that could be resolved by better intraoperative care. Although some countries maintain useful national registries of healthcare outcomes, they are often not sufficiently granular for specific practice improvement. A notable exception is the National Audit approach in the United Kingdom, which has generated useful recommendations for clinical care including prevention of undesired intraoperative recall and management of difficult airways.[19,20]

Monitoring Strategies to Track Common Adverse Events

In part as a result of previously described advances in anesthesia performance, adverse events during modern anesthesia practice are rare.[21] In principle, once an event occurs and safety countermeasures are implemented, the event can be considered "solved." However, perioperative care is dynamic, and changes in patient, procedure, surgeon, care personnel, or equipment may neutralize countermeasures or create latent hazards that can increase the incidence of adverse outcomes. Examples include changes in drug packaging that contribute to medication errors or surgical protocols specifying tucked arms that prevent easy detection of infiltrated intravenous (IV) access.

To monitor trends in adverse anesthesia outcomes, almost all anesthesia departments either operate their own event-reporting system or have access to hospital or perioperative systems. Such reports allow quality or safety personnel to catalog and trend the incidence of known anesthesia complications and identify potentially worrisome trends. The local incidence of events such as mortality,[1] reintubation,[22] and acute kidney injury[23] allow for rough comparisons to published benchmarks, although usually without the ability to adjust for differences in risk based on case type or patient population.

Because most relevant perioperative outcomes (including death) occur after the patient has left the perioperative area, self-report by clinicians or patients is rarely an effective way to identify these outcomes because it requires the provider to follow their patients for the duration of the outcome window. An anesthesiologist who anesthetizes 20 patients per week and is tasked with reporting 7-day

mortality must make multiple inquiries of the medical record to verify that their patient is still alive. Repeat this process for each outcome of interest, and it is easy to see that a process other than self-report is needed.

Fortunately, effective strategies exist for automating the detection of many relevant anesthesia outcomes. If clinical charting is done *via* electronic medical record, reports using threshold laboratory values can be created to detect episodes of acute kidney injury, hyperglycemia, elevated troponin, and pain scores. Although such strategies do not detect all events (due to missing data), they likely capture enough to permit meaningful clinical review.

Outcomes such as stroke and postoperative intubation are more difficult to identify due to clinical complexity. Differentiating a stroke from a reversible ischemic neurologic deficit can require neurologic consultation,[24] whereas postoperative intubation due to respiratory failure should be differentiated from reintubation for a subsequent planned procedure. For such complex outcomes, an effective approach is to collaborate with other entities in the medical center with an interest in the relevant outcome and merge their data with the anesthesia billing database. For example, postoperative stroke often leads to neurologic intervention, and as a result, the neurology department (or stroke center, if the hospital has one) may keep a list of new or ongoing strokes in hospitalized patients. If so, such a list can be merged with the anesthesia billing database to identify postoperative stroke. If ophthalmologists are consulted for corneal abrasions (or if antibiotic ointment is routinely prescribed for such injuries), then billing records for such consults or prescriptions can likewise be merged with the anesthesia billing database. A list of hospital inpatients who have died (Medicare discharge diagnosis code 20) may similarly be used to identify postoperative deaths. Postoperative anesthesia activity can also be used to identify outcomes of interest. If anesthesiologists perform intubations in the intensive care unit, for example, then billing records for that activity can be used to identify postoperative reintubations.

Even if an outcome detection strategy is not perfect, it can still be effective for quality improvement. For postoperative myocardial infarction (MI), for example, merging a list of cardiac catheterization procedures with the anesthesia billing database will generate a list of potential candidates. However, some patients on that list will have undergone postoperative cardiac catheterization for a nonischemia indication, and many patients in the anesthesia billing database may not undergo catheterization even if they meet criteria for MI. Similarly, postoperative troponin monitoring will miss patients in whom postoperative troponins are not measured and will include patients with elevated troponins who do not meet the clinical criteria for MI. There is also nuance in the interpretation of perioperative biomarkers, because even minor changes in creatinine clearance[25] or postoperative troponin[26] are associated with increased long-term risk for renal failure or myocardial dysfunction. Nevertheless, such lists can generate value by targeting patients or processes for detailed review. Because such passive surveillance systems may also identify patients not already "on the radar" of concerned anesthesiologists, they are a needed complement to voluntary event-reporting systems for identification of relevant case outcomes.

Identifying Novel Events

In addition to a monitoring process independent of self-report, an ideal anesthesia quality program should maintain a separate event-reporting pathway to identify novel or latent safety issues. Although this system may overlap with the automated strategies described above, it will also help clinicians identify new or potential threats to patient safety.

Such an "early warning" system can play a key role in safe anesthesia practice. Although the basic conduct of general and regional anesthesia changes infrequently, the specifics of anesthesia care are surprisingly dynamic due to constantly evolving protocols, surgical preferences, and new procedures and patients. The recent introduction of sodium-glucose cotransporter-2 inhibitors and glucagon-like peptide-1 weight loss agents are examples of the ongoing need for anesthesia clinicians to adapt to clinical circumstances. Because the safety and quality implications of such changes may take time to reveal themselves, a robust event-reporting system is potentially the best way to identify clinically relevant vulnerabilities.

The goal of the department's event-reporting system is to alert practitioners to real or potential unsafe conditions that arise in the course of clinical practice. Because anesthesiologists mostly practice alone, a reporting system can allow an event or latent hazard experienced by one practitioner to be disseminated to all, raising group awareness and facilitating the development of countermeasures. Examples of such early warning events include notification of look-alike vials, unexpected behaviors of new equipment, or clinical consequences of new surgical protocols.

Although an event-reporting system has considerable potential to improve quality and safety, the realized clinical benefit of such a system may be uneven due to real-world shortcomings of self-reporting. Among these are a blame-focused departmental or hospital culture that inhibits self-reporting, a reporting process that requires excessive effort, and a lack of clarity as to what constitutes a reportable event. Practitioners may worry that retaliation can occur with an adverse reporting event or find that reporting requires multiple passwords and websites. Even under ideal conditions, existing evidence suggests that the number of reported events may often represent the tip of an iceberg and not capture all or even most of the events that occur.[27]

Key to reporting system performance is a departmental culture that prioritizes cooperation and information sharing. To function as an early warning system, an optimal reporting system depends critically on the willing and interested participation of practitioners in the environment.

The ideal answer to the question "What should I report?" is "What you think your colleagues need to know to practice safely." Such a definition would then include not only adverse events but also changes in preoperative patient protocols, existing or new equipment idiosyncrasies, or consequences of new surgical positions or monitors. Lowering or removing barriers to reporting will also help bring out near misses and other "almost" events that otherwise may not be reported. Once reports are received, a nonpunitive safety culture is key, with an explicit goal to not deter practitioners who might otherwise fear retaliation.

How such events are handled and fed back to clinicians can reinforce participation in and acceptance of a robust event-reporting system. If practitioners see that their submission is widely shared throughout the department or that a resolution is being sought, they be more likely to continue to report going forward. Because the goal is to share events among the department, a forum where such events can be presented and discussed is a particularly effective method both for disseminating information from event reports and for encouraging more reporting. Providing data on past instances of similar events, such as "this is the fourth corneal abrasion in the last 3 months" can also help stimulate reporting, as practitioners begin to look for root causes.

To minimize perceived risk of retaliation or punishment, one helpful approach is to anonymize the event and have a neutral moderator present the case. Although such an approach risks inaccuracies in the presentation, it can also remove interpersonal overtones that can make frank discussion difficult. In parallel, allowing practitioners who want to present their own cases to do so creates maximum flexibility and helps build the desired culture, particularly when senior and respected members of the department take thoughtful responsibility for their own adverse events.

Developing a reporting system requires trust and steady consistency to define what events should be reported and how best to disseminate them. However, the advantages of such an early warning system are considerable, and a reporting system can be instrumental to rapidly detecting and addressing potential safety issues.

Measuring Patient Experience

Patient experience is a relevant quality domain and a major component of federal regulatory oversight of hospitals and clinicians.[28] Better patient experience is also strongly associated with improved clinical outcomes.[29] Healthcare is a people business, and one can argue that if the patient is satisfied with their care—regardless of outcome—then quality has been achieved. Like quality, however, "satisfaction" is a subjective concept that is difficult to define, measure, and benchmark. A key early goal of the ASA Anesthesia Quality Institute was to better define and measure anesthesia-specific patient satisfaction. The resulting Anesthesia Quality Institute recommendations led software vendors to develop widely available cost-effective tools for surveying large numbers of patients in a standardized fashion. From a regulatory perspective, measurement of patient satisfaction was adopted by the Center for Medicare and Medicaid Services (Baltimore, Maryland) in 2018 as a recommended measure for anesthesia practices reporting to the Merit-based Incentive Payment System. The result has been an increase in our understanding of anesthesia patient satisfaction and our ability to influence it. At least one national anesthesia practice has been able to collect and use hundreds of thousands of returned surveys over the past decade, with demonstrable improvements in performance.[30]

Patient or family satisfaction can be measured after any anesthesia procedure but is typically limited by low response rates that raise concern regarding the validity of results. However, practices with experience in this area can achieve response rates of 25 to 35%, although satisfaction bias among respondents may limit interpretation of satisfaction surveys. It is unknown whether patients at the extremes of satisfaction are more or less likely to respond.[31]

Mechanisms that increase response rate include:

- Sending surveys early after the procedure, ideally within 7 days
- Using a form factor that is easy to respond to; text messaging works best at present
- Keeping the survey questions short and simple
- Making the survey readily available in multiple languages
- Including the survey as part of ongoing efforts at patient engagement, including preoperative educational materials and good communication on the day of surgery

Measurement of patient satisfaction is necessary but not sufficient for improvement. Analysis of results and active mitigation strategies are also required. More academic work needs to be done to identify which domains of patient satisfaction are most amenable to improvement. For example, efforts to minimize nausea and shivering in the PACU may be more or less addressable than efforts to better explain anesthesia in the preoperative evaluation process. Clinician education is effective in relating the importance of patient satisfaction, the mechanisms for measurement and reporting, and best practices for communication. Confidential individual feedback (both positive and negative) is especially helpful in modifying behavior and easy to automate with inclusion of specific patient quotes. In the private practice experience noted above, positive comments outnumber negative ones about 100:1, but sharing specific, real, actionable, negative comments was a tremendous spur for improvement: *e.g.*, "I liked my anesthesiologist but was upset that he did not talk directly to my family during the preop interview." Aggregation of negative comments, for example regarding hospital parking or the preoperative check-in process, can also drive systematic institutional improvement in nonanesthesia domains.

Quality Improvement Projects

As noted above, the essential work of quality improvement leaders is the prioritization of effort. The goal is to match

available resources (*e.g.*, time, attention, money) to opportunities for improvement, ideally prioritizing the ones likely to have the greatest impact on outcomes. In reality, long-term, high-impact interventions (*e.g.*, implementation of quantitative neuromuscular blockade monitoring throughout the operating room suite) must vie for attention with day to day "firefighting" exercises (*e.g.*, root-cause analysis of an isolated adverse event). One useful tool for the leader is the ability to launch and support individual quality improvement projects with predefined timelines and endpoints.

Formal quality improvement projects are intended to improve the health and well-being of patients and clinicians and can arise from a single individual's desire to advance the group's practice or through an organized process of selection and assignment by the departmental quality improvement committee. Initiating and organizing such projects are an opportunity for department members at all levels. Both anesthesiology residents and student nurse anesthetists have in-training requirements for quality improvement and may meet these requirements through completion of local quality improvement projects. In private practice, ascension to partnership or leadership roles may depend on completion of assigned administrative tasks, many of which will be quality improvement projects. Priority and supportive resources should be directed to individual projects that align with the goals of the department or hospital.

Barriers to Quality Improvement Work and Tactics to Overcome Them

Barriers to quality improvement project work include insufficient departmental support, vague or ambiguous goals, and lack of individual expertise. In the current climate, anesthesia clinicians are in very high demand for procedural care, making it challenging to allot time to quality improvement projects. Successful departments and practices prioritize these activities, however, recognizing that high-quality care is correlated with highly efficient care, because the same mechanisms of introspection, analysis, and continuous improvement apply to both. Departmental support can take a number of different forms including protected time out of the operating room (rare), financial incentives for completed activities, or the assistance of nonclinician personnel. For the simplest projects, all that is commonly needed is the opportunity to improve care and recognition by department leadership.

Identifying focused and attainable goals for quality improvement projects is important for motivating others and building a culture of continuous improvement. Goals should be defined at the outset of the project and should be SMART: specific, measurable, achievable, relevant, and time bound.[32] The department quality improvement leader or committee should approve individual-initiated projects based on these criteria and should launch its own with goals already defined. In particular, projects launched by the quality improvement leader or committee should adhere to the principle above of being the activity most likely to improve care at that moment.

Lack of individual expertise in quality improvement can be overcome with a mindful, team-based approach. Mentorship is useful: every trainee or junior faculty assigned a project should have a senior sponsor who can help them navigate departmental and institutional politics, make introductions to key personnel in other departments, define an appropriate scope of efforts, and provide historical perspective on what has worked in the past. Systematically, the department quality committee can provide education on quality improvement methodology, set a timeline for the project, and collect periodic updates until it is completed.

Table 1 shows typical quality improvement initiatives, ranging from simple to complex, with issues most likely to threaten successful completion. The quality improvement leader should keep a running scorecard of all active projects and should not be afraid to terminate efforts that are bogged down, consuming excessive resources, no longer relevant, or if external conditions change (*e.g.*, during a global pandemic).

Whatever the structure employed, the quality improvement leader can improve culture over time by keeping track of completed quality improvement projects and periodically reporting to the department or practice on successful improvements. This activity helps to combat the demoralized feeling that can often accompany difficult or protracted quality improvement efforts and contributes to a negative culture where "nothing ever changes." The antidote to this attitude is a periodic look back and presentation of all the systematic changes that have occurred, perhaps accompanied by review of a "great save" rather than an unfortunate adverse event. Such positively oriented quality improvement presentations will improve morale directly and also build a culture that emphasizes proactivity, self-determination, and continuous improvement.

Future Opportunities for Quality Improvement in Anesthesiology

New Safety Models

As perioperative care becomes increasingly complex, the recognition that high-complexity systems may not be effectively analyzed by traditional safety perspectives has also grown. A traditional approach assumes that system components either work correctly or not, that each component can be analyzed independently of other parts of the system, and that humans are mostly a liability or hazard due to unpredictable variability in their behavior. Within this conceptual framework, called "Safety 1," accident investigation seeks to identify and estimate the likelihood of "root causes" and contributory factors linked to the event. Such "find and fix" investigations often end in additional documentation, educational modules, and other weak solutions that seem to leave the process no safer than before.

Table 1. Example Quality Improvement Projects

Project	Likely Issues
Simple change in electronic medical record presentation	Need to engage hospital IT personnel
Guideline for managing a specific kind of patient (*e.g.*, dialysis patient for an outpatient procedure)	Achieving consensus on the best practices to recommend
Creation of new department resources (*e.g.*, a dedicated difficult intubation cart)	Cost of new equipment; unintended consequences such as the need for periodic restocking and readiness checks
Documenting the preblock anesthesia time-out	Creating a standard paper or online form; achieving adoption by all clinicians
Implementing an enhanced recovery protocol for a specific surgical line	Surgeon buy-in; nursing engagement in building standard order sets; consolidation of data to track implementation and outcome improvement
Introduction of a new medication into clinical practice (*e.g.*, amisulpride, remimazolam)	Internal: Resistance of "nonbelievers"; lack of education External: Financial constraints of institution; bureaucratic barriers (*e.g.*, the pharmacy and therapeutics committee)
Department participation in an external registry	IT costs (people and time) for creation and export of data; political risks of external benchmarking
Implementation of a new hospital-wide electronic medical record	Conflicting goals for documentation between departments; need to prioritize preimplementation design in the face of ongoing clinical demands

The list is roughly organized from simple to complex and ranges from "entry-level" issues suitable for assignment to trainees to multifaceted issues that will require coordinated effort both inside and outside the department.

IT, information technology.

Frustrations with "find and fix" approaches have led to a new approach called "Safety 2." In this conceptual framework, systems are too complex to be easily deconstructed into individual components, each component may have a "partially working" state in addition to a "is or is not working" status, perfect conditions are rarely present, and the role of humans in the system is to adjust their work to existing conditions to achieve the desired outcomes. In this conceptual framework, safety might better be improved by examining the cases that produced good outcomes rather than bad outcomes (see https://psnet.ahrq.gov/issue/safety-i-safety-ii-white-paper).

The Safety 2 approach[9,33] has implications for perioperative care. If the role of humans in a complex system is to adjust for imperfect conditions and imperfectly working systems, then a focus of quality improvement should be to help providers become more resilient and develop strategies for how to adjust to these unavoidable perturbations. An example is the working IV that infiltrates partway through the case, causing the clinician to place a new one. A Safety 1 approach would be to institute routine checks of IV patency throughout the case, whereas a Safety 2 approach might in addition explore how the clinician identified the infiltration, what diagnostic steps were taken, how the issue was solved, and the overall impact on patient care.

An emerging "Safety 3" perspective again focuses on adverse events but accepts that human resilience and flexibility are integral parts of a well functioning system. Safety 3 imagines that accidents occur because hazards are not adequately controlled and safety controls are inadequate. Safety 3 in addition recognizes that not all failures have the same impact and seeks first to address those that cause "unacceptable loss." In the above example, a Safety 3 approach would include a proactive analysis of risk factors for IV infiltration, possibly add a constraint that a second IV be available when the primary IV is at high risk for infiltration, and institute special precautions when IV agents capable of tissue damage are administered. Table 2 illustrates relevant differences between Safety 1, Safety 2, and Safety 3 perspectives.

Metacognition and Decision-making

A recent advance in anesthesia practice with implications for anesthesia quality and safety is the recognition that human decision-making may lead to predictable errors and that the incidence of those errors may be reduced by training. The origins of this approach to anesthesia quality improvement lie in the "dual process" model of human cognition originally proposed by Kahneman and Tversky in 1979.[34] They postulated that humans have two cognitive "engines" for making decisions: a rapid, intuitive "System 1" and a slower, deliberate, conscious "System 2." They further observed that intuitive decision-making is vulnerable to cognitive assumptions (or "shortcuts") that can lead to predictable deviations from rational behavior. Examples include estimating the incidence of an event based on ease of recall ("base rate fallacy") and preferring a sure thing to a similarly valued gamble ("risk aversion").

The study of cognitive biases has since grown to include numerous examples of cognitive biases that are both unconscious and clinically relevant.[35] In anesthesia, examples include prioritizing the first value in a dynamic environment (anchoring bias) and only seeking out evidence that supports a suspected hypothesis (confirmation bias). Table 3 lists common cognitive biases in anesthesia practice and the most relevant mitigation strategies.

Although cognitive biases due to rapid System 1 cognition affect all branches of medicine, they can be particularly relevant to anesthesiologists. Many perioperative decisions

Table 2. Safety Perspectives

Event: Infiltrated IV Leading to Soft Tissue Injury	Safety 1	Safety 2	Safety 3
Formulation	Failure to identify infiltration	How do clinicians identify infiltrated IVs? What strategies are taken once an infiltrated IV is identified? What are reasonable solutions to the problem?	IVs will infiltrate, but an unacceptable infiltration is one that causes tissue injury; we can expect humans to identify most and need to design a system to prevent the unacceptable situation
Strategy	Routine IV patency checks	Disseminate information on how best to identify infiltrated IVs and in what cases to have a backup	Analyze risk factors for infiltration; suggest multiple IVs for high-risk cases; suggest administering a test medication before administering a vesicant
Threat	Human may fail to identify infiltrated IV and administer dangerous IV agent	NA (Safety 2 focuses on successes more than failures)	Inadequate risk and hazard information

NA, not applicable.

Table 3. Examples of Cognitive Bias in Anesthesiology

Cognitive Bias	Example	Possible Mitigation
Anchoring	Clinicians interpret high airway pressures as bronchospasm in a patient with an asthma history and fail to rule out endotracheal tube kink	Recognizing cognitive biases Education Routinely considering alternatives Outside provider
Availability	After experiencing an intraoperative pulmonary embolism, clinicians interpret hypotension in the next case as pulmonary embolism	Recognizing cognitive biases Education (including base rates) Routinely considering alternatives Outside provider Treatment algorithms
Commission bias	Clinicians transfuse blood for a spuriously low Hb value in a stable patient without rechecking	Recognizing cognitive biases Education Treatment algorithms
Confirmation bias	Believing that the absence of $ETco_2$ is a broken detector rather than an esophageal intubation	Recognizing cognitive biases Outside provider Education
Loss aversion	Choosing not to proceed with aortic dissection repair due to risk of stroke	Recognizing cognitive biases Outside provider Education (including base rates)
Sunk cost	Continuing with trauma resuscitation despite intractable massive bleeding	Recognizing cognitive biases Outside provider Education

$ETco_2$, end-tidal carbon dioxide.

must be made in real time and with incomplete information, constraints that prioritize System 1 thinking. Anesthesia examples include anchoring on initial diagnoses, such as assuming that hypotension is due to anesthetic agents rather than blood loss and misinterpreting pulse oximeter readings due to a high incidence of artifacts. Strategies to mitigate the impact of System 1 biases include deliberate reflection to promote System 2 activity, simulation to broaden the experience base of the clinician with respect to rare events, and education to avoid base-rate errors. The 2022 ASA difficult airway guidelines are an example of how cognitive training principles can be integrated into anesthesia-specific algorithms.[36] In response to evidence that clinicians may perseverate on intubation efforts during airway management, the 2022 guidelines now recommend limiting intubation attempts as a mitigation strategy.[37]

Current evidence is mixed regarding the value of cognitive training to reduce decision error during anesthesia care.[35] However, the potential for metacognition to improve anesthesia outcomes is great, and further work will hopefully develop strategies to improve cognitive behavior.

Implementation Science

Implementation science might best be defined as the formal study of how best to disseminate and translate evidence-based best practices into routine clinical care and

is a rapidly growing area of quality research. Evidence that a considerable lag exists between evidence-based findings and incorporation into clinical practice has persisted for more than two decades, and work to address that gap has been variously described as knowledge translation or translational research. Relevant implementation research might include intervention development, economic studies, evaluation methods, and outcome assessment. Implementation science is related to but distinct from quality improvement in that quality improvement is local, pragmatic, and empiric, whereas implementation science is generalizable and uses conceptual frameworks to drive investigation.[38] Implementation science also emphasizes multidisciplinary collaboration and makes heavy use of qualitative methods to identify barriers to implementation and optimize implementation strategies.[39]

Much of anesthesia practice is well suited to implementation science and examples of effective implementations that have improved outcomes include use of pulse oximeters and ultrasound guidance and documentation of neuromuscular blockade reversal[40] and corneal abrasion.[41] The highly granular data available in the perioperative period, discrete episodes of care, and limited care responsibility present opportunities for interventions such as enhanced recovery protocols,[42] conservative fluid management, and limited opioid utilization. Such data also can identify current "translation gaps," such as that between recommendations regarding the risk of delirium and use of benzodiazepines in high-risk patients

Potential barriers to more widespread use of implementation science include a lack of quality literature, a possible need for increased administrative efforts by providers to comply with implementation mandates, the potential that even consensus-level evidence may be proven wrong over time, and the dynamic nature of the perioperative period possibly rendering extensive implementation efforts irrelevant. Future work is needed to better understand how a formal implementation science framework may best be used to improve anesthesia quality.

Risk Prediction and Benchmarking

One area of quality improvement in which anesthesiology lags other specialties is the ability to accurately predict the risk of individual patients and then benchmark clinical performance based on these data. Although multiple methods exist for calculating clinical risk in individual cases, these tools have not yet been systematically integrated into formal benchmarking targets for departments or hospitals. In trauma surgery, for example, decades of aggregating data on the national level have led to the development of complex statistical models that link specific physical injuries and presenting vital signs to 30-day survival after trauma center admission. Observed, risk-adjusted survival at a given center can then be compared to predicted results based on admission characteristics to yield a system-wide measure of performance that can be tracked over time.[43] In cardiac surgery, the Society for Thoracic Surgery data registry captures more than 90% of all cardiac procedures performed in the United States, and risk-adjusted outcomes are available to all participating centers[44] Similar systems have been developed for obstetrics[45] and heart failure.[46] Unfortunately, this national benchmarking is notably missing in anesthesia, leading to an inability to compare outcomes across locations. In addition to overall comparisons, benchmarking may also identify unexpected survivors and mortalities, and readily available risk scores can enable earlier intervention in problematic patients and cases.

Although easy to conceptualize,[47] a universal data model for anesthesiology has proven elusive. Reasons for this difficulty include the magnitude of the problem, with a hundred times more anesthetics performed in the United States each year than, for example, trauma admissions; a tremendously variable scope of anesthesia practice ranging from neonatal procedures to obstetrics to cardiac and transplant surgery to cataract excision in nonagenarians; the difficulty in linking anesthetic care to long-term patient outcomes; and the cost of collecting the data. In some ways, anesthesiology has been a victim of its own success: as the rate of mortality decreases into the "anecdotal" category, it becomes increasingly difficult to demonstrate statistically valid differences in performance or to generate enthusiasm for spending money to improve what is publicly regarded as a commodity.

The steadily improving connectivity of healthcare records offers the prospect for a better understanding of anesthesia outcomes in the next decade. Widespread adoption of hospital system-based electronic medical records, with inclusion of postoperative and outpatient documentation features, have lowered the cost and increased the capability for national-level data aggregation. Collaboratives such as the Multicenter Perioperative Outcomes Group have shown the considerable potential in data aggregation across multiple institutions. Although costly in both time and effort and consisting today of mostly large academic hospitals (and not private practice), the Multicenter Perioperative Outcomes Group nonetheless illustrates the potential benefits of big-picture efforts to address common anesthesia issues.[48]

An even larger aggregation of data is available in the National Anesthesia Clinical Outcomes Registry, maintained by the ASA's Anesthesia Quality Institute.[49] The National Anesthesia Clinical Outcomes Registry is currently the largest aggregator of basic demographic ("administrative") data in U.S. anesthesia, with more than 100 million anesthetics recorded in the past decade, and is the most widely used conduit for anesthesia practices to report quality performance data to the Centers for Medicare and Medicaid Services under the federal Merit-Based Improvement Performance System. Data from the National Anesthesia Clinical Outcomes Registry are

useful for identifying ongoing trends in anesthesia practice[50] but unfortunately not granular enough to benchmark performance or guide care at the level of individual practices.

Anesthesia departments and practices should seek cost-effective opportunities to participate in registries such as the National Anesthesia Clinical Outcomes Registry or the Multicenter Perioperative Outcomes Group, because of the improving ability to use such data for internal benchmarking, the altruistic opportunity to contribute to quality improvement efforts of the specialty as a whole, and, more cynically, in recognition of a future regulatory environment in which such participation is mandatory for accreditation or payment—a factor that has historically driven registry participation in high-profile, focused specialties such as trauma surgery and cardiac care.

Patient Engagement

A final, more subjective area for quality improvement in anesthesiology is increased engagement throughout the arc of perioperative care. As noted above, patient satisfaction is greater when there is more and more consistent connection between the anesthesia team and the patient and their family. Ideally, what the patient wants when scheduled for a medical or surgical procedure is a single stream of accurate, compassionate, and timely information to guide them through what is almost always a novel and life-disturbing event. As the facilitators of that procedure—our core function as anesthesiologists—we are uniquely positioned to provide that guidance.

The ideal future perioperative process might look something like this:

- The patient is scheduled for a surgery or procedure that will require anesthesia.
- First contact occurs immediately, by text, email, or face-to-face in the office:
  - The planned sequence of pre-, intra-, and post-procedure events is described.
  - The patient is asked how they most like to receive information.
  - A single point of contact (email and phone number) for their questions is provided.
- In the days and weeks before the procedure, the patient receives a series of messages, each in the same format and bearing a single brand (typically the hospital or health system):
  - Solicitation of medical information needed for the anesthesia assessment
  - Instructions regarding medications, diet, and "prehabilitation"
  - Appointments for needed consultations (including anesthesia preoperative assessment) or diagnostic testing
  - Logistical information about when and where to arrive for the procedure
  - The opportunity to discuss billing and financial information
- On the day of the procedure, the same format is used for communication to the patient's designated support person, and updates on the course of care.
- After the procedure, a similar chain of daily and then weekly messages follow:
  - Instructions for diet, wound care, pain management, and physical therapy
  - Answers to commonly asked questions
  - Schedule reminders and instructions for postoperative visits
  - Solicitation of specialty specific (*e.g.*, anesthesia, the surgical service) and facility satisfaction surveys
  - Collection of objective, patient-reported outcome data on such things as daily activities, return to work, new disabilities, and need for ongoing analgesic medication

Integration of Quality Improvement Efforts

Anesthesia quality improvement efforts today most often occur on an individual basis in a fragmented and chaotic way. Meaningful expansion of anesthesia quality improvement efforts into the postoperative arena will likely require integrating individual and departmental efforts into the greater hospital ecosystem, collaborating with surgical and procedural services, and including both physician and nursing input. Performance benchmarking should be based on shared outcome metrics that are meaningful to patients and relevant to all participants in the process. Current examples include hospital length of stay, total cost of care, patient return to preprocedure function, opioid use at 90 days, and postdischarge mortality.

Integration of quality improvement efforts under a single framework can improve not just patient satisfaction but also clinical outcomes and operational efficiency.[51] Patient compliance with medications, preparation, and recovery is higher; case delays, cancellations, and preventable complications are lower. Anesthesiologists have been working with surgeons and facilities for a decade to implement enhanced recovery protocols and the perioperative surgical home. With evolving computerization, the ability to go "all in" on such social and facilitative aspects of perioperative care is advancing rapidly. Automation of many steps in the communication sequence presented above is already possible, with the potential for two-way interaction with the patient throughout the arc of perioperative care. New artificial intelligence–driven language tools offer the near-term promise of customizing messaging on the fly to match the needs of individual patients and specific procedures. High-quality anesthesia departments and practices should consider opportunities afforded by technical developments in this space, and embrace—or lead—opportunities with surgeon and hospital partners to improve the overall experience for

our patients. Many examples of successful projects already exist,[52] suggesting that multidisciplinary quality improvement collaboration is possible for any anesthesia practice or department.

Conclusions

Continuous quality improvement remains a core goal of anesthesiologists, no less than in earlier eras. Although serious adverse outcomes are now rare when compared to previous eras, infinite opportunities still exist to improve patient outcomes, especially if multiple dimensions of quality are considered. Mindful anesthesia groups recognize that investment in quality improvement and reaching out to other stakeholders to create multidisciplinary improvement projects will yield benefits not just to patient safety but also to operational efficiency, clinician morale, and reputation within the hospital system.

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Competing Interests

Dr. Tung receives royalties for *The ICU Manual*, 3rd edition. Dr. Dutton declares no competing interests.

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References

1. Whitlock EL, Feiner JR, Chen LL: Perioperative mortality, 2010 to 2014: A retrospective cohort study using the National Anesthesia Clinical Outcomes Registry. Anesthesiology 2015; 123:1312–21
2. Bainbridge D, Martin J, Arango M, Cheng D; Evidence-based Peri-operative Clinical Outcomes Research (EPiCOR) Group: Perioperative and anaesthetic-related mortality in developed and developing countries: A systematic review and meta-analysis. Lancet 2012; 380:1075–81
3. Eichhorn JH, Cooper JB, Cullen DJ, Maier WR, Philip JH, Seeman RG: Standards for patient monitoring during anesthesia at Harvard Medical School. JAMA 1986; 256:1017–20
4. Kent CD, Metzner JI, Domino KB: Anesthesia hazards: Lessons from the anesthesia closed claims project. Int Anesthesiol Clin 2020; 58:7–12
5. Gibbs NM, Culwick M, Merry AF: A cross-sectional overview of the first 4,000 incidents reported to webAIRS, a de-identified web-based anaesthesia incident reporting system in Australia and New Zealand. Anaesth Intensive Care 2017; 45:28–35
6. Gaba DM, DeAnda A: A comprehensive anesthesia simulation environment: Re-creating the operating room for research and training. Anesthesiology 1988; 69:387–94
7. Jones CPL, Fawker-Corbett J, Groom P, Morton B, Lister C, Mercer SJ: Human factors in preventing complications in anaesthesia: A systematic review. Anaesthesia 2018; 73(Suppl 1):12–24
8. Sinclair CM, Thadsad MK, Barker I: Modern anaesthetic machines. Continuing Educ Anaesth Crit Care Pain 2006; 6:75–8
9. Ball DR, Frerk C: A new view of safety: Safety 2. Br J Anaesth 2015; 115:645–7
10. Terje A: A risk science perspective on the discussion concerning Safety I, Safety II and Safety III. Reliabil Eng Syst Safety 2022; 217:108077
11. Institute of Medicine: Crossing the Quality Chasm: A New Health System for the 21st Century. Washington, D.C., National Academies Press, 2001.
12. Beecher HK, Todd DP: A study of the deaths associated with anesthesia and surgery: Based on a study of 599,548 anesthesias in ten institutions 1948–1952, inclusive. Ann Surg 1954; 140:2–35
13. Pearse RM, Moreno RP, Bauer P, et al.; European Surgical Outcomes Study (EuSOS) group for the trials groups of the European Society of Intensive Care Medicine and the European Society of Anaesthesiology: Mortality after surgery in Europe: A 7 day cohort study. Lancet 2012; 380:1059–65
14. Fecho K, Lunney AT, Boysen PG, Rock P, Norfleet EA: Postoperative mortality after inpatient surgery: Incidence and risk factors. Ther Clin Risk Manag 2008; 4:681–8
15. Madding GF: Subtotal cholecystectomy in acute cholecystitis. Am J Surg 1955; 89:604–7
16. Fleisher LA: Quality anesthesia: Medicine measures, patients decide. Anesthesiology 2018; 129:1063–9
17. Sessler DI: The gathering storm: The 2023 Rovenstine lecture. Anesthesiology 2024; 140:1068–75
18. Nepogodiev D, Martin J, Biccard B, Makupe A, Bhangu A; National Institute for Health Research Global Health Research Unit on Global Surgery: Global burden of postoperative death. Lancet 2019; 393:401
19. Pandit JJ, Cook TM, Jonker WR, O'Sullivan E; 5th National Audit Project (NAP5) of the Royal College of Anaesthetists and the Association of Anaesthetists of Great Britain and Ireland: A national survey of anaesthetists (NAP5 Baseline) to estimate an annual incidence of accidental awareness during general anaesthesia in the UK. Anaesthesia 2013; 68:343–53
20. Cook TM, Woodall N, Frerk C; Fourth National Audit Project: Major complications of airway management in the UK: Results of the Fourth National Audit Project

of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: Anaesthesia. Br J Anaesth 2011; 106:617–31

21. Neily J, Silla ES, Sum-Ping SJT, et al.: Anesthesia adverse events voluntarily reported in the Veterans Health Administration and lessons learned. Anesth Analg 2018; 126:471–7
22. Saad M, Dubovoy TZ, Kheterpal S, Colquhoun DA: Automated detection of postoperative reintubation using electronic health record data. Anesthesiology 2024; 140:173–5
23. Prowle JR, Forni LG, Bell M, et al.: Postoperative acute kidney injury in adult non-cardiac surgery: Joint consensus report of the Acute Disease Quality Initiative and PeriOperative Quality Initiative. Nat Rev Nephrol 2021; 17:605–18
24. Saver JL: Proposal for a universal definition of cerebral infarction. Stroke 2008; 39:3110–5
25. Kork F, Balzer F, Spies CD, et al.: Minor postoperative increases of creatinine are associated with higher mortality and longer hospital length of stay in surgical patients. Anesthesiology 2015; 123:1301–11
26. Botto F, Alonso-Coello P, Chan MT, et al.; Vascular events In noncardiac Surgery patIents cOhort evaluatioN (VISION) Writing Group, on behalf of the Vascular events In noncardiac Surgery patIents cOhort evaluatioN (VISION) Investigators: Myocardial injury after noncardiac surgery: A large, international, prospective cohort study establishing diagnostic criteria, characteristics, predictors, and 30-day outcomes. Anesthesiology 2014; 120:564–78
27. Bates DW, Cullen DJ, Laird N, et al.; ADE Prevention Study Group: Incidence of adverse drug events and potential adverse drug events: Implications for prevention. JAMA 1995; 274:29–34
28. Chen HC, Cates T, Taylor M, Cates C: Improving the US hospital reimbursement: How patient satisfaction in HCAHPS reflects lower readmission. Int J Health Care Qual Assur 2020 [Epub ahead of print July 9]
29. Doyle C, Lennox L, Bell D: A systematic review of evidence on the links between patient experience and clinical safety and effectiveness. BMJ Open 2013; 3:e001570
30. Dutton RP, Swygert TH, Maloney M, et al.: Scaling up quality in an anesthesia practice. Int J Qual Health Care 2023; 35:mzad011
31. Pozdnyakova A, Tung A, Dutton R, Wazir A, Glick DB: Factors affecting patient satisfaction with their anesthesiologist: An analysis of 51,676 surveys from a large multihospital practice. Anesth Analg 2019; 129:951–9
32. Doran GT: There's a S.M.A.R.T. way to write management's goals and objectives. Manage Rev 1981; 70:35–6
33. Staender S: Safety-II and resilience: The way ahead in patient safety in anaesthesiology. Curr Opin Anaesthesiol 2015; 28:735–9
34. Kahneman D, Tversky A: Prospect theory: An analysis of decision under risk. Econometrica 1979; 47:263–91
35. Yan L, Karamchandani K, Gaiser RR, Carr ZJ: Identifying, understanding, and minimizing unconscious cognitive biases in perioperative crisis management: A narrative review. Anesth Analg 2024; 139:68–77
36. Apfelbaum JL, Hagberg CA, Connis RT, et al.: 2022 American Society of Anesthesiologists practice guidelines for management of the difficult airway. Anesthesiology 2022; 136:31–81
37. Cook TM, Woodall N, Harper J, Benger J; Fourth National Audit Project: Major complications of airway management in the UK: Results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: Intensive care and emergency departments. Br J Anaesth 2011; 106:632–42
38. Lane-Fall MB: What anesthesiology has to learn from implementation science and quality improvement. Anesthesiology 2022; 136:875–6
39. Peden CJ, Ghaferi A, Vetter T, Kain ZN: Perioperative health services research: Far better played as a team sport. Anesth Analg 2021; 133:553–7
40. Weigel WA, Williams BL, Hanson NA, et al.: Quantitative neuromuscular monitoring in clinical practice: A professional practice change initiative. Anesthesiology 2022; 136:901–15
41. Martin DP, Weingarten TN, Gunn PW, et al.: Performance improvement system and postoperative corneal injuries: Incidence and risk factors. Anesthesiology 2009; 111:320–6
42. Ellis DB, Agarwala A, Cavallo E, et al.: Implementing ERAS: How we achieved success within an anesthesia department. BMC Anesthesiol 2021; 21:36
43. Dutton RP, Stansbury LG, Leone S, Kramer E, Hess JR, Scalea TM: Trauma mortality in mature trauma systems: Are we doing better? An analysis of trauma mortality patterns, 1997–2008. J Trauma 2010; 69:620–6
44. Wyse RK, Taylor KM: Using the STS and multinational cardiac surgical databases to establish risk-adjusted benchmarks for clinical outcomes. Heart Surg Forum 2002; 5:258–64
45. Glance LG, Hasley S, Glantz JC, et al.: Measuring childbirth outcomes using administrative and birth certificate data. Anesthesiology 2019; 131:238–53
46. Cunningham LC, Fonarow GC, Yancy CW, et al.: Regional variations in heart failure quality and outcomes: Get with the guidelines—Heart Failure Registry. J Am Heart Assoc 2021; 10:e018696

47. Glance LG, Neuman M, Martinez EA, Pauker KY, Dutton RP: Performance measurement at a "tipping point." Anesth Analg 2011; 112:958–66
48. Colquhoun DA, Vaughn MT, Bash LD, et al.; Multicenter Perioperative Outcomes Group (MPOG) Perioperative Clinical Research Committee: Association between choice of reversal agent for neuromuscular block and postoperative pulmonary complications in patients at increased risk undergoing non-emergency surgery: STIL-STRONGER, a multicentre matched cohort study. Br J Anaesth 2023; 130:e148–59
49. Liau A, Havidich JE, Onega T, Dutton RP: The National Anesthesia Clinical Outcomes Registry. Anesth Analg 2015; 121:1604–10
50. Nagrebetsky A, Gabriel RA, Dutton RP, Urman RD: Growth of nonoperating room anesthesia care in the United States: A contemporary trends analysis. Anesth Analg 2017; 124:1261–7
51. Liu TJ, Tokita HK, Simon BA: An enhanced ambulatory surgery experience for patients with cancer through end-to-end patient engagement. Adv Anesth 2022; 40:33–44
52. Perioperative Quality Improvement. Edited by Peden CJ, Fleisher LA, and Engelsbe M. Amsterdam, Elsevier, 2022