Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 14 May 2026
Revised 22 June 2026
Accepted 18 July 2026

Natural Resources for Human Health 2026, Vol. 6 (6s): 61–69

KEYWORDS:
Digital transformation; anesthesia care; anesthesia technologists; artificial intelligence; perioperative care; patient safety; clinical decision support; anesthesia information management systems; smart operating room.

Digital Transformation in Anesthesia Care: Implications for the Future Role of Anesthesia Technologists

[1]Shaima Khalid AlHobishi, [2]Abdullah Shabbab Alameri, [3]Abdulaziz Ibrahim Alomar, [4]Omar Abdullah Aljalooq, [5]Abdulmohsen Bader Alshuail, [6]Danah Mohammad Aldossary, [7]Maha Ridn Al-Mutairi, [8]Saud Aedh AlQahtani, [9]Souad Al-Basri, [10]Asma Rukhyes Alanazi,

[1]Anesthesia Technologist Security Force Hospital Dammam, Kingdom of Saudi Arabia
[2]Anesthesia Technologist Security Forces Hospital Dammam, Kingdom of Saudi Arabia
[3]Anesthesia Technologist Security Forces Hospital Dammam, Kingdom of Saudi Arabia
[4]Anesthesia Technologist Security Forces Hospital Dammam, Kingdom of Saudi Arabia
[5]Anesthesia Technologist Security Forces Hospital Dammam, Kingdom of Saudi Arabia
[6]Anesthesia Technologist Security Force Hospital Dammam, Kingdom of Saudi Arabia
[7]Anesthesia Technologist Security Force Hospital Dammam, Kingdom of Saudi Arabia
[8]Anesthesia Technologist Security Forces Hospital Dammam, Kingdom of Saudi Arabia
[9]Anesthesia Technician Security Forces Hospital Dammam, Kingdom of Saudi Arabia
[10]Anesthesia Technician King Abdullah bin Abdulaziz University Hospital Riyadh, Kingdom of Saudi Arabia

ABSTRACT: Digital transformation is increasingly reshaping anesthesia care through the integration of electronic health records, anesthesia information management systems, advanced monitoring, artificial intelligence, clinical decision-support tools, automation, closed-loop drug delivery, and smart operating room technologies. These developments are changing how anesthesia is planned, delivered, monitored, documented, and evaluated. As essential members of the anesthesia care team, anesthesia technologists are directly affected by this transformation. This narrative review discusses the impact of digital transformation on anesthesia care and examines its implications for the future role, responsibilities, and competencies of anesthesia technologists. The review highlights that digital technologies may improve patient safety, enhance workflow efficiency, support early risk detection, reduce selected errors, and strengthen quality improvement. However, these technologies also introduce challenges related to training, cybersecurity, data privacy, alarm fatigue, algorithmic bias, data quality, and overreliance on automation. The future role of anesthesia technologists is expected to expand beyond traditional equipment preparation and intraoperative assistance toward digital system readiness, equipment integration, troubleshooting, data quality support, electronic documentation assistance, alarm management, and patient safety activities. Preparing anesthesia technologists for this future requires structured education, continuous professional development, simulation-based training, institutional support, and clear role definitions.

INTRODUCTION

Anesthesia care has always been closely associated with technological advancement. Over the past decades, the development of anesthesia machines, ventilators, infusion pumps, capnography, pulse oximetry, and multiparameter monitoring systems has

contributed significantly to safer perioperative practice. Today, anesthesia is entering a new phase of transformation driven by digital health technologies, artificial intelligence, electronic documentation, automated monitoring, clinical decision-support systems, and smart operating room platforms.

Digital transformation in anesthesia refers to the integration of digital tools and connected systems into the planning, delivery, monitoring, documentation, and evaluation of anesthesia care. This transformation is not limited to the use of advanced devices; rather, it involves a broader shift toward data-driven practice, real-time decision support, automation, and improved communication across perioperative teams. In this context, anesthesia care is increasingly supported by electronic health records, anesthesia information management systems, smart alarms, automated drug delivery systems, and artificial intelligence-based prediction tools.

The importance of this transformation is directly linked to patient safety. Anesthesia is a high-risk clinical field that requires continuous monitoring, rapid response to physiological changes, accurate medication administration, and effective teamwork. The World Health Organization–World Federation of Societies of Anaesthesiologists international standards for safe anesthesia practice emphasize professional competence, appropriate facilities and equipment, essential medications and intravenous fluids, monitoring, and safe conduct of anesthesia care (Gelb et al., 2018). Similarly, the World Health Organization's Global Patient Safety Action Plan 2021–2030 highlights the need to eliminate avoidable harm and improve safety and quality across healthcare services (World Health Organization, 2021).

Recent developments in artificial intelligence and clinical decision-support systems have created new opportunities to improve perioperative care. These technologies may support preoperative risk assessment, prediction of intraoperative complications, optimization of anesthetic drug delivery, detection of abnormal physiological trends, medication safety, and postoperative monitoring. A recent systematic review and meta-analysis of clinical decision-support systems in real-world perioperative care found that many systems were associated with improved guideline adherence, reduced medication errors, and selected improvements in patient safety outcomes, although results varied across studies and no significant improvement in postoperative mortality was observed (Cai et al., 2024). In addition, artificial intelligence has been described in anesthesiology across several application areas, including depth-of-anesthesia monitoring, control of anesthesia, event and risk prediction, ultrasound guidance, pain management, and operating room logistics (Hashimoto et al., 2020).

Within this rapidly changing environment, the role of anesthesia technologists is expected to evolve. Traditionally, anesthesia technologists have been responsible for preparing anesthesia machines, checking equipment, maintaining supplies, assisting anesthesia providers, supporting airway management, and ensuring operating room readiness. As anesthesia care becomes more digitally integrated, these responsibilities are likely to expand toward digital equipment management, system connectivity, troubleshooting, data quality support, electronic documentation assistance, alarm management, and participation in patient safety and quality improvement activities.

This shift requires anesthesia technologists to develop new competencies beyond traditional technical skills. Future anesthesia technologists will need digital literacy, familiarity with integrated monitoring systems, basic understanding of artificial intelligence and automation, cybersecurity awareness, and stronger communication skills within multidisciplinary perioperative teams. They will also need to understand the limitations of digital technologies and recognize that automation should support, rather than replace, human clinical judgment.

Therefore, this article aims to discuss digital transformation in anesthesia care and examine its implications for the future role of anesthesia technologists. It highlights how emerging technologies may reshape anesthesia workflows, patient safety practices, professional responsibilities, and educational needs for anesthesia technologists in modern healthcare systems.

METHODS

This article was designed as a narrative review to explore the impact of digital transformation on anesthesia care and its implications for the future role of anesthesia technologists. A narrative review approach was considered appropriate because the topic is broad, interdisciplinary, and rapidly evolving, involving clinical anesthesia practice, digital health, artificial intelligence, patient safety, perioperative workflow, and professional role development.

Relevant literature was reviewed from peer-reviewed articles, international standards, professional guidelines, and global health documents related to anesthesia safety, digital health technologies, anesthesia information management systems, artificial

intelligence in anesthesiology, perioperative clinical decision-support systems, automated monitoring, closed-loop anesthesia systems, alarm fatigue, cybersecurity, and anesthesia workforce development.

The reviewed literature was organized into major thematic areas: anesthesia safety standards, electronic documentation and anesthesia information management systems, advanced monitoring and alarms, clinical decision-support systems, artificial intelligence, automation and closed-loop anesthesia systems, patient safety risks, and future competencies for anesthesia technologists. The purpose of the review was not to perform a quantitative meta-analysis, but to synthesize current evidence and provide a structured discussion of how digital transformation may reshape the professional responsibilities of anesthesia technologists.

LITERATURE REVIEW AND EVIDENCE BASE

The evidence supporting digital transformation in anesthesia care can be organized into several interrelated areas: anesthesia safety standards, electronic anesthesia documentation, anesthesia information management systems, clinical decision-support systems, artificial intelligence, automated drug delivery, advanced monitoring, alarm safety, and digital patient safety risks.

International standards emphasize that safe anesthesia care depends on trained personnel, appropriate monitoring, essential equipment, reliable medications, and organized systems of care (Gelb et al., 2018). The American Society of Anesthesiologists standards for basic anesthetic monitoring also emphasize continual evaluation of oxygenation, ventilation, circulation, and temperature during anesthesia (American Society of Anesthesiologists, 2025). These standards provide the safety foundation for digital transformation because digital tools are valuable only when they support safe monitoring, accurate documentation, and effective clinical response.

Electronic health records and anesthesia information management systems have become central to modern anesthesia practice. Anesthesia information management systems allow automatic collection, storage, and presentation of perioperative patient data, and they may support quality assurance, clinical research, billing, and performance improvement (Ehrenfeld & Rehman, 2011; Simpao et al., 2018). Previous reviews have also highlighted the role of anesthesia information management systems in meaningful use, perioperative data capture, and improved documentation practices (Gálvez et al., 2015). However, database quality, missing data, and access issues remain important limitations when these systems are used for research and quality improvement (Epstein & Dexter, 2018; Hofer et al., 2016).

Clinical decision-support systems represent another important area of digital transformation. In perioperative care, these systems can provide alerts, reminders, and recommendations related to medication safety, antibiotic timing, hemodynamic management, transfusion decisions, temperature management, and guideline adherence. A systematic review and meta-analysis found that many perioperative clinical decision-support systems were associated with improved guideline adherence, decreased medication errors, and selected improvements in patient safety outcomes, although the evidence varied across studies (Cai et al., 2024). Other work has shown that anesthesia information management system-based near-real-time decision support may influence provider behavior and improve management of intraoperative events such as hypotension and hypertension (Nair et al., 2014).

Artificial intelligence is increasingly discussed as a major driver of digital transformation in anesthesia. AI applications in anesthesiology include depth-of-anesthesia monitoring, control of anesthesia delivery, prediction of perioperative events, ultrasound guidance, pain management, and operating room logistics (Hashimoto et al., 2020). Broader medical AI literature also emphasizes the potential of machine learning to improve clinical prediction, diagnosis, and workflow support, while warning that clinical implementation requires validation, transparency, ethical governance, and protection against bias (Char et al., 2018; Esteva et al., 2019; Kelly et al., 2019; Rajkomar et al., 2019; Topol, 2019; Wiens et al., 2019).

One specific anesthesia-related AI application is hypotension prediction. Machine-learning models using high-fidelity arterial pressure waveform data have been studied to predict intraoperative hypotension before it occurs (Hatib et al., 2018). A randomized clinical trial found that use of a machine learning-derived early warning system, combined with hemodynamic diagnostic guidance and treatment protocol, reduced the depth and duration of intraoperative hypotension compared with standard care in elective noncardiac surgery (Wijnberge et al., 2020). These findings suggest that AI-supported early warning systems may assist anesthesia teams, but they require appropriate interpretation, validation, and human supervision.

Automation and closed-loop anesthesia delivery systems are another important part of the digital anesthesia landscape. Closed-loop systems use real-time physiological or electroencephalographic data to adjust anesthetic drug delivery according to predefined targets. Clinical studies and reviews have explored closed-loop propofol and remifentanil delivery, bispectral index-guided control, and automated titration of hypnotic agents (Absalom & Kenny, 2003; Brogi et al., 2017; Liu et al., 2006; Liu et al., 2011; Rinehart et al., 2012; Struys et al., 2001). These systems may improve precision and reduce manual workload, but they still require human supervision, correct sensor placement, backup planning, and trained users.

Advanced monitoring and smart alarm systems also contribute to digital transformation. Digital monitors support continuous assessment of oxygenation, ventilation, circulation, temperature, anesthetic depth, neuromuscular function, and hemodynamic variables. However, increased monitoring complexity may contribute to alarm fatigue. Alarm fatigue occurs when excessive or non-actionable alarms reduce staff responsiveness and may create patient safety risks (Ruskin, 2015; Ruskin & Bliss, 2019). Therefore, smart alarm design, appropriate alarm settings, staff training, and human factors awareness are essential.

Overall, the literature suggests that digital transformation can strengthen anesthesia care when implemented within a strong patient safety framework. For anesthesia technologists, this evidence supports the need for new competencies in digital literacy, anesthesia information management system support, equipment connectivity, data quality, alarm management, troubleshooting, cybersecurity awareness, and interprofessional communication. The future role of anesthesia technologists should therefore be linked not only to equipment preparation but also to the safe integration of digital systems in the perioperative environment.

DIGITAL TRANSFORMATION IN ANESTHESIA CARE, KEY TECHNOLOGIES, AND IMPLICATIONS FOR ANESTHESIA TECHNOLOGISTS

Digital transformation in anesthesia care refers to the integration of digital technologies, connected devices, electronic systems, automation, and data-driven tools into perioperative practice. This transformation affects how anesthesia is planned, delivered, monitored, documented, and evaluated. It is not limited to the use of modern anesthesia machines or advanced monitors; rather, it represents a broader shift toward integrated systems that support clinical decision-making, patient safety, workflow efficiency, and quality improvement.

In anesthesia, digital transformation is particularly important because anesthesia care requires continuous monitoring, rapid recognition of physiological changes, accurate medication administration, and coordinated teamwork. Digital tools can support these requirements by improving real-time access to patient data, reducing documentation gaps, supporting standardized checklists, and enabling earlier identification of clinical deterioration. These goals align with international patient safety priorities and anesthesia monitoring standards (American Society of Anesthesiologists, 2025; Gelb et al., 2018; World Health Organization, 2021).

Several digital technologies are currently influencing anesthesia care. Electronic health records and anesthesia information management systems are among the most widely used tools. These systems allow documentation of patient data, vital signs, medications, fluids, airway management, intraoperative events, and postoperative handover information. Compared with paper-based records, electronic systems may improve documentation completeness, readability, time accuracy, and access to data for audit and quality improvement (Ehrenfeld & Rehman, 2011; Gálvez et al., 2015; Simpao et al., 2018).

Advanced monitoring systems are another central component of digital anesthesia care. Modern monitors provide continuous information about oxygenation, ventilation, circulation, temperature, neuromuscular function, anesthetic depth, and hemodynamic status. Smart monitoring systems may also analyze trends and generate alerts when patient parameters move outside safe ranges. These technologies can support early detection of deterioration, but their effectiveness depends on correct sensor placement, functioning cables, appropriate alarm settings, and timely staff response.

Clinical decision-support systems are digital tools that provide alerts, reminders, recommendations, or evidence-based guidance to clinicians. In perioperative care, these systems may support medication safety, antibiotic timing, prevention of postoperative nausea and vomiting, transfusion decisions, temperature management, and guideline adherence. Their impact depends on good design, user acceptance, workflow integration, and avoidance of excessive or poorly targeted alerts (Cai et al., 2024; Nair et al., 2014).

Artificial intelligence is also becoming increasingly relevant in anesthesiology. AI may assist in perioperative risk prediction, depth-of-anesthesia monitoring, anesthetic drug delivery, ultrasound guidance, pain management, airway assessment, operating

room logistics, and postoperative risk stratification (Hashimoto et al., 2020). AI-based tools may help anesthesia teams interpret large volumes of clinical data, identify patterns, and support decision-making. However, AI should not be viewed as a replacement for clinical judgment because anesthesia decisions depend on patient condition, surgical context, clinical expertise, and direct observation.

Automation and closed-loop anesthesia systems represent another important area of development. These systems use patient monitoring data to adjust drug delivery according to predefined targets, such as anesthetic depth or hemodynamic stability. Although automation may improve precision and consistency, it does not remove the need for human supervision. Accurate sensor data, proper system setup, backup planning, and continuous clinical oversight remain essential (Brogi et al., 2017; Liu et al., 2011; Rinehart et al., 2012).

Smart operating rooms integrate anesthesia, surgical, imaging, communication, documentation, and monitoring systems into a connected environment. These systems may support workflow coordination, reduce delays, improve communication, and provide real-time access to clinical information. In such environments, safe anesthesia care depends not only on the availability of technology but also on the ability of perioperative team members to use, monitor, and troubleshoot these systems effectively.

Digital transformation has significant implications for the role of anesthesia technologists. Traditionally, anesthesia technologists have been responsible for preparing anesthesia machines, checking equipment, maintaining supplies, supporting airway management, assisting anesthesia providers, and ensuring operating room readiness. These responsibilities remain essential, but the digital environment expands the role into more advanced areas of technology management, data quality support, troubleshooting, and patient safety.

First, anesthesia technologists are expected to play a greater role in digital equipment readiness. Modern anesthesia care depends on connected anesthesia machines, monitors, infusion pumps, electronic records, alarm systems, and digital interfaces. Before anesthesia begins, technologists may need to confirm that devices are functional, correctly connected, calibrated, and ready for use. This includes checking sensors, cables, breathing circuits, monitors, infusion devices, backup equipment, and electronic interfaces.

Second, anesthesia technologists may contribute to data quality. Digital anesthesia systems depend on accurate and reliable data. Poor sensor placement, disconnected cables, incorrect patient selection, signal artifacts, or device malfunction may produce inaccurate information. Since anesthesia decisions are increasingly supported by digital data, technologists have an important role in ensuring that data collection begins correctly and remains reliable throughout the procedure.

Third, the role of anesthesia technologists may expand toward troubleshooting and digital workflow support. In digitally integrated operating rooms, workflow interruptions may result not only from missing equipment but also from software issues, connectivity failures, monitor errors, alarm problems, or electronic documentation delays. Anesthesia technologists who can identify and escalate these problems quickly contribute directly to patient safety and operating room efficiency.

Fourth, anesthesia technologists may become more involved in safety checklists, quality improvement, and incident reporting. Digital systems can generate data for audits, equipment checks, medication safety reviews, and perioperative quality improvement. Technologists can support these processes by ensuring accurate equipment checks, reporting technical issues, participating in safety briefings, and contributing to the analysis of technology-related incidents.

Overall, digital transformation may strengthen the professional identity of anesthesia technologists. As anesthesia care becomes more technologically complex, the technologist's role becomes increasingly specialized. Rather than being viewed only as equipment assistants, anesthesia technologists can be recognized as digitally competent perioperative team members who support safe technology use, clinical workflow, documentation quality, and patient safety.

FUTURE COMPETENCIES, CHALLENGES, AND RECOMMENDATIONS FOR ANESTHESIA TECHNOLOGISTS

The future role of anesthesia technologists requires a broader set of competencies that combines traditional technical skills with digital literacy, patient safety awareness, and interprofessional communication. As anesthesia care becomes increasingly supported by electronic systems, artificial intelligence, automation, and integrated monitoring, anesthesia technologists will need to adapt to a more complex and technology-rich perioperative environment.

Digital literacy is one of the most essential future competencies. Anesthesia technologists should be able to use electronic systems confidently, understand basic software functions, recognize common technical errors, and support the safe use of electronic anesthesia records and connected medical devices. Digital literacy does not require advanced programming knowledge; rather, it refers to the practical ability to operate digital tools safely, identify problems, and communicate technical concerns effectively within the anesthesia team.

Equipment integration and troubleshooting are also central to the future role of anesthesia technologists. Modern anesthesia care depends on the interaction between anesthesia machines, ventilators, monitors, infusion pumps, electronic documentation systems, sensors, and hospital information networks. If one component fails, the quality of monitoring, documentation, or drug delivery may be affected. Therefore, anesthesia technologists should understand how these systems connect and should be able to identify common problems such as sensor failure, disconnected cables, poor signal quality, device malfunction, or data transfer errors.

A basic understanding of artificial intelligence and automation is increasingly important. AI tools depend on accurate input data and may be affected by poor signal quality, incomplete information, or algorithmic limitations. For this reason, anesthesia technologists should understand that AI can support clinical decision-making but should not replace human supervision or professional judgment (Char et al., 2018; Hashimoto et al., 2020; Kelly et al., 2019).

Cybersecurity awareness is another important competency. As anesthesia machines, monitors, electronic records, and hospital systems become more connected, cybersecurity becomes part of patient safety. Anesthesia technologists should follow institutional policies related to password protection, device access, patient confidentiality, and reporting unusual system behavior. Protecting digital systems is important not only for privacy but also for maintaining safe clinical workflow.

Human factors and patient safety skills are equally important. Digital systems may reduce some errors, but they can also introduce new risks such as alarm fatigue, overreliance on automation, incorrect data entry, and communication failure. International anesthesia safety standards emphasize the need for safe systems, appropriate monitoring, trained personnel, and professional competence (American Society of Anesthesiologists, 2025; Gelb et al., 2018). Therefore, anesthesia technologists should support safe practices such as pre-use equipment checks, checklist compliance, clear communication, rapid escalation of technical concerns, and participation in safety briefings.

Despite its potential benefits, digital transformation in anesthesia care introduces several challenges and risks. One major risk is overreliance on technology. Digital systems, alarms, and decision-support tools can assist clinical teams, but they should not replace direct observation, clinical reasoning, or professional responsibility. In anesthesia, patient conditions can change rapidly, and not all clinical problems can be detected by automated systems.

Alarm fatigue is another important challenge. Modern monitoring systems may produce frequent alarms, some of which may be false or clinically insignificant. Excessive alarms can reduce staff responsiveness and increase the risk that important alarms may be missed. Smart alarm systems may help reduce this problem, but they require appropriate settings, user training, regular evaluation, and clinical judgment (Ruskin, 2015; Ruskin & Bliss, 2019).

Data privacy and confidentiality are also central concerns. Electronic anesthesia records and connected systems store sensitive patient information. Institutions must ensure that patient data are protected, accessed only by authorized personnel, and managed according to legal and ethical standards. In digital anesthesia care, patient safety includes protecting both clinical safety and patient information.

Algorithmic bias and lack of transparency are additional concerns in the use of artificial intelligence. AI systems may generate inaccurate or unequal recommendations if they are trained on incomplete, biased, or non-representative data. Some AI models may also be difficult to interpret, making it unclear how a recommendation was produced. These limitations require validation, transparency, human oversight, and careful integration into clinical practice (Char et al., 2018; Kelly et al., 2019; Wiens et al., 2019).

Training gaps may limit the benefits of digital transformation. If anesthesia technologists and other perioperative staff are not adequately trained, new technologies may increase stress, delay workflow, or create new safety risks. Clinical decision-support systems, for example, may improve guideline adherence and reduce selected medication errors, but their effectiveness depends

on proper implementation, workflow integration, and user acceptance (Cai et al., 2024). Therefore, technology should be introduced together with structured education, simulation, competency assessment, and ongoing technical support.

To support safe and effective digital transformation in anesthesia care, several recommendations can be made. First, digital health and anesthesia technology should be integrated into anesthesia technologist education programs. Training should include electronic documentation, advanced monitoring, smart alarms, infusion technologies, artificial intelligence, automation, cybersecurity, and patient safety.

Second, hospitals should provide hands-on training before introducing new digital anesthesia systems. Staff should not be expected to use complex technologies safely without structured preparation. Training should include practical demonstrations, supervised practice, emergency scenarios, and troubleshooting exercises.

Third, simulation-based education should be used to prepare anesthesia technologists for digital system failures. Simulation can help technologists practice responses to monitor failure, alarm overload, electronic record downtime, infusion pump errors, sensor problems, and equipment connectivity issues. This approach can improve readiness for rare but high-risk events.

Fourth, institutions should develop clear policies defining the responsibilities of anesthesia technologists in digital anesthesia environments. These policies should clarify expectations related to equipment checks, device connectivity, documentation support, troubleshooting, escalation pathways, and reporting of technology-related incidents.

Fifth, anesthesia technologists should be included in technology implementation and evaluation processes. Because they work directly with anesthesia equipment and operating room workflow, their feedback can help identify practical problems, training needs, safety risks, and opportunities for improvement.

Sixth, collaboration should be strengthened between anesthesia departments, biomedical engineering, information technology, nursing, surgery, and quality improvement teams. Digital anesthesia care requires teamwork across clinical and technical disciplines. Anesthesia technologists can serve as an important link between clinical users and technical support teams.

Finally, patient safety should remain the central goal of digital transformation. Technology should be implemented to support safer care, not merely to modernize equipment. Digital systems should support anesthesia teams, but they should not replace human supervision, professional judgment, communication, or direct patient care.

CONCLUSION

Digital transformation is reshaping anesthesia care through the increasing use of electronic documentation, advanced monitoring, artificial intelligence, clinical decision-support systems, automation, closed-loop anesthesia systems, and smart operating room technologies. These developments have the potential to improve patient safety, enhance workflow efficiency, support early risk detection, reduce selected errors, and strengthen quality improvement in perioperative practice.

For anesthesia technologists, this transformation is expected to expand the professional role beyond traditional equipment preparation and intraoperative assistance. Future anesthesia technologists will need to support digital system readiness, equipment integration, troubleshooting, data quality, alarm management, electronic documentation, cybersecurity awareness, and patient safety activities. As anesthesia care becomes more technologically complex, the need for well-trained and digitally competent anesthesia technologists will increase.

This transformation should not be understood as a replacement of human roles by technology. Rather, digital tools should be viewed as supportive systems that strengthen safe anesthesia care when used by competent professionals within effective clinical teams. Human supervision, professional judgment, communication, and direct patient care remain essential in anesthesia practice.

Preparing anesthesia technologists for this future requires structured education, continuous professional development, simulation-based training, institutional support, and clear role definitions. Educational institutions and healthcare organizations should ensure that anesthesia technologists are equipped with the digital, technical, and safety-related competencies needed for modern perioperative care. In the future, anesthesia technologists who combine traditional technical expertise with digital readiness and patient safety awareness will play an increasingly important role in delivering safe, efficient, and high-quality anesthesia services.

REFERENCES

[1] Absalom, A. R., & Kenny, G. N. C. (2003). Closed-loop control of propofol anaesthesia using bispectral index: Performance assessment in patients receiving computer-controlled propofol and manually controlled remifentanil infusions for minor surgery. *British Journal of Anaesthesia, 90*(6), 737–741.

[2] Agarwal, J., Puri, G. D., Mathew, P. J., & Singh, H. (2009). Comparison of closed loop versus manual administration of propofol using the bispectral index in cardiac surgery. *Annals of Cardiac Anaesthesia, 12*(2), 95–101.

[3] American Society of Anesthesiologists. (2023). *Statement on documentation of anesthesia care*. https://www.asahq.org/standards-and-practice-parameters/statement-on-documentation-of-anesthesia-care

[4] American Society of Anesthesiologists. (2025). *Standards for basic anesthetic monitoring*. https://www.asahq.org/standards-and-practice-parameters/standards-for-basic-anesthetic-monitoring

[5] Brogi, E., Cyr, S., Kazan, R., Giunta, F., Hemmerling, T. M., & Zaouter, C. (2017). Clinical performance and safety of closed-loop systems: A systematic review and meta-analysis of randomized controlled trials. *Anesthesia & Analgesia, 124*(2), 446–455.

[6] Cai, J., Liu, S., Yang, K., Wang, H., & Li, Y. (2024). Outcomes of clinical decision support systems in real-world perioperative care: A systematic review and meta-analysis. *International Journal of Surgery, 110*(12), 8057–8071. https://doi.org/10.1097/JS9.0000000000001897

[7] Char, D. S., Shah, N. H., & Magnus, D. (2018). Implementing machine learning in health care: Addressing ethical challenges. *The New England Journal of Medicine, 378*(11), 981–983.

[8] Ehrenfeld, J. M., & Rehman, M. A. (2011). Anesthesia information management systems: A review of functionality and installation considerations. *Journal of Clinical Monitoring and Computing, 25*(1), 71–79. https://doi.org/10.1007/s10877-010-9256-y

[9] Epstein, R. H., & Dexter, F. (2018). Database quality and access issues relevant to research using anesthesia information management system data. *Anesthesia & Analgesia, 127*(1), 105–114.

[10] Esteva, A., Robicquet, A., Ramsundar, B., Kuleshov, V., DePristo, M., Chou, K., Cui, C., Corrado, G., Thrun, S., & Dean, J. (2019). A guide to deep learning in healthcare. *Nature Medicine, 25*(1), 24–29.

[11] Gálvez, J. A., Rothman, B. S., Doyle, C. A., Morgan, S., Simpao, A. F., & Rehman, M. A. (2015). A narrative review of meaningful use and anesthesia information management systems. *Anesthesia & Analgesia, 121*(3), 693–706. https://doi.org/10.1213/ANE.0000000000000881

[12] Gelb, A. W., Morriss, W. W., Johnson, W., Merry, A. F., & International Standards for a Safe Practice of Anesthesia Workgroup. (2018). World Health Organization–World Federation of Societies of Anaesthesiologists international standards for a safe practice of anesthesia. *Anesthesia & Analgesia, 126*(6), 2047–2055. https://doi.org/10.1213/ANE.0000000000002927

[13] Hashimoto, D. A., Witkowski, E., Gao, L., Meireles, O., & Rosman, G. (2020). Artificial intelligence in anesthesiology: Current techniques, clinical applications, and limitations. *Anesthesiology, 132*(2), 379–394. https://doi.org/10.1097/ALN.0000000000002960

[14] Hatib, F., Jian, Z., Buddi, S., Lee, C., Settels, J., Sibert, K., Rinehart, J., & Cannesson, M. (2018). Machine-learning algorithm to predict hypotension based on high-fidelity arterial pressure waveform analysis. *Anesthesiology, 129*(4), 663–674.

[15] Haynes, A. B., Weiser, T. G., Berry, W. R., Lipsitz, S. R., Breizat, A.-H. S., Dellinger, E. P., Herbosa, T., Joseph, S., Kibatala, P. L., Lapitan, M. C. M., Merry, A. F., Moorthy, K., Reznick, R. K., Taylor, B., Gawande, A. A., & Safe Surgery Saves Lives Study Group. (2009). A surgical safety checklist to reduce morbidity and mortality in a global population. *The New England Journal of Medicine, 360*(5), 491–499.

[16] Hofer, I. S., Gabel, E., Pfeffer, M., Mahbouba, M., & Mahajan, A. (2016). A systematic approach to creation of a perioperative data warehouse. *Anesthesia & Analgesia, 122*(6), 1880–1884. https://doi.org/10.1213/ANE.0000000000001201

[17] Kelly, C. J., Karthikesalingam, A., Suleyman, M., Corrado, G., & King, D. (2019). Key challenges for delivering clinical impact with artificial intelligence. *BMC Medicine, 17*, Article 195.

[18] Liu, N., Chazot, T., Genty, A., Landais, A., Restoux, A., McGee, K., Laloë, P. A., Trillat, B., Barvais, L., & Fischler, M. (2006). Titration of propofol for anesthetic induction and maintenance guided by the bispectral index: Closed loop versus manual control. *Anesthesiology, 104*(4), 686–695.

[19] Liu, N., Chazot, T., Hamada, S., Landais, A., Boichut, N., Dussaussoy, C., Trillat, B., Rives, B., Fischler, M., & Bissonnette, B. (2011). Closed-loop coadministration of propofol and remifentanil guided by bispectral index: A randomized multicenter study. *Anesthesia & Analgesia, 112*(3), 546–557.

[20] Nair, B. G., Horibe, M., Newman, S. F., Wu, W. Y., Peterson, G. N., & Schwid, H. A. (2014). Anesthesia information management system-based near real-time decision support to manage intraoperative hypotension and hypertension. *Anesthesia & Analgesia, 118*(1), 206–214.

[21] Rajkomar, A., Dean, J., & Kohane, I. (2019). Machine learning in medicine. *The New England Journal of Medicine, 380*(14), 1347–1358.

[22] Rinehart, J., Liu, N., Alexander, B., & Cannesson, M. (2012). Review article: Closed-loop systems in anesthesia: Is there a potential for closed-loop fluid management and hemodynamic optimization? *Anesthesia & Analgesia, 114*(1), 130–143.

[23] Ruskin, K. J. (2015). Alarm fatigue: Impacts on patient safety. *Current Opinion in Anaesthesiology, 28*(6), 685–690.

[24] Ruskin, K. J., & Bliss, J. P. (2019). Alarm fatigue and patient safety. *APSF Newsletter, 34*(1), 1–4.

[25] Simpao, A. F., Ahumada, L. M., Gálvez, J. A., & Rehman, M. A. (2018). Anesthesia information management systems. *Anesthesiology Clinics, 36*(4), 513–525.

[26] Struys, M. M. R. F., De Smet, T., Versichelen, L. F. M., Van De Velde, S., Van den Broecke, R., & Mortier, E. P. (2001). Comparison of closed-loop controlled administration of propofol using bispectral index as the controlled variable versus standard practice controlled administration. *Anesthesiology, 95*(1), 6–17.

[27] Topol, E. J. (2019). High-performance medicine: The convergence of human and artificial intelligence. *Nature Medicine, 25*(1), 44–56.

[28] Wiens, J., Saria, S., Sendak, M., Ghassemi, M., Liu, V. X., Doshi-Velez, F., Jung, K., Heller, K., Kale, D., Saeed, M., Ossorio, P. N., Thadaney-Israni, S., & Goldenberg, A. (2019). Do no harm: A roadmap for responsible machine learning for health care. *Nature Medicine, 25*(9), 1337–1340.

[29] Wijnberge, M., Geerts, B. F., Hol, L., Lemmers, N., Mulder, M. P., Berge, P., Schenk, J., Terwindt, L. E., Hollmann, M. W., Vlaar, A. P. J., Veelo, D. P., & Geerts, B. F. (2020). Effect of a machine learning-derived early warning system for intraoperative hypotension vs standard care on depth and duration of intraoperative hypotension during elective noncardiac surgery: The HYPE randomized clinical trial. *JAMA, 323*(11), 1052–1060.

[30] World Health Organization. (2021). *Global patient safety action plan 2021–2030: Towards eliminating avoidable harm in health care*. World Health Organization. https://www.who.int/publications/i/item/9789240032705