Saudi J. Med. Pub. Health **Vol. 1,** No. 2, pp 1467-1472 (2024)

Saudi Journal of Medicine and Public Health

https://saudijmph.com/index.php/pub
https://doi.org/10.64483/202412414

Remote and Automated Anesthesia: Telemedicine, Closed-Loop Systems, and the Future of Procedural Sedation

Mohammed Khalid Alyahya [(1)] , Waleed Mualla Almukhlifi , Abdullah Mohammed S Albalawi [(2)] , Mordi Nasser Al Dosari [(3)] , Mordy Abdullah Al Talasat [(4)] , Almohanad Mohammed Alqarni [(3)] , Abdullah Mushari Alshahrani [(3)] , Waleed Ghalib Alotaibi [(3)] , Talal Fawaz Saeid Aleidyani [(3)] , Ahmad A. Sonbol [(3)] , Awatif Hamoud Najem Alsolmi [(5)], Abdullah Ibrahim ALORAYYIDH[(3)], Saad Abdullah Alsubait[(3)], Abdullah bandar bin Sayyar [(3)], . Maram Fahad Alsuwaidan[(3)], Muhannad Hazza ALSharif[(6)]

(1) Imam Abdulrahman Al Faisal Hospital,Ministry of Health, Saudi Arabia,
(2) Riyadh, Hawtat Sudair General Hospital, Ministry of Health, Saudi Arabia,
(3) King Salman Hospital, Riyadh, Ministry of Health, Saudi Arabia,
(4) Ministry Of Health, Saudi Arabia,
(5) Imam Abdulrahman Al Faisal Hospital City- Riyadh Ministry of Health, Saudi Arabia
(6) Maternity and Children's Hospital, Al-Madinah Al-Munawwarah, Ministry of Health, Saudi Arabia

Abstract
Background: The fields of telemedicine and artificial intelligence (AI) are converging with clinical anesthesia, promising to reshape the delivery of procedural sedation and perioperative care. Remote monitoring technologies and closed-loop drug delivery systems offer potential solutions to pressing challenges, including geographic disparities in access to anesthesia expertise, workforce shortages, and the pursuit of heightened precision in drug administration. **Aim:** This narrative review synthesizes contemporary evidence (2015-2024) to critically evaluate the technological foundations, clinical efficacy, and broader implications of remote anesthesia monitoring and automated sedation systems. **Methods:** A comprehensive search of PubMed, IEEE Xplore, Scopus, and CINAHL databases was conducted. **Results:** Evidence indicates that tele-anesthesia platforms can safely extend specialist oversight to non-operating room anesthesia (NORA) sites and remote locations, improving compliance with monitoring standards. Closed-loop systems for propofol sedation demonstrate superior maintenance of target depth compared to manual control, with potential benefits in hemodynamic stability. However, successful integration is contingent on robust connectivity, intuitive human-machine interfaces, and clear liability frameworks. These technologies necessitate a redefinition of the anesthesiologist's role toward system supervision and management of complex exceptions. **Conclusion:** Remote and automated anesthesia represents a paradigm shift toward a hybrid model of care. Its responsible adoption requires co-evolution of technology, validation through pragmatic clinical trials, updated training curricula, and proactive policy development to ensure these tools augment rather than replace clinical judgment, ultimately expanding safe access to high-quality sedation.
Keywords: Telemedicine; Closed-Loop Systems; Propofol; Non-Operating Room Anesthesia; Artificial Intelligence

Introduction

The practice of anesthesia stands on the precipice of a technological transformation, driven by the convergence of advanced telecommunications, machine learning algorithms, and precision engineering. This evolution is not merely incremental but promises to fundamentally alter the anesthesiologist's role, the geography of care, and the very nature of drug delivery. The impetus for this change is multifactorial, stemming from persistent systemic pressures and the relentless pursuit of improved patient outcomes (Gottumukkala et al., 2023). Key drivers include the exponential growth of procedures performed outside the traditional operating room (OR)—in endoscopy suites, interventional radiology, and cardiology labs—where anesthesia coverage may be inconsistent or provided by non-specialists (Bhananker et al., 2006). Concurrently, global shortages of anesthesia providers exacerbate access disparities, particularly in rural and resource-limited settings (Kempthorne et al., 2017). Furthermore, the inherent limitations of manual drug titration, subject to human vigilance lapses and cognitive biases, have spurred the development of automated systems to optimize pharmacological precision (Bong et al., 2023).

Two technological streams are at the forefront: telemedicine-enabled remote anesthesia (tele-anesthesia) and closed-loop control (CLC) systems for intravenous sedation (da Silva Aquino & Suffert, 2022). Tele-anesthesia leverages audiovisual links and data transmission to allow a remote anesthesiologist to monitor patients and guide on-site providers (Lassarén et al., 2022). Closed-loop

*Corresponding author e-mail: MAlotaibi442@moh.gov.sa (Mohammed Khalid Alyahya).
Receive Date: 15 December 2024, Revise Date: 30 December 2024, Accept Date: 31 December 2024

systems, often described as "autopilots" for anesthesia, use real-time physiological feedback (typically from processed electroencephalogram (EEG) monitors like the Bispectral Index or Patient State Index) to automatically adjust the infusion rate of propofol to maintain a user-set target depth of sedation (Seger & Cannesson, 2020). While often discussed separately, these technologies are synergistic. A closed-loop system managing routine sedation could be overseen by a remote expert, freeing that expert to manage multiple sites or intervene only during exceptions. This review aims to synthesize the current evidence on the efficacy, safety, and implementation challenges of these technologies. It will explore their technical foundations, clinical validation data, the evolving human roles within tech-augmented workflows, and the critical ethical, legal, and regulatory frameworks required for their responsible integration into mainstream practice.

The Infrastructure and Evidence for Tele-Anesthesia

Tele-anesthesia involves the use of telecommunications technology to deliver anesthetic care and support over a distance. Its infrastructure is built upon a "hub-and-spoke" model, where a central hub staffed by anesthesiologists provides remote support to multiple procedural "spoke" sites (Caruso et al., 2020). The technological core requires high-fidelity, low-latency bidirectional audiovisual communication, secure and reliable transmission of real-time physiological data (e.g., ECG, SpO2, blood pressure, end-tidal CO2, and EEG depth-of-anesthesia monitors), and integration with the site's electronic health record and device alarms (Wilson & Maeder, 2015). Advanced platforms may incorporate pan-tilt-zoom cameras, ambient microphones, and annotation tools to allow the remote provider to "point" to items on the screen for the on-site team.

Clinical applications are broad. The strongest evidence supports its use in extending expert oversight to Non-Operating Room Anesthesia (NORA) locations. Studies have demonstrated that tele-anesthesia supervision can significantly improve adherence to monitoring standards for capnography in procedural sedation, a known patient safety metric (Yatabe et al., 2021). In a landmark trial, telemedicine-directed pre-anesthesia evaluations were found to be non-inferior to in-person assessments for low-risk patients, offering significant efficiency gains (Baxter et al., 2023). Furthermore, tele-anesthesia is being piloted to provide intraoperative support in remote and rural hospitals, enabling complex surgeries to be performed locally with remote specialist guidance, thereby mitigating geographic barriers (Owolabi et al., 2022). Evidence indicates that when technical reliability is assured, tele-anesthesia does not compromise patient safety and can improve access and standardization of care. However, its success is contingent on seamless technology, well-defined protocols for handover and crisis management, and a collaborative relationship between the remote anesthesiologist and the on-site proceduralist or anesthesia assistant.

Closed-Loop Control Systems

Closed-loop control represents the pinnacle of automation in anesthetic drug delivery. In a CLC system, a controller (an algorithm) continuously compares a measured output variable—most commonly a processed EEG index reflecting sedation depth—to a clinician-set target value. It then computes and executes adjustments to the input variable, the infusion rate of an anesthetic like propofol, to minimize the error between the target and the measured state (Bong et al., 2023). This creates a dynamic feedback loop that responds in real-time to the patient's individual pharmacokinetics and pharmacodynamics, as well as surgical stimulation.

The evidence base for CLC systems, particularly for propofol sedation during procedures like colonoscopy, is robust and growing. Multiple randomized controlled trials and meta-analyses have consistently shown that CLC systems maintain the target depth of sedation within a tighter range than manual administration by anesthesiologists or nurses (Wang et al., 2021). This improved precision translates into measurable clinical benefits: a significant reduction in the incidence of oversedation (burst suppression on EEG) and undersedation (patient movement), more stable hemodynamic parameters, lower total propofol consumption, and faster recovery times (Kuck & Johnson, 2017; Wingert et al., 2021).

The systems demonstrate particular utility in managing the variable stimulation of procedures, automatically increasing infusion rates during painful phases and decreasing them during quieter periods. From a human factors perspective, CLC reduces the cognitive workload of the attending provider, allowing them to focus on higher-order tasks such as overall patient assessment, crisis planning, and communication (Ghita et al., 2020; West et al., 2018). However, these systems are not fully autonomous "black boxes." They are designed as clinician-in-the-loop tools, requiring the provider to set appropriate targets, monitor system performance and raw physiological signals, and be prepared to immediately take over manual control if the system malfunctions or the clinical situation deviates from expected parameters (Table 1). Figure 1 illustrates a hub-and-spoke tele-anesthesia model in which a central tele-anesthesia hub, staffed by anesthesiologists, provides real-time audiovisual communication and continuous physiologic monitoring to multiple remote procedural "spoke" sites.

Table 1: Comparative Analysis of Remote Monitoring vs. Closed-Loop Systems in Anesthesia

Feature	Tele-Anesthesia (Remote Monitoring/Guidance)	Closed-Loop Control (CLC) Systems
Core Function	Extends the geographical reach of expert knowledge and oversight.	Automates precise titration of anesthetic drugs (e.g., propofol).
Primary Technology	High-bandwidth telecom, data streaming, audiovisual links.	Processed EEG monitor, control algorithm, smart infusion pump.
Key Input	Real-time vitals, video feed, audio communication.	Real-time EEG-derived depth-of-anesthesia index (e.g., BIS, PSI).
Key Output	Remote guidance, decision support, and audit of compliance.	Automated adjustment of IV anesthetic infusion rate.
Human Role	**Active remote supervision;** Management of exceptions & crises.	**Supervision of automation;** Target setting, system monitoring, and manual override.
Best Evidence For	Standardizing care in NORA sites, supporting rural surgery, and pre-op assessment.	Maintaining precise sedation depth in endoscopy and ICU sedation.
Major Challenges	Latency, connectivity loss, liability demarcation, and team dynamics.	Algorithm validation for complex patients, cost, "automation bias," and alarm management.
Impact on Workflow	Enables care delegation with oversight; centralizes expertise.	Reduces manual titration burden; allows task shifting/multi-tasking.

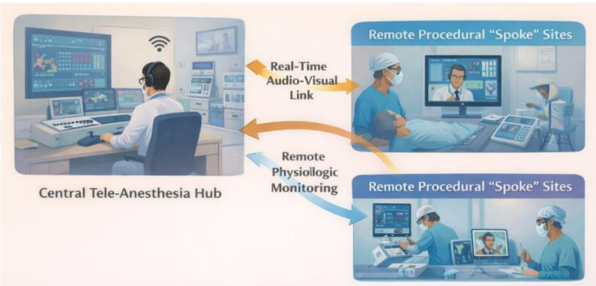

Figure 1: Remote Anesthesia Monitoring Using a Hub-and-Spoke Telemedicine Model

The Evolving Human Role from Manual Operator to System Supervisor

The integration of remote and automated technologies necessitates a fundamental shift in the cognitive and practical role of the anesthesia provider. This transition is from being a direct, hands-on operator of equipment and titrator of drugs to becoming a supervisor of automated systems and a manager of complex, non-routine situations—a concept known as "human supervisory control" (Parasuraman et al., 2000). In this new paradigm, the anesthesiologist's expertise is applied at a higher level: defining the goals (setting sedation targets), monitoring the overall system performance (watching both the patient and the automation), interpreting context that the machine cannot (e.g., surgical progress, verbal cues), and intervening when the situation exceeds the system's design boundaries (Ruskin et al., 2020).

This shift has profound implications for training and competency. Future curricula must emphasize skills in human-technology interaction, including the recognition and mitigation of "automation bias"—the tendency to over-trust automated systems and disregard contradictory information (Goddard et al., 2012). Anesthesiologists must be trained to recognize automation failure modes and maintain manual proficiency despite decreased daily practice. Concurrently, the role of the anesthesia assistant or nurse is also transformed (Weinger, 2012). With a CLC system managing routine titration, the on-site provider can focus more on airway security, intravenous access, and direct patient interaction, potentially allowing one provider to monitor multiple simultaneous sedations under the remote oversight of a single anesthesiologist. This model, however, raises critical questions about appropriate staffing ratios, scope of practice, and the necessary training for assistants to function effectively in this tech-mediated environment (Kamdar, 2021). The success of this transition hinges on designing intuitive human-machine interfaces that promote situation awareness rather than hinder it, ensuring the human remains the informed, final authority in the loop.

Regulatory, Ethical, and Legal Frontiers

The deployment of remote and automated anesthesia systems exists in a regulatory gray zone, challenging traditional frameworks of medical licensure, liability, and device approval. Regulatory bodies like the U.S. Food and Drug Administration (FDA) classify advanced CLC systems as Class III medical devices, requiring rigorous pre-market approval demonstrating safety and efficacy (Zhu et al., 2022; Clark et al., 2023). However, the regulatory pathway for the integrated *system of care* involving telemedicine, remote supervision, and partial automation is less clear. Key questions persist: Is the practice of tele-anesthesia considered to occur at the location of the patient or the provider? How do interstate or international licensure requirements apply? (Alrasheedi et al., 2023).

Ethically, the principles of beneficence, non-maleficence, and justice are paramount. While these technologies promise greater access (justice) and precision (beneficence), they also introduce novel risks (non-maleficence). A primary ethical concern is ensuring equitable access to avoid exacerbating existing healthcare disparities; will these technologies only be available in well-resourced centers, creating a two-tiered system? (Mittelstadt et al., 2016). Informed consent processes must evolve to explain the use of automated systems and remote supervision. Legally, liability in the event of an adverse outcome becomes complex. If a CLC system administers an overdose, is the liability with the manufacturer (for algorithm error), the hospital (for system implementation), the remote supervising anesthesiologist (for inadequate oversight), or the on-site assistant (for failure to intervene)? (Habli et al., 2020). Clear protocols, contractual agreements, and potentially new insurance models are required to delineate responsibility. Furthermore, the vast amounts of sensitive physiological and video data generated necessitate robust cybersecurity measures to protect patient privacy, a non-negotiable requirement in a connected healthcare ecosystem (Kruse et al., 2017).

Table 2: Framework for Implementing a Hybrid Remote/Automated Sedation Service

Phase	Component	Key Actions & Considerations
Pre-Implementation	**Needs Assessment & Governance**	Identify clinical need (e.g., NORA coverage gap). Form multidisciplinary oversight committee (Anesthesia, IT, Legal, Risk Mgmt.). Define scope: which procedures/patients are eligible?
	Technology Selection & Validation	Choose a validated, FDA-cleared/CE-marked CLC system. Procure a reliable, secure telemedicine platform with low latency. Conduct technical dry-runs and failure mode testing.
	Protocol & Policy Development	Create detailed clinical protocols for patient selection, target setting, handover, and emergency override. Draft clear liability and licensing agreements for remote supervision. Update informed consent documents.
Implementation	**Staff Training & Credentialing**	Train all users (anesthesiologists, assistants, proceduralists) on system use, limitations, and crisis management. Simulate failure scenarios (e.g., loss of connection, CLC fault). Establish credentialing process for remote providers.
	Piloting & Phased Roll-Out	Begin with a limited pilot in a controlled environment (e.g., healthy patients, straightforward procedures). Collect safety and usability data.
Post-Implementation	**Continuous Quality Assurance**	Monitor key metrics: technical failure rate, sedation quality, adverse events, and recovery times. Conduct regular audits of recorded sessions for protocol compliance.
	Feedback Loop & Iterative Improvement	Hold regular debriefs with front-line users. Use data to refine protocols, training, and technology configuration. Report outcomes to the oversight committee.

Synthesis and Future Directions

The future of procedural sedation lies not in the wholesale replacement of human providers by machines, but in the thoughtful integration of technology to create a hybrid model of care. This model leverages the respective strengths of humans and machines: the computational speed, precision, and vigilance of automated systems, combined with the contextual understanding, ethical judgment, and adaptability of the human expert (Topol, 2019). In practice, this could manifest as an "anesthesia command center," where a senior anesthesiologist remotely supervises several procedural suites. In each suite, a CLC system manages the propofol infusion for routine sedation, while an on-site anesthesia assistant manages the airway and patient monitoring. The remote anesthesiologist monitors the aggregated data streams, provides verbal guidance, and intervenes directly via the system's remote control capabilities or by instructing the on-site team if a complication arises.

For this vision to be realized, several critical avenues for research and development must be pursued. First, pragmatic clinical trials are needed to evaluate the impact of these integrated systems on hard outcomes like major morbidity, mortality, and patient satisfaction in diverse real-world settings (Cascella et al., 2023). Second, AI and machine learning can move beyond simple control algorithms to predictive analytics, forecasting hemodynamic shifts or recovery trajectories, thereby transitioning systems from reactive to proactive (Kendale et al., 2023). Third, interoperability standards must be developed to allow seamless data flow between devices from different manufacturers and the electronic health record, creating a cohesive "digital cockpit" for the anesthesiologist. Finally, the socio-technical integration—how these systems change workflows, communication, and professional identity—requires ongoing study from human factors and organizational psychology perspectives (Carayon et al., 2021). The goal is not autonomy for its own sake, but augmented intelligence, where technology empowers providers to deliver safer, more consistent, and more accessible anesthetic care.

Conclusion

Remote and automated anesthesia technologies are transitioning from experimental concepts to clinically viable tools with the potential to address systemic challenges in healthcare delivery. The evidence to date supports the efficacy of tele-anesthesia in extending specialist oversight and the superiority of closed-loop systems in maintaining precise sedation depth. However, their successful integration into the fabric of perioperative medicine is a profoundly socio-technical challenge, extending far beyond engineering. It demands the co-evolution of technology, clinical practice, education, regulation, and ethics. The anesthesia community must engage proactively to shape this future, ensuring that these powerful tools are implemented in a manner that prioritizes patient safety, enhances the professional role of the provider, and promotes equitable access. By embracing a model of collaborative intelligence—where human expertise is amplified by machine precision—we can navigate toward a future where high-quality procedural sedation is both more universally available and more consistently excellent.

References

1. Alrasheedi, N. T., Alkhubran, A. J., Alanazi, S. D. S., Al-Sahman, S. M. A., Asiri, R. A. A., Almoushawa, A. A., ... & Aldosari, A. F. (2023). Tele-Anesthesia and Remote Supervision: Changing Perioperative and General Medical Care. *Journal of Angiotherapy*, *7*(1), 1-9. https://doi.org/10.25163/angiotherapy.7110317
2. Baxter, S. N., Johnson, A. H., Brennan, J. C., Dolle, S. S., Turcotte, J. J., & King, P. J. (2023). The efficacy of telemedicine versus in-person education for high-risk patients undergoing primary total joint arthroplasty. *The Journal of Arthroplasty*, *38*(7), 1230-1237. https://doi.org/10.1016/j.arth.2023.01.015
3. Bhananker, S. M., Posner, K. L., Cheney, F. W., Caplan, R. A., Lee, L. A., & Domino, K. B. (2006). Injury and liability associated with monitored anesthesia care: a closed claims analysis. *Anesthesiology*, *104*(2), 228-234. https://doi.org/10.1097/00000542-200602000-00005
4. Bong, C. L., Balanza, G. A., Khoo, C. E. H., Tan, J. S. K., Desel, T., & Purdon, P. L. (2023). A narrative review illustrating the clinical utility of electroencephalogram-guided anesthesia care in children. *Anesthesia & Analgesia*, *137*(1), 108-123. *DOI:* 10.1213/ANE.0000000000006267
5. Carayon, P., Wust, K., Hose, B. Z., & Salwei, M. E. (2021). Human factors and ergonomics in health care. *Handbook of human factors and ergonomics*, 1417-1437. https://doi.org/10.1002/9781119636113.ch53
6. Cascella, M., Tracey, M. C., Petrucci, E., & Bignami, E. G. (2023). Exploring artificial intelligence in anesthesia: a primer on ethics, and clinical applications. *Surgeries*, *4*(2), 264-274. https://doi.org/10.3390/surgeries4020027
7. Caruso, T. J., Qian, J., Lawrence, K., Armstrong-Carter, E., & Domingue, B. W. (2020). From socrates to virtual reality: a historical review of learning theories and their influence on the training of anesthesiologists. *The Journal of Education in Perioperative Medicine: JEPM*, *22*(2), E638.https://doi.org/10.46374/volxxii-issue2-Caruso
8. Clark, P., Kim, J., & Aphinyanaphongs, Y. (2023). Marketing and US Food and Drug Administration clearance of artificial intelligence and machine learning enabled software in and as medical devices: a systematic review. *JAMA network open*, *6*(7), e2321792-e2321792. doi:10.1001/jamanetworkopen.2023.21792
9. da Silva Aquino, E. R., & Suffert, S. C. I. (2022). Telemedicine in neurology: advances and possibilities. *Arquivos de Neuro-psiquiatria*, *80*(S 05), 336-341. DOI: 10.1590/0004-282X-ANP-2022-S127
10. Ghita, M., Neckebroek, M., Muresan, C., & Copot, D. (2020). Closed-loop control of anesthesia: Survey on actual trends, challenges and perspectives. *Ieee Access*, *8*, 206264-206279. https://doi.org/10.1109/ACCESS.2020.3037725
11. Goddard, K., Roudsari, A., & Wyatt, J. C. (2012). Automation bias: a systematic review of frequency, effect mediators, and mitigators. *Journal of the American Medical Informatics Association*, *19*(1), 121-127. https://doi.org/10.1136/amiajnl-2011-000089
12. Gottumukkala, V., Vetter, T. R., & Gan, T. J. (2023). Perioperative medicine: what the future can hold for anesthesiology. *Anesthesia & Analgesia*, *136*(4), 628-635. *DOI:* 10.1213/ANE.0000000000006412

13. Habli, I., Lawton, T., & Porter, Z. (2020). Artificial intelligence in health care: accountability and safety. *Bulletin of the World Health Organization*, *98*(4), 251. https://doi.org/10.2471/BLT.19.237487
14. Kamdar, N. (2021). The electronic health record: marching anesthesiology toward value-added processes and digital patient experiences. *International Anesthesiology Clinics*, *59*(4), 12-21. *DOI:* 10.1097/AIA.0000000000000331
15. Kempthorne, P., Morriss, W. W., Mellin-Olsen, J., & Gore-Booth, J. (2017). The WFSA global anesthesia workforce survey. *Anesthesia & Analgesia*, *125*(3), 981-990. *DOI:* 10.1213/ANE.0000000000002258
16. Kendale, S., Bishara, A., Burns, M., Solomon, S., Corriere, M., & Mathis, M. (2023). Machine learning for the prediction of procedural case durations developed using a large multicenter database: algorithm development and validation study. *Jmir ai*, *2*(1), e44909. https://doi.org/10.2196/44909
17. Kruse, C. S., Frederick, B., Jacobson, T., & Monticone, D. K. (2017). Cybersecurity in healthcare: A systematic review of modern threats and trends. *Technology and Health Care*, *25*(1), 1-10. https://doi.org/10.3233/THC-161263
18. Kuck, K., & Johnson, K. B. (2017). The three laws of autonomous and closed-loop systems in anesthesia. *Anesthesia & Analgesia*, *124*(2), 377-380. *DOI:* 10.1213/ANE.0000000000001602
19. Lassarén, P., Tewarie, I. A., Gerstl, J. V., Florman, J. E., Smith, T. R., & Broekman, M. L. (2022). Telemedicine and the right to health: A neurosurgical perspective. *Journal of Clinical Neuroscience*, *102*, 71-74. https://doi.org/10.1016/j.jocn.2022.06.011
20. Mittelstadt, B. D., Allo, P., Taddeo, M., Wachter, S., & Floridi, L. (2016). The ethics of algorithms: Mapping the debate. *Big Data & Society*, *3*(2), 2053951716679679. https://doi.org/10.1177/2053951716679679
21. Owolabi, E. O., Mac Quene, T., Louw, J., Davies, J. I., & Chu, K. M. (2022). Telemedicine in surgical care in low-and middle-income countries: a scoping review. *World journal of surgery*, *46*(8), 1855-1869. https://doi.org/10.1007/s00268-022-06549-2
22. Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on systems, man, and cybernetics-Part A: Systems and Humans*, *30*(3), 286-297. https://doi.org/10.1109/3468.844354
23. Ruskin, K. J., Corvin, C., Rice, S. C., & Winter, S. R. (2020). Autopilots in the operating room: safe use of automated medical technology. *Anesthesiology*, *133*(3), 653-665. https://doi.org/10.1097/ALN.0000000000003385
24. Seger, C., & Cannesson, M. (2020). Recent advances in the technology of anesthesia. *F1000Research*, *9*, F1000-Faculty. https://doi.org/10.12688/f1000research.24059.1
25. Topol, E. J. (2019). High-performance medicine: the convergence of human and artificial intelligence. *Nature medicine*, *25*(1), 44-56. https://doi.org/10.1038/s41591-018-0300-7
26. Wang, D., Song, Z., Zhang, C., & Chen, P. (2021). Bispectral index monitoring of the clinical effects of propofol closed-loop target-controlled infusion: Systematic review and meta-analysis of randomized controlled trials. *Medicine*, *100*(4), e23930. *DOI:* 10.1097/MD.0000000000023930
27. Weinger, M. B. (2012). Human factors in anesthesiology. *Handbook of Human Factors and Ergonomics in Health Care and Patient Safety. 2nd ed. Boca Raton, FL: Taylor & Francis*.
28. West, N., Van Heusden, K., Görges, M., Brodie, S., Rollinson, A., Petersen, C. L., ... & Merchant, R. N. (2018). Design and evaluation of a closed-loop anesthesia system with robust control and safety system. *Anesthesia & Analgesia*, *127*(4), 883-894. *DOI:* 10.1213/ANE.0000000000002663
29. Wilson, L. S., & Maeder, A. J. (2015). Recent directions in telemedicine: review of trends in research and practice. *Healthcare informatics research*, *21*(4), 213-222. https://doi.org/10.4258/hir.2015.21.4.213
30. Wingert, T., Lee, C., & Cannesson, M. (2021). Machine learning, deep learning, and closed loop devices—anesthesia delivery. *Anesthesiology clinics*, *39*(3), 565-581. https://doi.org/10.1016/j.anclin.2021.03.012
31. Yatabe, J., Yatabe, M. S., Okada, R., & Ichihara, A. (2021). Efficacy of telemedicine in hypertension care through home blood pressure monitoring and videoconferencing: randomized controlled trial. *JMIR cardio*, *5*(2), e27347. https://doi.org/10.2196/27347
1. Zhu, S., Gilbert, M., Chetty, I., & Siddiqui, F. (2022). The 2021 landscape of FDA-approved artificial intelligence/machine learning-enabled medical devices: an analysis of the characteristics and intended use. *International journal of medical informatics*, *165*, 104828. https://doi.org/10.1016/j.ijmedinf.2022.104828