

## EDITORIAL VIEW

## PERIOPERATIVE MEDICINE

# Artificial intelligence–assisted monitoring in anesthesia: from depth of sedation to predicting hemodynamic instability

Mostafa Ahmed Abdellah Ahmed <sup>1</sup>, Mahnoor Nasar <sup>2</sup>, Haseeb Khaliq <sup>3</sup>

**Authors affiliations:**

1. Mostafa Ahmed Abdellah Ahmed, Department of General Surgery, Frimley Health NHS Foundation Trust, Frimley, UK; Email;

[mostafa\\_masinho.50@yahoo.com](mailto:mostafa_masinho.50@yahoo.com)

2. Mahnoor Nasar, Faculty of Computing and Information Technology, University of the Punjab, Lahore, Pakistan; Email;

[mahnoor.nasar2004@gmail.com](mailto:mahnoor.nasar2004@gmail.com)

3. Haseeb Khaliq, Department of Pathology, University of Health Sciences, Lahore, Pakistan; Email; [haseebkhaliq119@gmail.com](mailto:haseebkhaliq119@gmail.com)

**Correspondence:** Haseeb Khaliq, Email; [haseebkhaliq119@gmail.com](mailto:haseebkhaliq119@gmail.com)

## ABSTRACT

Artificial intelligence (AI) is rapidly changing the work of perioperative monitoring and making anesthesia reactive as opposed to proactive. Besides the traditional signs of the degree of sedation, artificial intelligence algorithms can be used to integrate a range of different sources that predict unstable hemodynamic processes, oxygen desaturation, and nociceptive changes in advance of clinical symptoms. One of the key elements of the future of precision perioperative medicine is AI-assisted monitoring because of the possibility of offering significant potential for increased patient safety and resource optimization. This can be facilitated by its predictive capacity, whereby the same method of safety can be applied to a heterogeneous group of patients to limit variation in results. The development of AI-assisted anesthesia is not a new part of the current structure, but it is a step towards the new era of perioperative procedures.

**Keywords:** Artificial Intelligence; Closed-loop Anesthesia; Hemodynamic Instability; Nociception Monitoring; Prediction; Predictive Analytics; Perioperative Medicine

**Citation:** Ahmed MAA, Nasar M, Khaliq H. Artificial intelligence–assisted monitoring in anesthesia: from depth of sedation to predicting hemodynamic instability (Editorial). *Anaesth. pain intensive care* 2025;29(8):825-827.

**DOI:** [10.35975/apic.v29i8.3002](https://doi.org/10.35975/apic.v29i8.3002)

**Received:** October 23, 2025; **Accepted:** October 26, 2025

The anesthesiologist now has the dual challenge of ensuring that he or she achieves optimal sedation and avoiding acute physiological instability. Conventional monitoring techniques are relevant but reactive, meaning that they represent a response to changes after they have already been made.<sup>1</sup> Quite on the contrary, AI turns the retrospective research into a proactive surveillance mode with continuous learning using the large amounts of electroencephalography (EEG), hemodynamic waves and patient characteristics. This prevention capability is of particular importance to the high-risk population, in which even some small physiological variation can be the difference between reliability and unreliability.<sup>2</sup>

The AI-based sedation depth monitoring has outperformed the conventional processed EEG indices by using a deep neural network that can distinguish between weak cortical oscillatory activities linked to states of consciousness.<sup>3</sup> In contrast to older algorithms that mix up the anesthetic effects with signal artifacts, machine learning models adapt to drug-specific patterns and patient variability.<sup>4</sup> This ability helps to reduce the risk of intraoperative awareness and overdose so that anesthetic titration is optimized in accordance with the principle of precision medicine. Real-time emergence trajectory prediction also optimizes recovery profiles and reduces post-anesthesia cognitive dysfunction.

The role of AI in predicting hemodynamic instability intraoperatively is also a revolutionary change. Hemodynamic instability is one of the greatest predictors of postoperative morbidity, but it occurs suddenly with little time to react.<sup>5</sup> Advanced forms of predictive analytics can now identify micro-patterns in arterial pressure waveforms, stroke volume variation, and tissue perfusion markers minutes before overt hypotension or shock occurs. Using thresholds derived from the millions of intraoperative events studied, systems continually improve these limits, so clinicians can intervene with vasopressors or fluid adjustments preemptively rather than reactively. This change has the potential to transform the intra-operative safety standard, to minimize cardiac and renal complications due to unrecognized hypotension.<sup>6</sup>

AI is changing the field of nociception monitoring through the creation of multidimensional pain indices based on the integration of hemodynamic, pupillometry, and EEG-based stimulation.<sup>7</sup> AI can detect nonlinear physiological interactions that characterize nociceptive stress rather than using crude surrogates (e.g., blood pressure or heart rate).<sup>8</sup> This reduces one of the longest-standing iatrogenic costs of anesthesia by reducing opioid misuse and allowing more precise delivery of analgesics.<sup>9</sup> Moreover, within surgical procedures, adaptive algorithms continue to improve such frameworks through the real-time continuous learning feedback from the patients.

AI, in conjunction with closed-loop systems, is the future of anesthesia administration. Such systems have predictive algorithms coupled directly to infusion pumps that titrate anesthetic depth or vasoactive agents automatically, within a set of safety overrides and clinician supervision.<sup>10</sup> Pilot studies have shown that drug dosage, hemodynamic disturbances, and emergence times are lower as compared to manual titration.<sup>11</sup> Ethical and regulatory challenges aside, the direction is obviously towards a semi-autonomous delivery of anesthesia in which human agents are replaced by hand controllers and intelligent technologies.

The wider impact of AI-assisted monitoring is in its capacity to bring perioperative care outside of the operating room. Predictive analytics would be able to identify patients at risk of developing postoperative complications and thus inform ICU triage.<sup>12</sup> With the predictive intelligence implemented in the perioperative processes, anesthesia becomes not just the art of keeping patients in a vegetative state and stabilizing them, but the science of prediction, prevention, and personalization.

AI-assisted anesthetic monitoring is not a step towards improvement; rather, it is a fundamental change in care offered throughout the perioperative phase. AI changes the role of anesthesiologist by measuring the cerebral

signature of awareness and transforms the role from a passive responder to change to an active strategist. Human expertise together with machine intelligence will always merge, and the future of anesthesia is dictation by the integration of predictive technologies. The future operating room will not only be monitored but also predicted.

## Conflict of interest

Authors declare no conflict of interest.

## Authors contribution

All authors took part in the concept, literature search and manuscript drafting.

## REFERENCES

1. Kuck K, Lofgren L, Lybbert C. Anesthesia Patient Monitoring 2050. *Anesth Analg*. 2024 Feb 1;138(2):273-283. DOI: PMID: 38215707; DOI: [10.1213/ANE.0000000000006660](https://doi.org/10.1213/ANE.0000000000006660)
2. Lee B, Marhalik-Helms J, Penzi L. Anesthesia Risk Alert Program: A Proactive Safety Initiative. *Jt Comm J Qual Patient Saf*. 2023 Sep;49(9):441-449. PMID: 37429758; DOI: [10.1016/j.jcjq.2023.06.005](https://doi.org/10.1016/j.jcjq.2023.06.005)
3. . Cao Y, Wang Y, Liu H, Wu L. Artificial intelligence revolutionizing anesthesia management: advances and prospects in intelligent anesthesia technology. *Front Med (Lausanne)*. 2025 Aug 6;12:1571725. PMCID: [PMC12364868](https://pubmed.ncbi.nlm.nih.gov/PMC12364868/); DOI: [10.3389/fmed.2025.1571725](https://doi.org/10.3389/fmed.2025.1571725).
4. Yuan I, Bong CL, Chao JY. Intraoperative pediatric electroencephalography monitoring: an updated review. *Korean J Anesthesiol*. 2024 Jun;77(3):289-305. PMCID: [PMC11150110](https://pubmed.ncbi.nlm.nih.gov/PMC11150110/); DOI: [10.4097/kja.23843](https://doi.org/10.4097/kja.23843).
5. Abebe MM, Arefayne NR, Temesgen MM, Admass BA. Incidence and predictive factors associated with hemodynamic instability among adult surgical patients in the post-anesthesia care unit, 2021: A prospective follow up study. *Ann Med Surg (Lond)*. 2022 Jan 29;74:103321. □ PMCID: [PMC8818524](https://pubmed.ncbi.nlm.nih.gov/PMC8818524/); □ DOI: [10.1016/j.amsu.2022.103321](https://doi.org/10.1016/j.amsu.2022.103321) .
6. Guarracino F, Bertini P. Perioperative hypotension: causes and remedies. *J Anesth Analg Crit Care*. 2022 Apr 14;2(1):17. □ PMCID: [PMC10245539](https://pubmed.ncbi.nlm.nih.gov/PMC10245539/); □ DOI: [10.1186/s44158-022-00045-8](https://doi.org/10.1186/s44158-022-00045-8)
7. Cascella M, Schiavo D, Cuomo A, Ottaiano A, Perri F, Patrone R, et al. Artificial Intelligence for Automatic Pain Assessment: Research Methods and Perspectives. *Pain Res Manag*. 2023 Jun 28;2023:6018736. □ PMCID: [PMC10322534](https://pubmed.ncbi.nlm.nih.gov/PMC10322534/); □ DOI: [10.1155/2023/6018736](https://doi.org/10.1155/2023/6018736) .
8. Subramanian S, Tseng B, Del Carmen M, Goodman A, Dahl DM, Barbieri R, et al. Monitoring surgical nociception using multisensor physiological models. *Proc Natl Acad Sci U S A*. 2024 Oct;121(40):e2319316121. □

- PMCID: [PMC11459174](#) DOI: [10.1073/pnas.2319316121](#) .
9. Fuica R, Krochek C, Weissbrod R, Greenman D, Freundlich A, Gozal Y. Reduced postoperative pain in patients receiving nociception monitor guided analgesia during elective major abdominal surgery: a randomized, controlled trial. *J Clin Monit Comput.* 2023 Apr;37(2):481-491. □ PMCID: [PMC9383658](#); □ DOI: [10.1007/s10877-022-00906-1](#)
  10. Wingert T, Lee C, Cannesson M. Machine Learning, Deep Learning, and Closed Loop Devices-Anesthesia Delivery. *Anesthesiol Clin.* 2021 Sep;39(3):565-581. □ PMCID: [PMC9847584](#); □ DOI: [10.1016/j.anclin.2021.03.012](#)
  11. Coeckelenbergh S, Boelefahr S, Alexander B, Perrin L, Rinehart J, Joosten A, et al. Closed-loop anesthesia: foundations and applications in contemporary perioperative medicine. *J Clin Monit Comput.* 2024 Apr;38(2):487-504. PMID: 38184504; DOI: [10.1007/s10877-023-01111-4](#)
  12. Singam A. Revolutionizing Patient Care: A Comprehensive Review of Artificial Intelligence Applications in Anesthesia. *Cureus.* 2023 Dec 4;15(12):e49887. □ PMCID: [PMC10762564](#); □ DOI: [10.7759/cureus.49887](#)