Online-Journals.org

iJOE International Journal of Online and Biomedical Engineering

iJOE | eISSN: 2626-8493 | Vol. 21 No. 10 (2025) | OPEN ACCESS

https://doi.org/10.3991/ijoe.v21i10.55925

SHORT PAPER

Applications and Challenges of Artificial Intelligence in Oncologic Surgical Education

Jorge Buele[1] (✉), **Jairo Terán-Albuja**[2], **Anthony Gutiérrez-Martínez**[2]

[1]Centro de Investigación en Mecatrónica y Sistemas Interactivos (MIST), Facultad de Ingenierías, Universidad Tecnológica Indoamérica, Ambato, Ecuador

[2]Facultad de Ingenierías, Universidad Tecnológica Indoamérica, Ambato, Ecuador

jorgebuele@uti.edu.ec

ABSTRACT

Surgical training faces significant challenges due to the technical complexity of procedures and the imperative to ensure patient safety during the learning process. In this context, artificial intelligence (AI), machine learning, and robotic platforms are transforming traditional models of surgical education. This paper presents a narrative overview of the impact of these tools on oncologic surgical training. The reviewed evidence indicates that artificial intelligence contributes to improved clinical decision-making, enhances surgical planning, and enables the implementation of automated evaluation systems with objective, real-time feedback. These solutions promote personalized learning pathways and strengthen competency standardization. Moreover, robotic surgery assisted by artificial intelligence provides advanced simulation environments that facilitate the acquisition of technical skills in a safe and controlled manner. Recent developments also emphasize the importance of ethical governance, multi-phase validation in clinical settings, and alignment with international standards such as ISO/IEC 42001:2023 to ensure equitable and effective adoption of these technologies. Nonetheless, significant limitations remain, such as limited validation in real clinical settings, methodological heterogeneity across existing studies, and the high costs associated with implementation. These barriers hinder equitable and sustainable adoption. Future efforts should focus on validating AI-based training systems in real clinical environments to ensure their effectiveness, safety, and relevance in surgical oncology education. This study was registered in the Open Science Framework under the code 10.17605/OSF.IO/QUTC4.

KEYWORDS

surgical training, artificial intelligence (AI), robotic surgery, machine learning, medical education

1 INTRODUCTION

Surgery is one of the most demanding medical disciplines, requiring prolonged and structured training to develop advanced technical skills, precise clinical judgment,

Buele, J., Terán-Albuja, J., Gutiérrez-Martínez, A. (2025). Applications and Challenges of Artificial Intelligence in Oncologic Surgical Education. *International Journal of Online and Biomedical Engineering (iJOE)*, 21(10), pp. 128–136. https://doi.org/10.3991/ijoe.v21i10.55925

Article submitted 2025-04-16. Revision uploaded 2025-05-19. Final acceptance 2025-05-20.

and decision-making abilities in high-pressure environments [1]. Unlike other areas of medicine, where learning can be based on observation and theoretical reasoning, surgery necessitates a combination of anatomical knowledge, manual dexterity, and complex cognitive skills to ensure safe and effective procedures [2]. Historically, surgical training has followed the progressive learning model introduced by William Halsted in the late 19th century, which establishes a tiered approach where residents advance from observation to supervised independent practice [3].

While this approach has been the foundation of modern surgical education, it has inherent limitations. The variability in clinical case exposure depends on patient availability and procedural complexity, which can impact the development of surgical competencies [4]. Furthermore, performance evaluation in clinical settings has traditionally been subjective, relying on instructor observation, which can lead to inconsistencies in skill assessment [5]. Additionally, the ethical challenges of surgical training on real patients, where ensuring patient safety is the highest priority, further limit practice opportunities for trainee surgeons [6].

To overcome these limitations, the integration of advanced technologies, particularly artificial intelligence (AI), robotic surgery, and machine learning, has gained increasing relevance in surgical education. These tools allow practice in simulated or augmented environments, improving patient safety and supporting performance analysis through automated, data-driven systems [7], [8], [9]. AI has emerged as a key enabler in personalizing surgical training and optimizing skill acquisition through objective, real-time feedback [10].

However, despite notable progress in general surgical education, there is limited consensus on the effectiveness and scalability of these technologies in the specific context of oncologic surgery training [11], [12]. This short article offers a narrative synthesis of recent evidence on the role of emerging technologies in surgical oncology training. The aim is to explore current applications, identify existing limitations, and outline future directions to foster a more effective, data-driven, and personalized approach to surgical oncology education.

2 OVERVIEW OF TECHNOLOGIES APPLIED TO ONCOLOGIC SURGICAL TRAINING

Artificial intelligence and its applications in medical education are transforming the way surgical competencies are acquired and assessed, particularly in the field of oncology. Several approaches have been proposed to enhance decision-making and risk prediction through machine learning, as exemplified by Boehm et al. [13], who demonstrated that integrating histopathological and clinical data using AI improves risk stratification in high-grade ovarian cancer, an insight that can inform personalized surgical learning paths. In neurosurgical oncology, Baker et al. [14] reviewed the growing use of AI for preoperative planning and intraoperative support, underscoring its contribution to complex clinical decision-making in high-risk procedures.

In the educational domain, Chen et al. [15] and Liu et al. [16] analyzed trends in the use of AI in medical training, concluding that automated performance analysis enables the creation of more efficient and adaptive learning pathways. These platforms not only enhance feedback mechanisms but also help identify recurring errors, thereby supporting deliberate practice. Parallel to these trends, the role of robotic surgery as both a clinical and educational platform has been reviewed by Tamborino et al. [17] and Zhang et al. [18], who emphasize that AI-augmented robotic systems create immersive, low-risk environments where trainees can rehearse advanced procedures under guidance. Furthermore, Guni et al. [19] and Savage et al. [20] describe the future role of digital twins and predictive algorithms in tailoring surgical education, enabling continuous monitoring and simulation of learner progress.

Table 1 summarizes practical implementations of AI across diverse surgical training contexts, ranging from high-fidelity robotic systems to accessible low-cost simulation tools. These include real-time anatomical guidance during oncologic procedures, AI-based tutoring systems for technical skills acquisition, and box trainers enhanced with AI for psychomotor evaluation. Together, these applications reveal how AI supports not only the development of surgical proficiency but also the personalization and democratization of surgical education through scalable, data-driven learning environments.

Table 1. Real-world applications of AI in surgical training

Reference	Training Context	AI Contribution	Outcome Summary
Yilmaz et al. 2023 [21]	Simulated brain tumor resections	Real-time AI tutor giving instant feedback with error-video clips	Outperformed human instruction in learning curve and OSATS scores
Fazlollahi et al. 2022 [22]	Neurosurgical simulation	VOA system offering audiovisual metric-based feedback	Equivalent OSATS scores to expert debriefing; better skill transfer
Ryu et al. 2024 [23]	Laparoscopic colorectal surgery	"Eureka" AI system for real-time nerve segmentation	Enabled safe dissection with no complications; used in live training
Nakamura et al. 2024 [24]	Robot-assisted gastrectomy	AI semantic segmentation of pancreas during surgery	Prevents misidentification errors and may reduce complications
Alonso-Silverio et al. 2018 [25]	Laparoscopic simulation with box trainer	AI-based psychomotor skill assessment using low-cost open-source hardware	90% improvement in surgical dexterity; high perceived educational value.

3 IMPLICATIONS AND FUTURE CHALLENGES

The integration of AI and machine learning into oncologic surgical training has driven a paradigm shift toward educational models centered on personalized, data-driven instruction. AI-assisted evaluation platforms enable continuous monitoring of surgical performance with immediate, objective feedback, significantly advancing traditional methods often limited by subjectivity. Studies such as Zhou et al. [26] report that these platforms promote competency standardization and support adaptive learning pathways based on individual progress.

In this context, AI not only assesses but also predicts and guides learning trajectories. These adaptive environments may soon form the foundation of personalized surgical education, combining performance analytics with automated recommendations to optimize clinical skill acquisition [27], [28]. However, their implementation demands robust infrastructure, faculty preparation, and appropriate governance frameworks for clinical and educational data. Methodological heterogeneity across the literature continues to limit comparability and the establishment of unified validation standards [29], [30].

A critical area of development is the validation of AI-driven training systems in clinical environments. While current studies often emphasize short-term outcomes in simulated settings, few incorporate longitudinal metrics capturing real-world skill transfer. Future research should adopt multi-phase validation frameworks encompassing baseline skill benchmarking, simulation-based performance evaluation, skill retention, and in vivo assessments using instruments such as OSATS or entrustable professional activities [31], [32]. Automated video analysis, motion tracking, and biometric data can further enhance objectivity in these stages [33].

Ethical and regulatory considerations must also be explicitly addressed. These include algorithmic transparency, accountability, and the protection of sensitive clinical and educational data. Practitioners and educators should be trained not only in system operation but also in recognizing limitations, biased sources, and data dependencies [34]. Recent findings show that ethical engagement with AI is influenced more by users' reflective understanding than by frequency of use, reinforcing the importance of educational framing [35].

Institutionally, ethical frameworks should align with international standards such as the UNESCO Recommendation on the Ethics of AI, the OECD AI Principles, and technical norms like ISO/IEC 42001:2023 or the NIST AI Risk Management Framework [37]. These promote fairness, human oversight, and accountability. As Memarian and Doleck [36] argue, adopting the FATE principles (Fairness, Accountability, Transparency, and Ethics) is essential to ensure equitable and trustworthy AI integration. Without these safeguards, generative systems may undermine academic integrity and reinforce inequities.

Moreover, a gap persists between simulated learning environments and actual clinical performance. Most current evaluations lack longitudinal follow-up to demonstrate effective skill transfer. According to Branstetter et al. [37], addressing this evidence gap is critical, alongside conducting cost-effectiveness studies to support sustainable institutional adoption.

On another front, the emergence of approaches such as digital twins and autonomous surgical assistance systems represents a promising frontier. According to Savage et al. [20], these technologies will enable the dynamic and realistic replication of complex clinical scenarios, contributing not only to technical training but also to the development of advanced cognitive competencies.

4 LIMITATIONS

One of the main limitations identified in the literature is that most studies have been conducted in simulated environments, without adequately validating the effective transfer of skills to real clinical settings. This methodological gap prevents confirmation that improvements observed in simulators translate into safer and more effective surgical performance with actual patients. For instance, Nagao et al. [38] highlighted the potential of AI in endoscopic procedures but did not address clinical follow-up after virtual training. Similarly, Jacob et al. [39] emphasized the benefits of clinical prediction through machine learning, yet without direct evidence of its long-term educational impact.

Another significant obstacle is the methodological heterogeneity among the reviewed studies. There is considerable variability in study designs, ranging from small-scale pilot studies to systematic reviews and clinical trials. This variability affects inclusion criteria, evaluation metrics, and the surgical contexts analyzed, making it difficult to compare findings across studies. Salloum et al. [40] illustrate this diversity by employing various multimodal analysis approaches and digital platforms for clinical training, thereby complicating the formulation of generalizable conclusions.

Additionally, a notable absence of longitudinal validations is observed. Most studies focus on immediate or short-term outcomes, without assessing the sustainability of benefits or their long-term impact on professional surgical practice. This lack of follow-up hinders assessment of the true transformative potential of these technologies. While studies such as Liu et al. explore bibliometric trends in AI and medical education, they do not examine extended clinical performance after virtual training.

From an operational standpoint, high implementation costs represent a major barrier. AI- and robotics-based solutions require not only significant initial investment but also ongoing maintenance, skilled personnel, and continuous updates. Howard et al. [41] emphasize that these requirements limit adoption in resource-constrained environments, widening disparities in access to advanced training technologies.

Finally, regulatory and ethical gaps emerge concerning the use of automated platforms for pedagogical or clinical decision-making. Although not thoroughly addressed in the reviewed studies, authors such as Goyal et al. [42] have already raised concerns about the need for regulatory frameworks to ensure the ethical use of these tools in sensitive educational contexts such as surgical oncology.

These limitations must be considered in the design of future research. Only through comparable methodologies, longitudinal evaluation, and cost-effectiveness analyses can the effective, scalable, and ethical adoption of these technologies be supported in surgical training programs, ultimately contributing to the improvement of oncologic care quality.

5 CONCLUSION

This short article highlights that the incorporation of technologies based on artificial intelligence, machine learning, and automated platforms is substantially transforming the model of oncologic surgical training. The observed benefits include improvements in learning personalization, diagnostic accuracy, and the standardization of evaluation processes, paving the way for more dynamic, data-driven educational models. However, the current body of evidence remains largely rooted in simulated environments and presents methodological limitations that hinder the generalization of findings. The lack of longitudinal validations, high implementation costs, and regulatory gaps represent key challenges to sustained adoption.

The transformative impact of these technologies will depend not only on their curricular integration but also on the generation of robust empirical evidence supporting their effectiveness in real clinical practice. Additionally, it will be essential to promote institutional policies that enhance accessibility and ensure ethical use. Ultimately, the future of oncologic surgical education will require a multidisciplinary approach that combines technological innovation with pedagogical rigor, ensuring more effective, equitable training aimed at improving clinical outcomes in surgical oncology.

6 FUNDING

This study was funded by Universidad Tecnológica Indoamérica, under the project “Innovación en la Educación Superior a través de las Tecnologías Emergentes,” Grant Number: IIDI-022-25.

7 REFERENCES

[1] A. Levitskyi, I. Benzar, V. Vitiaz, D. Golovatiuk, and O. Karabenyuk, "Teaching pediatric surgery in the online environment: Challenges and opportunities," *Int. J. Online Biomed. Eng. (IJOE)*, vol. 17, no. 5, pp. 119–132, 2021. https://doi.org/10.3991/ijoe.v17i05.22051

[2] B. Al-Halabi, M. Vassiliou, and M. Gilardino, "Teaching and assessing cognitive competencies in aesthetic and plastic surgery," *Plast. Reconstr. Surg.*, vol. 150, no. 2, pp. 455e–464e, 2022. https://doi.org/10.1097/PRS.0000000000009295

[3] W. S. Halsted, *The Training of the Surgeon*. Baltimore, MD: Johns Hopkins Press, 1904.

[4] J. Meyer-Szary *et al.*, "The role of 3D printing in planning complex medical procedures and training of medical professionals—cross-sectional multispecialty review," *Int. J. Environ. Res. Public. Health*, vol. 19, no. 6, p. 3331, 2022. https://doi.org/10.3390/ijerph19063331

[5] I.-H. A. Chen *et al.*, "Evolving robotic surgery training and improving patient safety, with the integration of novel technologies," *World J. Urol.*, vol. 39, no. 8, pp. 2883–2893, 2021. https://doi.org/10.1007/s00345-020-03467-7

[6] M. Laspro, L. Groysman, A. N. Verzella, L. L. Kimberly, and R. L. Flores, "The use of virtual reality in surgical training: Implications for education, patient safety, and global health equity," *Surgeries*, vol. 4, no. 4, pp. 635–646, 2023. https://doi.org/10.3390/surgeries4040061

[7] M. Ayala-Chauvin and F. Avilés-Castillo, "Optimizing natural language processing: A comparative analysis of GPT-3.5, GPT-4, and GPT-4o," *Data Metadata*, vol. 3, p. 359, 2024. https://doi.org/10.56294/dm2024.359

[8] T. Igaki *et al.*, "Automatic surgical skill assessment system based on concordance of standardized surgical field development using artificial intelligence," *JAMA Surg.*, vol. 158, no. 8, p. e231131, 2023. https://doi.org/10.1001/jamasurg.2023.1131

[9] J. Barcik *et al.*, "Development of surgical tools and procedures for experimental preclinical surgery using computer simulations and 3D printing," *Int. J. Online Biomed. Eng. (IJOE)*, vol. 16, no. 9, pp. 183–195, 2020. https://doi.org/10.3991/ijoe.v16i09.15183

[10] M. E. Jihaoui, O. E. K. Abra, K. Mansouri, and M. E. H. Ech-Chhibat, "Towards a literature review methodology: A practical guide in the context of using artificial intelligence in education," *Int. J. Eng. Pedagogy (IJEP)*, vol. 14, no. 7, pp. 119–145, 2024. https://doi.org/10.3991/ijep.v14i7.50261

[11] T. M. Ward, P. Mascagni, A. Madani, N. Padoy, S. Perretta, and D. A. Hashimoto, "Surgical data science and artificial intelligence for surgical education," *J. Surg. Oncol.*, vol. 124, no. 2, pp. 221–230, 2021. https://doi.org/10.1002/jso.26496

[12] Y. Li, N. Raison, S. Ourselin, T. Mahmoodi, P. Dasgupta, and A. Granados, "AI solutions for overcoming delays in telesurgery and telementoring to enhance surgical practice and education," *J. Robot. Surg.*, vol. 18, no. 1, 2024. https://doi.org/10.1007/s11701-024-02153-9

[13] K. M. Boehm *et al.*, "Multimodal data integration using machine learning improves risk stratification of high-grade serous ovarian cancer," *Nat. Cancer*, vol. 3, no. 6, pp. 723–733, 2022. https://doi.org/10.1038/s43018-022-00388-9

[14] C. R. Baker, M. Pease, D. P. Sexton, A. Abumoussa, and L. B. Chambless, "Artificial intelligence innovations in neurosurgical oncology: A narrative review," *J. Neurooncol.*, vol. 169, no. 3, pp. 489–496, 2024. https://doi.org/10.1007/s11060-024-04757-5

[15] F. Chen, J. Xia, X. Yu, and J. Zhuge, "Landscape and trends in the application of artificial intelligence in medical education," in *2023 International Conference on Intelligent Education and Intelligent Research (IEIR)*, 2023, pp. 1–6. https://doi.org/10.1109/IEIR59294.2023.10391248

[16] J. Liu, K. T. Chui, L.-K. Lee, F. L. Wang, S. K. S. Cheung, and Y. K. Hui, "Artificial intelligence and machine (deep) learning in medical education: A bibliometric analysis based on VOSviewer and CiteSpace," in *2024 International Symposium on Educational Technology (ISET)*, 2024, pp. 80–86. https://doi.org/10.1109/ISET61814.2024.00025

[17] F. Tamborino *et al.*, "Current status, evolution, and future perspectives in robotic platform systems for prostate cancer treatment: A narrative review," *Chin. Clin. Oncol.*, vol. 13, no. 5, 2024. https://doi.org/10.21037/cco-24-47

[18] C. Zhang, M. S. Hallbeck, H. Salehinejad, and C. Thiels, "The integration of artificial intelligence in robotic surgery: A narrative review," *Surgery*, vol. 176, no. 3, pp. 552–557, 2024. https://doi.org/10.1016/j.surg.2024.02.005

[19] A. Guni, P. Varma, J. Zhang, M. Fehervari, and H. Ashrafian, "Artificial intelligence in surgery: The future is now," *Eur. Surg. Res.*, vol. 65, no. 1, pp. 22–39, 2024. https://doi.org/10.1159/000536393

[20] S. A. Savage, I. Seth, Z. G. Angus, and W. M. Rozen, "Advancements in microsurgery: A comprehensive systematic review of artificial intelligence applications," *J. Plast. Reconstr. Aesthet. Surg.*, vol. 101, pp. 65–76, 2025. https://doi.org/10.1016/j.bjps.2024.11.023

[21] R. Yilmaz *et al.*, "Comparing the efficiency of a real-time artificial intelligence instructor to human expert instructors in simulated surgical technical skills training – a randomized controlled trial," *Neuro-Oncol. Adv.*, vol. 5, no. Supplement_2, p. i1, 2023. https://doi.org/10.1093/noajnl/vdad071.003

[22] A. Fazlollahi *et al.*, "510 artificial intelligence tutoring compared with expert instruction in neurosurgical simulation training: A randomized controlled trial," *Neurosurgery*, vol. 68, no. Supplement_1, pp. 128–129, 2022. https://doi.org/10.1227/NEU.0000000000001880_510

[23] S. Ryu, K. Goto, Y. Imaizumi, and Y. Nakabayashi, "Laparoscopic colorectal surgery with anatomical recognition with artificial intelligence assistance for nerves and dissection layers," *Ann. Surg. Oncol.*, vol. 31, no. 3, pp. 1690–1691, 2024. https://doi.org/10.1245/s10434-023-14633-7

[24] T. Nakamura *et al.*, "Precise highlighting of the pancreas by semantic segmentation during robot-assisted gastrectomy: Visual assistance with artificial intelligence for surgeons," *Gastric Cancer*, vol. 27, no. 4, pp. 869–875, 2024. https://doi.org/10.1007/s10120-024-01495-5

[25] G. A. Alonso-Silverio *et al.*, "Development of a laparoscopic box trainer based on open source hardware and artificial intelligence for objective assessment of surgical psychomotor skills," *Surg. Innov.*, vol. 25, no. 4, pp. 380–388, 2018. https://doi.org/10.1177/1553350618777045

[26] N. Zhou, X. Li, D. Wang, C. Jin, W. Wang, and X. Cui, "Experimental teaching system of human physiology and artificial intelligence application in basic medical education," in *2023 IEEE 5th Eurasia Conference on Biomedical Engineering, Healthcare and Sustainability (ECBIOS)*, 2023, pp. 158–160. https://doi.org/10.1109/ECBIOS57802.2023.10218415

[27] A. Kirubarajan, D. Young, S. Khan, N. Crasto, M. Sobel, and D. Sussman, "Artificial intelligence and surgical education: A systematic scoping review of interventions," *J. Surg. Educ.*, vol. 79, no. 2, pp. 500–515, 2022. https://doi.org/10.1016/j.jsurg.2021.09.012

[28] A. Y. Sheikh and J. I. Fann, "Artificial intelligence: Can information be transformed into intelligence in surgical education?" *Thorac. Surg. Clin.*, vol. 29, no. 3, pp. 339–350, 2019. https://doi.org/10.1016/j.thorsurg.2019.03.011

[29] K.-M. Lam, X.-J. He, and K.-S. Choi, "Using artificial neural network to predict mortality of radical cystectomy for bladder cancer," in *2014 International Conference on Smart Computing*, 2014, pp. 201–207. https://doi.org/10.1109/SMARTCOMP.2014.7043859

[30] N. T. Issa, V. Stathias, S. Schürer, and S. Dakshanamurthy, "Machine and deep learning approaches for cancer drug repurposing," *Semin. Cancer Biol.*, vol. 68, pp. 132–142, 2021. https://doi.org/10.1016/j.semcancer.2019.12.011

[31] G. Aruni, G. Amit, and P. Dasgupta, "New surgical robots on the horizon and the potential role of artificial intelligence," *Investig. Clin. Urol.*, vol. 59, no. 4, pp. 221–222, 2018. https://doi.org/10.4111/icu.2018.59.4.221

[32] B. C. Gin *et al.*, "Entrustment and EPAs for Artificial Intelligence (AI): A framework to safeguard the use of AI in health professions education," *Acad. Med. J. Assoc. Am. Med. Coll.*, vol. 100, no. 3, pp. 264–272, 2025. https://doi.org/10.1097/ACM.0000000000005930

[33] M. Crispin, "Artificial intelligence in surgical education and training," in *Clinical Education for the Health Professions: Theory and Practice,* D. Nestel, G. Reedy, L. McKenna, and S. Gough, Eds., Springer, Singapore, 2023, pp. 1435–1445. https://doi.org/10.1007/978-981-15-3344-0_133

[34] K. E. Allen, J. Breen, G. Hall, K. Zucker, N. Ravikumar, and N. M. Orsi, "#900 Comparative evaluation of ovarian carcinoma subtyping in primary versus interval debulking surgery specimen whole slide images using artificial intelligence," *Int. J. Gynecol. Cancer*, vol. 33, pp. A429–A430, 2023. https://doi.org/10.1136/ijgc-2023-ESGO.900

[35] J. Buele, Á. R. Sabando-García, B. J. Sabando-García, and H. Yánez-Rueda, "Ethical use of generative artificial intelligence among ecuadorian university students," *Sustainability*, vol. 17, no. 10, p. 4435, 2025. https://doi.org/10.3390/su17104435

[36] B. Memarian and T. Doleck, "Fairness, Accountability, Transparency, and Ethics (FATE) in Artificial Intelligence (AI) and higher education: A systematic review," *Comput. Educ. Artif. Intell.*, vol. 5, p. 100152, 2023. https://doi.org/10.1016/j.caeai.2023.100152

[37] R. Branstetter, E. Piedy, R. Rajendra, A. Bronstone, and V. Dasa, "Navigating the intersection of technology and surgical education: Advancements, challenges, and ethical considerations in orthopedic training," *Orthop. Clin.*, vol. 56, no. 1, pp. 21–28, 2025. https://doi.org/10.1016/j.ocl.2024.07.003

[38] S. Nagao *et al.*, "Implementation of artificial intelligence in upper gastrointestinal endoscopy," *DEN Open*, vol. 2, no. 1, p. e72, 2022. https://doi.org/10.1002/deo2.72

[39] C. Jacob *et al.*, "AI for IMPACTS framework for evaluating the long-term real-world impacts of AI-powered clinician tools: Systematic review and narrative synthesis," *J. Med. Internet Res.*, vol. 27, no. 1, p. e67485, 2025. https://doi.org/10.2196/67485

[40] S. Salloum, K. Shaalan, R. Alfaisal, A. Salloum, and T. Gaber, "Integrating ChatGPT into medical education: A combined SEM-ML approach," in *2024 International Conference on Advancements in Smart, Secure and Intelligent Computing (ASSIC)*, 2024, pp. 1–5. https://doi.org/10.1109/ASSIC60049.2024.10507994

[41] F. M. Howard, S. Kochanny, M. Koshy, M. Spiotto, and A. T. Pearson, "Machine learning–guided adjuvant treatment of head and neck cancer," *JAMA Netw. Open*, vol. 3, no. 11, p. e2025881, 2020. https://doi.org/10.1001/jamanetworkopen.2020.25881

[42] H. Goyal *et al.*, "Scope of artificial intelligence in gastrointestinal oncology," *Cancers*, vol. 13, no. 21, p. 5494, 2021. https://doi.org/10.3390/cancers13215494

8 AUTHORS

Jorge Buele is a Ph.D. in Electronic Engineering from the University of Zaragoza, Spain, and a professor at Universidad Tecnológica Indoamérica, Ecuador. He is the president of EDUTEM. His research focuses on the application of emerging technologies in education and healthcare, particularly in extended reality, automation, and artificial intelligence (E-mail: jorgebuele@uti.edu.ec).

Jairo Terán-Albuja is an undergraduate student of Information Technologies at Universidad Tecnológica Indoamérica, Ecuador. He conducts research on the use of technology and artificial intelligence in medical training and education (E-mail: jtern@indoamerica.edu.ec).

Anthony Gutiérrez-Martínez is an undergraduate student of Information Technologies at Universidad Tecnológica Indoamérica, Ecuador. His research explores the role of emerging technologies and artificial intelligence in educational environments, particularly in health sciences (E-mail: agutierrez9@indoamerica.edu.ec).