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The State of Artificial Intelligence in Healthcare Simulation: A 2024 International Survey

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Abstract

Background

The role and landscape of Artificial Intelligence (AI) in simulation-based education have not been well described yet, and a comprehensive survey is essential to assess its current use and capabilities. This survey aimed to explore the application of AI in healthcare simulation, particularly to 1) identify primary users, 2) provide a picture of demographic trends, 3) examine the motivations driving adoption, 4) describe specific use cases, 5) analyze the diverse applications, 6) analyze the modalities or types of AI-driven simulations being implemented, and 7) investigate recruitment and training strategies for simulationists and staff.

Methods

This open-ended survey targeted professionals involved in healthcare simulation and was widely distributed from May 27 to June 23, 2024.

Results

A total of 158 respondents from 12 countries were included in the analysis. The majority of respondents (49%) reported the use of AI for healthcare simulation, 41% did not use AI, and 10% reported that they were not sure. Of the 41% (n=66) respondents not using AI, 96% of those who responded (n=47) were interested in learning more. Seventy-one percent (71.2%, n=52 of those using AI) of respondents were planning for future use of AI. The demand for workshops, certifications, and access to technical experts was evident by all respondents, highlighting the importance of developing robust training programs to equip staff with the necessary skills to leverage AI effectively.

Conclusion

This study gives a perspective into the rapid adaptation of AI into healthcare simulation, as well as future directions to pursue understanding and support of AI and its application in simulation-based education.

Categories: AI applications, AI Ethics and Fairness, Machine Learning (ML)
Keywords: ai, artificial intelligence, healthcare simulation, simulation-based education, faculty development

Introduction

Artificial intelligence (AI) is rapidly emerging as a central element in healthcare [1-6] due to its ability to deliver real-time, personalized information [2,6] and efficiently support healthcare technology infrastructures [7]. These advantages have enhanced both clinical care processes and innovations in health professions education. As AI tools mature, they require usability testing in safe, controlled environments, positioning healthcare simulation as an essential counterpart to clinical practice. Similarly, the rapid global expansion of AI technologies has begun to influence simulation-based education.

While AI's transformative impact on clinical settings is well documented [1,8-9], its application within healthcare simulation remains comparatively underexplored. Existing work consists largely of reviews and conceptual discussions rather than empirical investigations [6,10-11]. Known applications include AI-generated patient scenarios, automated scenario creation, dynamic simulation environments, augmented assessment processes, and personalized feedback [1,12]. However, given the pace of AI evolution, existing literature does not adequately capture how AI is currently being used in simulation programs or how its

use is changing in real time.

Despite the benefits of AI [13-14], significant challenges persist. These include concerns about algorithmic bias stemming from skewed training data [15], ethical considerations about AI's role in education and learner development [16], and the need for faculty and staff preparation to competently implement AI tools [17]. Ensuring that AI enhances, rather than compromises, human-centered simulation pedagogy is critical. A comprehensive, updated survey is therefore needed to clarify the present landscape of AI use in simulation-based education and identify opportunities, gaps, and emerging trends [18-19].

Study contribution

This study provides one of the first empirical, field-wide examinations of how AI is currently being adopted, operationalized, and supported within healthcare simulation programs. It contributes 1) a contemporary overview of who is using AI and in what ways, 2) insights into the motivations, barriers, and workforce preparation associated with implementation, and 3) a foundation for directing future research and guiding strategic investment in AI-supported simulation-based education. By offering a data-driven perspective, this work advances understanding of AI's present impact and future potential in healthcare simulation.

Aims and objectives

This survey sought to explore the current use of AI for and in healthcare simulation. The aims of this study were to:

• Identify primary users of AI-driven healthcare simulation,

• Provide a picture of demographic trends over time,

• Examine the motivations driving healthcare simulation programs to adopt AI,

• Describe specific use cases,

• Analyze the diverse applications of AI in healthcare simulation,

• Analyze the modalities or types of AI-driven simulations being implemented, and

• Investigate the recruitment and training strategies for staff involved in creating and facilitating AI-driven healthcare simulations.

By addressing these questions, our findings may provide valuable insights into the current state and future potential of AI integration in healthcare simulation, contributing to adoption and advancements in AI-supported simulation-based education and practice. Additionally, our findings will identify key barriers and drivers to adoption in tandem with understanding the interest and perceived benefits of simulation users.

Materials And Methods

Study design

We employed a cross-sectional study design [20], utilizing 75 content-related and eight demographic questions.

Development and testing of questionnaire survey

The core team consisted of experts in healthcare simulation research and practice (JCP, MB, AP, AM, and ITG), with NDG as the survey design expert. They followed several steps systematically to create the survey [21]. This process ensures that the survey accurately measures what it intends to measure, addressing potential inconsistencies and improving reliability and validity through rigorous design and testing protocols [21].

The survey design emerged from discussions among the research team regarding AI in simulation that could help answer the research questions. The study questions were informed by parallel work initiated in an international simulation meeting in January 2024, concluding in June 2024. This work done in parallel explored current AI use, guiding principles for AI application, and relevant legislation, and the findings have been reported separately in a white paper [12]. The current study's survey questions were developed based on the synthesized knowledge from this exploratory phase. The draft survey was created and circulated to the research team, with items continuously refined.

We validated the survey both internally and externally. All authors, who have decades of simulation experience and substantial knowledge of AI, reviewed the survey questions for content and delivery. After integrating internal feedback, we sought input from three external AI scientists and data engineers. After their feedback was integrated, the survey was pilot-tested by six scholars with varying experience levels in healthcare simulation, nursing education, and medical education. Overall, the survey underwent multiple iterations, integrating input from the larger author group, MB and JCP, JCP and an AI scientist, MB and an AI scientist, and, finally, MB and four pilot testers.

Survey administration

Study data were collected and managed using Research Electronic Data Capture (REDCap) tools hosted at Massachusetts General Brigham (MGB) account for Massachusetts General Hospital (MGH) Institute of Health Professions Center of Excellence in Healthcare Simulation Research [22,23]. REDCap is a secure, web-based software platform designed to support data capture for research studies, providing 1) an intuitive interface for validated data capture; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for data integration and interoperability with external sources.

Due to its descriptive nature, the survey did not involve randomization of questions. Adaptive questioning was implemented to ensure that participants answered questions relevant to their experiences. The survey consisted of 83 questions in total, including 75 content-related and eight demographic questions, displayed two to eight per page. A completeness check was conducted before the survey was distributed to ensure response quality. Additionally, the survey included a glossary to define terminology used in the questions.

All questions were optional except for the first mandatory question: "Do you or your simulation center currently use AI in healthcare simulation?" Respondents who answered "no" to the question were directed to the last section of the survey, which was a brief demographics section as it was recommended by our survey expert to place demographics at the end of the survey, while those who answered "yes" were guided to the full survey. Each question included a non-response option, such as "not applicable" or "not sure," allowing participants to select an option that best matched their knowledge or experience. Many questions permitted participants to select more than one response. The survey design included a back button, enabling respondents to review and modify their answers throughout the survey.

Participation in the survey was voluntary, with no incentives offered, and respondents could choose to exit the survey at any time. The survey link was open for responses over a four-week period, from May 27, 2024, to June 23, 2024.

Ethical consideration

The study was performed under the MGH IHP REBEL Lab and received ethical clearance from Mass General Brigham (MGB; 2024P001216) and was deemed exempt from further IRB review by MGB. Participants were informed about the scope and aims of the research, the survey duration (approximately 15-20 minutes), the research team, data confidentiality, the scope of their participation, and their right to withdraw at any time. Participants confirmed their understanding before beginning the survey, and completion implied consent. Participation was anonymous, with optional questions about institutional affiliation to facilitate sorting responses from various simulation centers. The survey was hosted and the data stored on the RedCap online platform [22], accessible only to JCP and MB. Identifiable data in free-text responses were redacted prior to analysis.

Sampling and recruitment

The sampling criteria included individuals using AI applications within healthcare education, especially simulation. Utilizing established professional and online networks, the survey was distributed as an "open survey" to the healthcare simulation community. The survey link was disseminated widely across the internet, allowing anyone meeting the eligibility criteria to participate. To maximize reach, the survey was promoted through social media and reminders were periodically posted on social media and via email to ensure continued visibility and participation. The research team monitored geographic response rates in weekly meetings, and additional efforts were made to target underrepresented regions by encouraging simulation leaders in those areas to share the survey link via their networks. This inclusive approach ensured broad participation and diverse input from various stakeholders involved in AI and healthcare simulation.

Data analysis and management

Data were cleaned, compiled, and analyzed using REDCap [22] and R [24]. For all responses, we calculated descriptive statistics, reporting frequencies and/or proportions. As the results were presented as descriptive statistics and summaries of responses, incomplete survey responses were removed. Depending on the specific analysis, data from respondents who indicated that they did not use AI were or were not

included in the analysis; each finding indicates how the data was analyzed in this regard. Because we used an open survey design where anyone with access to the link could respond to the survey, we could not calculate an overall response rate.

Results

After analyzing the demographics, we analyzed and organized the survey results based on our research questions and presented the findings accordingly. All responses were included in this analysis; however, many respondents skipped questions throughout the survey. For this reason, we report each item of our results with the number of responses and response rate.

Demographics

We gathered data from 158 respondents from 12 countries (Table *1*). Participants identified themselves as belonging to the United States, India, Pakistan, Canada, Austria, Sri Lanka, the Netherlands, Bahrain, Saudi Arabia, Italy, Germany, and Belgium. Among respondents, 78 (49.4%) reported using AI in their simulation activities either at their program or personal level, 65 (41.1%) indicated they do not use AI, and 15 (9.5%) were unsure.

Demographic	Categories	Use AI (n=78)	Do Not Use AI (n=65)
Geography		(N=44)	(N=52)
	Austria	1	0
	Bahrain	0	2
	Belgium	0	1
	Canada	0	2
	Germany	1	0
	India	5	12
	Italy	1	0
	Netherlands	1	0
	Pakistan	1	1
	Saudi Arabia	1	0
	Sri Lanka	0	1
	United States	33	33

TABLE 1: Respondent Demographics

Demographic	Categories	Use AI (n=78)
Reported Roles of Participants		
	Educator	32 (67%)
	Simulation researcher	19 (40%)
	Simulation educator	18 (38%)
	Simulation program director/administrator	15 (31%)
	Simulation operations specialist/technician	6 (13%)
	Engineer	2 (4%)
	Standardized patient program director/administrator	2 (4%)
	Industry developer/sales	1 (2%)
	Other	6 (13%)
Profession		
	Nurses/nursing students	37 (79%)
	Advanced practice providers	24 (51%)
	Physicians/medical students	21 (45%)
	Allied health providers	20 (43%)
	Prehospital/emergency medical services	13 (28%)
	Child life specialists	12 (26%)
	Respiratory therapists	11 (23%)
	Occupational therapists	10 (21%)
	Pharmacists	10 (21%)
	Physical therapists	10 (21%)
	Social workers	10 (21%)
	Dentists/dental students	8 (17%)
	Other	8 (17%)
	Not sure	1 (2%)

TABLE 2: Respondent Roles and Professions

AI uses

Primary Users of AI in Simulation

See Table *2* for a description of the roles and professions for users of AI. The majority of respondents who reported using AI were healthcare educators (n=32, 66.7%), followed by simulation researchers (n=19, 39.6%), simulation educators (n=18, 37.5%), and simulation administrators (n=15, 31.3%). Seventy-nine percent (n=37) of respondents using AI were nurses or nursing students. Additionally, when asked “Who in your sim program is using AI?,” respondents indicated simulation educators/coordinators (n=29, 47.5%), researchers (n=24, 39.3%), program directors (n=16, 26.2%), curriculum developers (n=16, 26.2%), clinical educators (n=13, 21.3%), program directors/managers/administrators (n=16, 26.2%), and sim specialists/technicians (n=11, 18%) with some respondents indicating more than one role.

Most respondents stated that they do not partner with AI developers at this time (n=26, 55.3%), while 45% indicated that they do (n=21). When asked which professions were involved in AI activities, 43 respondents answered healthcare educators/trainers (n=28, 65.1%), clinical researchers (n=17, 39.5%), software developers/engineers (n=17, 39.5%), data scientists (n=13, 30.2%), ethicists (n=5, 11.6%), regulatory and compliance officers (n=1, 2.3%), healthcare administrators (n=4, 9.3%), instructional

designers (n=19, 44.2%), behavioral or cognitive scientists (n=5, 11.6%), and patient advocates (n=4, 9.3%).

Of those not currently using AI, the majority expressed interest in learning about it (Yes, n = 47, 95.9% versus No, n = 2, 4.1%). For people who responded "yes" to AI use by themselves or their centers, we collected several data points regarding personal use, particularly relating to observed impact in their productivity. For those who reported using AI, 68% (n=42) reported that it has changed the way they work, with a majority (n=25, 40%) reporting that it saves them 1-4 hours per week. Barriers for AI users included lack of expertise (n=40; 64.5%), integration with existing systems (n=36; 58.1%), budget constraints (n=16; 25.8%), and ethical concerns (n=18; 29%). Ethical concerns included privacy and data protection (n=37; 82.2%), bias and fairness issues (n=29; 64.4%), transparency and accountability (n=28; 62.2%), employment displacement (n=11; 24.4%), and autonomous decision-making (n=15; 33.3%).

AI Use Trends Over Time

The increased attention to AI in 2024 had little impact at a 49% adoption rate. Seventy-one percent of respondents plan to use AI in the future (see Table *3*).

	Used AI Before 2024	Use AI Now	Plan for Future Use of AI
Amount	n=59	n=59	n=52
Less than 50% sim sessions	55 (93.2%)	48 (81.4%)	
About 50% sim sessions	3 (5.1%)	5 (8.5%)	Yes = 37 (71.2%); No = 3 (5.8%); Undecided = 12 (23.1%)
More than 50% sim sessions	1 (1.7%)	6 (10.2%)	

TABLE 3: Trends of AI Use

Drivers for AI Adoption

Individual, leadership, and organizational drivers and reasons preventing adoption as identified by respondents are listed in Table *4*.

Item	Choices	N (%)
Drivers identified by respondents (n=63)	Improved efficiency	45 (71.4%)
	Enhanced learning outcomes	42 (66.7%)
	Cost savings	17 (27%)
	Competitive advantage	23 (36.5%)
	Other (respondents indicated: research projects, directives, personal interest)	13 (20.6%)
Leadership priorities identified by respondents (n=63)	Improved efficiency	34 (54%)
	Enhanced learning outcomes	35 (55.6%)
	Cost savings	22 (34.9%)
	Competitive advantage	23 (36.5%)
	Not certain it is a priority	17 (27%)
	Other (respondents indicated:policy, security, business	7 (11%)

	case)	
For those who do not use AI, reasons identified by respondents to prevent use (n=58)	Too complicated for me	5 (8.6%)
	No funding	12 (20.7%)
	I don't know where to start	32 (55.2%)
	Institutional barriers	10 (17.2%)
	Other (respondents indicated: leadership decision, lack of knowledge)	12 (20.7%)
For those whose programs do not use AI, reasons identified by respondents to prevent programmatic use (n=56)	Continued in-person training	15 (26.8%)
	Decision to pause sim training	2 (3.6%)
	Lack of access to technology to use AI	27 (48.2%)
	Lack of access to personnel with experience in AI	32 (57.1%)
	Lack of interest of learners in participating in AI sim	3 (5.4%)
	Lack of interest of instructors in using AI in sim	13 (23.2%)
	Lack of organizational support	20 (35.7%)
	Lack of programmatic support	20 (35.7%)
	Other (respondents indicated: leadership decision, lack of knowledge)	8 (14.3%)
	Not sure	3 (5.4%)

TABLE 4: Drivers for AI Adoption

Policies and procedures regarding AI

With global concerns regarding ethical use and bias in AI, we sought to explore both issues of bias, as well as policy use and creation.

Bias

The majority of respondents have not detected any potential bias (N = 48; Yes: n=17, 35.4%; No: n=31, 64.6%) or are aware of a mechanism to control/monitor bias (N = 48; Yes: n=15, 31.3%; No: n=33, 68.6%). Additionally, most respondents reported that there are no processes in place for transparency of data used for AI-based sim (N = 47; Yes: n=16, 34%; No: n=31, 66%).

Despite concerns reported in the previous section, only 25% of the respondents use policies governing the use of AI (N = 47; Yes: n=12, 25.5%; No: n=35, 74.5%). The majority of respondents have not yet established internal policies (n=46); however, a majority proportion (n=33, 72%) are considering their development.

Use cases

Applications of AI in Healthcare Simulation

Utilization of AI for specific tasks varied among participants. The use of AI in curriculum development, simulation scenario generation, equipment or technology development, feedback and assessment, and research and analysis for specific simulation tasks is presented in Table 5.

	Curriculum (N = 38)	Simulation scenario generation (N = 41)	Equipment or technology development (N = 29)	Feedback and assessment (N = 35)	Research and analysis (N = 34)
Manikin-based simulation	20 (53%)	24 (59%)	12 (41%)	15 (43%)	15 (44%)
Virtual patient simulations	10 (26%)	18 (44%)	7 (24%)	10 (29%)	9 (27%)
Standardized patient-based sim or OSCEs	12 (32%)	15 (37%)	4 (14%)	4 (11%)	5 (15%)
Emergency response or just-in-time training	5 (13%)	8 (20%)	3 (10%)	5 (14%)	4 (12%)
Clinical skills, task, surgical, or equipment training	11 (29%)	9 (22%)	4 (14%)	7 (20%)	6 (18%)
Communication skills or team training	16 (42%	17 (42%)	6 (21%)	15 (43%)	10 (29%)
Research	17 (45%)	13 (32%)	13 (45%)	14 (40%)	20 (59%)

TABLE 5: Applications of AI in Healthcare Simulation

OSCE, Observed Structured Clinical Examination

Modalities or Types of AI-Driven Simulations Being Implemented

Participants (N=58) are using various AI modalities in simulation practices. The most commonly used included large language models (LLMs) such as ChatGPT (n=44, 75.9%), image generation (n=26, 44.8%), creating presentations (n=18, 31%), building AI models (n=13, 22.4%), using AI-powered virtual reality/augmented reality (AR/VR; n=12, 20.7%) and intelligent tutoring systems (n=6, 10.3%), and others (n=7, 12.1%).

AI knowledge and training

Knowledge and Training Strategies for Staff

See Table 6 for a summary of the training and support for AI knowledge and skills reported by respondents. Survey results of training, whether knowledge or recruitment and consultation with experts, indicated that the majority of respondents possess limited to moderate knowledge of AI, with only 12% considering their knowledge extensive. Most users have not undergone formal training, with 63% reporting no AI training at all. Among those trained, self-education (83%) and informal training from experts (67%) were the most common methods. While 48% of respondents plan to train their staff in AI concepts, there is a strong demand for workshops (70%) and formal certifications (55%). Specifically, respondents expressed a desire for AI applications in AI-enhanced scenario generation (80%), automated performance assessment (76%), and more realistic virtual patients (66%). To support AI adoption, training and education (81%) were indicated to be critical needs, alongside funding opportunities (60%) and access to technical experts (62%).

Attributes	Choices	Responses as N (%)
Level of knowledge (self-reported) N = 68	None	3 (4%)
	Limited	30 (44%)
	Moderate	27 (40%)
	Extensive	8 (12%)
Have you been trained? N = 68	Yes	24 (35%)
	No	43 (63%)
	Not sure	1 (2%)
How have you been trained? N = 56	Self-trained	20 (83%)
	Informal training from other experts	16 (67%)
	Workshops	13 (54%)
	Formal certification/degree	6 (25%)
Are any peers around you undergoing training in AI? N = 66	Yes	16 (24%)
	No	23 (35%)
	Not sure	27 (41%)
Are you planning to train your staff in AI concepts? N = 21	Yes	10 (48%)
	No	0
	Not sure	11 (52%)
What kind of training do you wish you could have? N = 67	Informal from other experts	32 (48%)
	Workshops	47 (70%)
	Certification/degree	37 (55%)
What additional areas would you like to see AI applied in your sim center? N = 50	Enhanced scenario generation	40 (80%)
	More realistic virtual patients	33 (66%)
	Automated performance assessment	38 (76%)
	Personalized learning paths	29 (58%)
What support/resources would help your organization adopt AI more effectively? N = 48	Training and education	39 (81%)
	Funding opportunities	29 (60%)
	Collaboration with industry	23 (48%)
	Access to technical experts	30 (63%)

TABLE 6: Training and Support for AI Knowledge and Skills

Discussion

This study aimed to explore the impact of AI within healthcare simulation by examining the demographic trends, motivations, applications, and training strategies associated with AI adoption. The survey results reveal several key insights into the current state of AI integration in healthcare simulation.

Demographic trends and primary users

The analysis of demographic data highlights a diverse international representation, with respondents from 12 countries. However, the adoption of AI varies significantly across these regions. Nearly half of the respondents (49.4%) reported using AI in their simulation activities, while a notable portion (41.1%) did not engage with AI, and a small percentage (9.5%) were uncertain about their usage. For those who do not use AI, 57% (n=32) felt like the lack of access to personnel with experience in AI was the major reason

impeding on programmatic use. Also for those who do not use AI, 55% (n=32) surprisingly indicated "I don't know where to start" as the reason for not using AI versus feeling like it was "too complicated" (8.6%, n=5). This supports the findings in faculty technology adoption literature, where for the appropriate adoption of technology tools, it is important to understand how faculty perceive the integration of classroom technology tools [25]. The data suggest that healthcare educators, particularly nurses and nursing students, are the primary users of AI in simulation, constituting 79% of the AI-utilizing respondents. It would be worthy of understanding how other professions perceive the integration in AI to better understand how to combat challenges [25]. While this demographic trend indicates a growing global interest in AI among healthcare educators and researchers who recognize its potential to enhance simulation-based training and education, we do not yet understand to what extent and we can anticipate that this extent will evolve rapidly.

Drivers and barriers for AI adoption

The primary motivations driving AI adoption in healthcare simulation were reported to be improved efficiency and enhanced learning outcomes. These factors align strategically with the goals of simulation programs to optimize educational experiences and streamline operations, as supported by the literature [26-27]. Additional drivers include increased access to training and opportunities for collaboration with other stakeholders. Collaboration among various stakeholders is necessary for a meaningful AI adoption [12,28]. Generative AI enhances simulation-based learning by removing logistical barriers and offering cost-effective, scalable, and realistic practice opportunities that support authentic decision-making and reflective learning [29]. To facilitate more effective AI adoption, following the Responsible AI Maturity Model may help align strategic goals with simulation program objectives [28].

However, the survey identified several significant barriers to AI adoption. These include a lack of knowledge and expertise, as well as difficulties integrating AI with existing systems, with some respondents expressing uncertainty about where to start. This knowledge gap may explain why many simulationists have not developed policies governing AI use in their programs [1,12]. Budgetary constraints also pose a considerable challenge, limiting the ability to invest in AI technologies. Ethical concerns, particularly those related to privacy, bias, and transparency, further complicate the adoption process [12]. Interestingly, most respondents reported not detecting any bias in their AI applications, which may indicate a lack of awareness regarding AI's ethical implications rather than the absence of bias itself [1]. These findings highlight the need for targeted support, including AI education, policy development, and addressing financial and technical barriers, to overcome these barriers and enable broader AI adoption and maximize AI's impact on simulation practices in healthcare simulation programs [12].

Applications and modalities of AI in simulation

The survey reveals a wide range of AI applications in healthcare simulation, with the most common being the use of LLMs such as ChatGPT, image generation tools, and presentation creation software. Our findings align with existing literature [30-32], which identifies similar and additional applications of simulation, including scenario design, debriefing, and structured feedback, leading to improved outcomes [32]. The widespread adoption of these generative AI applications can be attributed to the democratization of tools like ChatGPT (OpenAI). These applications highlight AI's versatility in enhancing various aspects of simulation, from scenario generation to the development of AI-powered virtual and augmented reality experiences [12]. However, verification of the output from all AI applications is imperative [33].

An interesting finding, the relatively low adoption rates of more advanced AI technologies - such as intelligent tutoring systems, AI-driven virtual patients, and adaptive learning platforms - suggest that significant barriers remain. One key barrier may be the cost of these technologies, as many applications are placed behind paywalls or require substantial funding [33], and respondents identified budgetary constraints as a major challenge. Despite these limitations, intelligent tutoring systems, virtual patients, and adaptive learning hold significant potential to become the standard in healthcare education and simulation [1,12]. To fully realize the benefits of AI in healthcare simulation, further exploration, investment, and integration of these advanced technologies are necessary.

Recruitment and training strategies

The findings indicate a gap in AI knowledge and training among simulation staff, with a majority of respondents reporting limited to moderate levels of AI expertise. While some respondents have received informal training or self-education, formal training and certification are less common. This lack of comprehensive training is a critical issue, as it hinders the effective implementation and utilization of AI in simulation programs. The demand for workshops, certifications, and access to technical experts, also evident by all participants planning to train their staff in using AI applications, highlights the importance of developing robust training programs to equip staff with the necessary skills to leverage AI effectively. Particularly, open-ended responses to types of training included research, prompt design, simulation design, curriculum development, simulation operations, use in debriefing, programming, manikin

interactions, ethics, and possibilities. This also aligns with the need and recommendations for healthcare educators to promote AI literacy and adoption [33-36].

Strengths and limitations

One of the strengths of this study is the expert validation conducted for the survey before it was distributed to participants. This process helped refine the survey, ensuring clarity and relevance to our target audience. Email and social media were the predominant recruitment channels utilized. While social media facilitated broad outreach, it inherently restricted participation to individuals actively engaged on these platforms, introducing selection bias. Another notable limitation was the lower response rate from populations outside the United States, leading to suboptimal global representation among respondents. Although the survey was longer than intended, the multiple choice design provided clear, objective data that was easy for researchers to analyze and compare across respondents, which is a key strength. However, the length may have contributed to respondent fatigue, as fewer responses were evident toward the end. Additionally, the glossary was provided close to the beginning of the survey, and respondents may have unintentionally reverted to their own definitions that may have differed from those offered in the glossary.

Future directions

Based on this study, there are a number of future directions (see Table *7*).

Future Direction	Description
Training and Capacity Building in AI Literacy	Develop comprehensive AI training programs for healthcare educators and simulation staff, including certifications, workshops, and interdisciplinary learning opportunities.
AI's Role in Enhancing Learning Outcomes	Investigate how AI impacts learning outcomes in healthcare simulation, particularly in improving skills retention, critical thinking, and decision-making capabilities.
Development of Standardized AI Integration Frameworks	Establish frameworks or guidelines for the integration of AI into healthcare simulation, addressing ethical considerations, bias detection, and standardization of best practices.
Longitudinal Studies on AI Adoption Trends	Track AI adoption in healthcare simulation over time to understand how motivations, barriers, and applications evolve, particularly as technology becomes more accessible.
More Agile AI reporting and publishing mechanisms.	There is a need for rapid publication of work given the rapid advancements of AI. High-impact journals often have a lengthy review process, promoting pre-print processes and publications in less credible journals. A more agile knowledge dissemination process can support the building upon knowledge and creation of networks of researchers.
Expansion of AI Modalities in Simulation	Explore underutilized AI technologies such as intelligent tutoring systems, adaptive learning platforms, and AI-powered virtual patients, assessing their potential impact on healthcare training.
Global Comparative Studies	Investigate AI adoption and applications across different countries and healthcare systems to identify region-specific barriers and enablers, promoting more inclusive global AI strategies.
Interdisciplinary Collaborations for AI Development	Foster partnerships between healthcare educators, AI developers, ethicists, and policymakers to create more robust, human-centric AI tools that align with clinical and educational needs.
Exploration of Ethical and Bias-Related Implications	Conduct focused studies on how AI bias affects healthcare simulation outcomes and develop methodologies to mitigate these biases, particularly in diverse clinical settings.
Cost-Effectiveness and Efficiency Studies	Analyze the cost implications of integrating AI into simulation programs, evaluating both short-term investments and long-term efficiencies to inform budget allocation decisions.
Policy and Governance Research	Study the development and implementation of institutional policies on AI use in healthcare simulation, focusing on governance, transparency, and regulatory compliance.
User-Centered Design and Feedback Mechanisms	Explore AI applications that provide personalized feedback and support tailored learning paths in simulation-based education, enhancing learner engagement and performance.
Evaluation of AI in Diverse Healthcare Roles	Examine how AI impacts different healthcare professions beyond nursing, such as physicians, allied health providers, and EMS personnel, to broaden the scope of AI benefits.
Diffusion of Innovation and Responsible AI Models	Apply models like the Diffusion of Innovation or the Responsible AI Maturity Model to study AI's progression in healthcare simulation, providing structured insights on adoption patterns.
Simulation-Based Testing for AI Tools in Clinical Practice	Use healthcare simulation environments to test and refine AI tools intended for direct clinical application, ensuring their usability, safety, and effectiveness before deployment.

TABLE 7: Future Directions for AI Research in Healthcare Simulation

These directions can guide further research, enhance AI integration in healthcare simulation, and ensure

ethical, efficient, and effective educational outcomes.

Conclusions

The results of this study provide valuable insights into the current landscape of AI adoption in healthcare simulation. While there is a clear interest and initial uptake of AI technologies, significant challenges remain, particularly in the areas of expertise, training, and ethical considerations. To fully realize the potential of AI in healthcare simulation, it is crucial to address these barriers through targeted training, resource allocation, and the development of policies that ensure ethical and effective AI use. Future research should focus on frequent short-turn-over studies as new technology emerges, as well as longitudinal studies to track the evolution of AI adoption and its impact on healthcare simulation outcomes.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. Mass General Brigham issued approval 2024P001216. Protocol #: 2024P001216 Date: To: From: Title of Protocol: Version/Number: Version Date: IRB Review Type: IRB Approval Date: Next Review: IRB Expiration Date: May 16, 2024 Palaganas, Janice, Ph.D, MSN IHP Mass General Brigham > IHP > School of Health Leadership Mass General Brigham IRB 399 Revolution Drive, Suite 710 Somerville, MA 02145 Exploring Generative Artificial Intelligence Use in Healthcare Simulation: A Survey to Guide the Way Forward v1 05/01/2024 Expedited 05/16/2024 Exempt Check In 05/16/2027 IRB Review Action: Exempt The IRB has determined that this project meets the criteria for exemption 45 CFR 46.104(d)(#). EXEMPTION (2) Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least ONE of the following criteria is met: (i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects; (ii) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or ANCILLARY COMMITTEES 1. MCA (MGB): Review not needed. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** Amar Patel declare(s) personal fees from CHESI LLC. Maria Bajwa, Amar Patel, Alex Morton, Janice Palaganas, and Isabel Gross declare(s) non-financial support from Cureus Journal, AI Healthcare Simulation Collaborative. Non-financial relationships: Maria Bajwa, Amar Patel, Alex Morton, Janice Palaganas, and Isabel Gross are the Founding Members of the AI Simulation Healthcare Collaborative. All authors declare non-financial support from AI Simulation Healthcare Collaborative and that all authors have served as invited speakers. Other relationships: All authors have declared that no other relationships or activities could appear to have influenced the submitted work. The AI Simulation Healthcare Collaborative is a legal entity listed as CHESI LLC dba AI Simulation Healthcare Collaborative. This Channel works through the CHESI LLC dba AI Simulation Healthcare Collaborative. This company also owns Power of One Consulting and employs Amar Patel. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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