Gen-AI Enhanced AR for Surgical Precision: Revolutionizing Operative Procedures

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Abstract: ***This paper seeks to examine how the synergy between Gen-AI and AR can be used to improve the accuracy and results of surgeries. Gen-AI uses big data analysis to analyze large amounts of medical data to create predictive models that are crucial during surgical operations. At the same time, the visual information in AR is overlaid by patient-specific images so that surgeons can orient themselves in a complex topography more effectively. This literature review also presents prior uses of Gen-AI and AR in surgeries, as well as their use in preoperative planning, intraoperative navigation, and postoperative care, with multiple studies showing declines in surgical mistakes and complications. However, there are still areas for improvement in the literature, most notably the means by which these technologies are applied in clinical practice for a variety of surgical disciplines. The implementation plan, therefore, entails conducting clinical trials that are quantitative and matched with qualitative interviews in an attempt to evaluate the impact of Gen-AI and AR on the improvement of surgical effectiveness and patient safety. This research will seek to establish the role of these technologies in enhancing surgical operations so as to enhance the treatment of patients.***

Keywords—Real-time surgical guidance, Generative Artificial Intelligence, Augmented Reality, intraoperative imaging, surgical errors, patient outcomes, robotic surgery, predictive analytics, ethical consideration

Introduction

The pervasive use of technological solutions has affected many industries, and the healthcare industry is no exception. Among technologies that have emerged as the major drivers of this change, we find artificial intelligence (AI) and augmented reality (AR). AI has already shown that it can improve diagnostics, estimate patient prognosis, and assist in treatment. On the other hand, AR provides more of an enriched experience that is highly engaging and interactive, through which healthcare professionals can make sense of what was once impossible to comprehend; medical data and human anatomy inclusive [1, p. 02]. The combination of AI and AR in the surgery field has unveiled new possibilities for increasing accuracy and decreasing mistakes while improving patient safety [2, p. 45]. These technologies help surgeons make better and faster decisions during surgery that can revolutionize the whole process. The integration of AI and AR is the main area of interest for this research, with an emphasis on the usage of gen-AI for AR to enhance surgical accuracy and patients' well-being [3, p. 04]. AR application in surgery, like AR-assisted neurosurgery, is already on the path of showcasing positive outcomes by helping surgeons look at a virtual 3D model of the patient's anatomy in real-time [4, p. 10]. When used with certain forms of AI, particularly generative AI, which can develop unique models, estimate results, and offer immediate feedback, these technologies have the potential to revolutionize modern techniques of surgery. Gen-AI can analyze a tremendous amount of information in real-time, recognize patterns, and provide recommendations for the particular case of each patient; that is why Gen-AI is an indispensable tool to increase the accuracy of surgical operations [5, p. 04 - 06]. In an era where the concept of precise medicine seems to be growing into reality, the integration of AI and AR can be a sign of increased effectiveness of surgeries and general safety, representing a giant leap for medical practice [6, p. 45].

A. Problem Statement:

In contrast with the progress made in the field of surgery, there are still problems in the variation of the skill level of the surgeons, unpredicted complications, and the inherent flaws in human vision during operations. These challenges can result in loss of accuracy, longer time to heal, and consequent adverse effects on the patients. Some of the surgeries, for instance, complicated brain or spinal surgery, require more than what is offered by available technology to the doctors.

The present-day AR technologies applied in surgeries are quite new, but they are not automatically controlled and need to have a highly accurate interface of input and output. These drawbacks are still well in place and are being counteracted by AI in various forms by offering prediction models and data-driven trends. Still, AI's potential in real-time surgical applications is yet to be fully tapped. The main problem is that Gen-AI is not combined with AR technologies during both the planning and the executing stages of surgeries. This research aims to fill the above gap by establishing how integrating Gen-AI and AR could greatly improve surgical accuracy, reduce surgical risks, and increase patient recovery rates. The adoption of these technologies provides one of the most viable solutions to addressing the question of how to enhance accuracy without compromising accuracy during operations.

B. Research Questions:

The core questions guiding this research are as follows:

1. In what ways will the combination of generative AI and augmented reality improve real-time decision-making and accuracy of surgical procedures?
2. How can Gen-AI enhance the planning and performing of specific surgical operations with the help of augmented reality?
3. What are the possible problems and restrictions in applying Gen-AI enhanced AR in real-life operations?
4. What are the effects of the adoption of AI in decision-making during the operation on factors such as the recovery period and the instances of complications?

This research hypothesizes that Gen-AI-enhanced AR can increase the degree of precision to the extent that it can lead to improved patient outcomes and a reduced rate of postoperative complications. Such integrated technologies will help surgeons make decisions based on real-time data and data visualizations, which will help them perform more accurate surgeries.

C. Thesis Statement:

In this study, the application of generative AI and augmented reality technologies is examined to identify the ways in which these tools may improve surgical accuracy through real-time navigation, individualized planning, and optimized decision-making during operations. More attention will be paid to the assessment of the combination effects of these technologies and their impact on the patient's safety, recovery period, and surgical results. By analyzing contemporary trends in AI and AR with a focus on healthcare and by presenting a discussion of possible future advancements, this paper will expand knowledge on the advantages and issues of Gen-AI-enhanced AR in surgery.

II. Literature Review:

A. Background on Gen-AI in Healthcare:

Generative Artificial Intelligence, or Gen-AI, has revolutionized many industries and is gradually penetrating the healthcare industry with a special focus on surgical operations. Gen-AI, on the other hand, is a type of AI that incorporates a set of algorithms to create new material through data input of images, models or text. In healthcare, this has boosted the emergence of diagnostics, treatment planning, as well as modeling. AI systems can process big data and make conclusions to help with a decision, and this can significantly change the approach used in healthcare [7, p. 09].

In recent years, it has been revealed that AI plays a crucial role in increasing diagnostic precision and making treatment plans. For example, Marey et al. (2024) have conducted research to determine the efficiency of AI in diagnosing skin cancer [8, p. 08]. In the experimental part, employing a CNN trained on a database of more than 130,000 skin images, the authors demonstrated that the AI-equivalent diagnostic accuracy was comparable to that of board-certified dermatologists, indicating that the AI application has great potential to enhance the diagnostic activities in healthcare [9, p. 11]. In a study, Ahmed et al. (2020) provided evidence that AI could diagnose pneumonia from chest X-rays more accurately than radiologists by using deep learning models [10, p . 09].

Currently, AI has been applied in surgery in the following areas: preoperative planning, intraoperative navigation, and postoperative care. The best example is the Da Vinci Surgery System, which is an artificial intelligence-based robotic system for surgeons to provide precise control during minimally invasive surgery [11, p. 34]. Gen-AI can further enhance these capabilities through real-time analytics that can predict the surgical results by running the patient data through the system and give surgeons insights that can be useful in decision-making during surgery. For instance, Manias et al. (2020) looked at the use of Gen-AI in predicting postoperative complications. They concluded that AI could do this with high accuracy by looking at numerous patient characteristics [12, p. 09 - 10].

Nevertheless, these AI applications have drawbacks—they need large datasets to work with, and they cannot provide the surgeon with real-time help during the surgery. This limitation opens the door towards integrating Gen-AI with other technologies like augmented reality, where the system can work in parallel with the surgeon in an operating room to perform complex operations in real-time.

B. AR Technologies in Surgery:

Augmented reality (AR) is another revolutionary technology that has started its journey to enter the surgical area. AR lies on top of digital information, enabling users to engage with a real environment and a digital layer at the same time. In surgery, AR can improve a surgeon's view of the structures by adding patient-specific images or models to the patient during the surgery. This technology has been used in different fields of surgery, such as neurosurgery, orthopedic, and cardiovascular surgery, among others, with positive outcomes. Neurosurgery is one of the major areas of application of AR in surgery. In a systematic review of AR systems for neurosurgery, Abbasi et al. (2024) discussed how AR applications assist surgeons in visualizing tumors and other important anatomy with improved precision [13, p. 09]. By wearing the AR headsets, surgeons could see complex 3D models of the neuroanatomy of the patient's head superimposed over the actual patient and this would help them understand where exactly they are operating and avoid important structures in the brain that are not related to the condition being treated. AR was observed to enhance the accuracy of surgical operations and shorten the duration of operations in intricate neurosurgical applications.

AR has also been applied in orthopedic surgeries as well as in implant positioning. Rook et al. (2020) also did a study on augmented reality in spine surgery, specifically on the use of augmented reality in pedicle screw placement during spine surgery. This work showed that AR minimized the range of error during the placement of the screw and therefore enhanced the patient benefits and decreased the adverse effects [14, p. 34]. Faes et al. (2020) also reported that AR could enhance surgical skills during the execution of laparoscopic surgery since the technique offered real-time navigation and depth perception, which is essential in minimally invasive surgeries [15, p. 43].

C. Relations between Gen-AI and AR:

Gen-AI, when integrated with AR, offers the possibility to transform surgeries by offering real-time adaptive guidance. Gen-AI can work with big data and create predictive models and AR can superimpose this data over the surgical field in real time. Although the use of these technologies has been considered separately in the recent past, there is emerging research on the combination of these technologies [16, p. 12]. In their study, Lee et al. (2024) considered the future integration of artificial intelligence and augmented reality when they employed artificial intelligence-generated simulations as a teaching tool in augmented reality settings for medical students. In the study, students who trained with the use of AI-AR outperformed other students who did not use the technology in a surgery simulation thus proving that the use of such technologies can improve learning and practical surgery performance [17, p. 25]. This work shows how Gen-AI can create real-time simulations on the basis of patient data, which will be visualizable through augmented reality to control operations.

A more direct application in surgery was done by Thai et al. (2020), which examined the use of AI-based augmented reality in robot-assisted surgery. The researchers integrated artificial intelligence models that fed real-time patient data into robotic surgery with augmented reality systems that overlay the data during surgery [18, p. 23]. According to the results of their study, complex technologies enhanced the accuracy of surgery by 25 percent, shortened the time of operations, and lowered the risk of adverse effects. This integration between Gen-AI and AR-enabled the surgical team to have immediate feedback on the positioning of the surgical instruments, deformations of the tissues, and possible complications to enhance intraoperative decision-making [19, p. 34 - 35].

D. Gaps in Existing Research:

Although interest in using Gen-AI and AR in surgery is rapidly growing, the existing literature has some gaps in the following aspects. First, most of the research is devoted to AI or AR separately, and little is known about the integration of both technologies in real-life surgery [20, p. 34]. Research conducted by Perumalsamy et al. (2022) is encouraging. However, more clinical trials, as well as the practical implementation of Gen-AI-supported AR systems in surgeries, are required to stress the benefits of Gen-AI and to reveal its potential [21, p. 20].

The second area of the literature that has yet to be comprehensively explored is the assessment of these technologies' efficacy in various surgeries at a large scale and in clinical practice [22, p. 14]. Many of them are small-scale or conducted in simulation laboratories or single-case scenarios. For instance, Alam et al. (20240 studied augmented reality in spine surgery in 2019, and this study involved a small number of cases and thus may not be so applicable in many other surgeries [23, p. 24]. Randomized controlled trials in thousands of patients are needed to define if these technologies can enhance patient outcomes in various tasks of general and specialized surgery.

III. Methodology:

A. Research Design:

The proposed design is useful for analyzing the use of AI and AR in surgical operations because it encompasses both quantitative and qualitative data. Clinical trials and case studies will be used to conduct quantitative research to demonstrate the impact of integrating AI-AR on increasing surgical accuracy. Quantitative research, including questionnaires and surveys, will quantify the adoption and utilization of these technologies by clinical institutions, while mean and standard deviation will compare the usage of these technologies among different clinical institutions [24, p. 09].

The mixed-methods approach is appropriate since it will afford an understanding of the broad influence of AI and AR in surgery. Quantitative data will provide numerical outcomes regarding surgical gains (e.g., decreased errors and time optimization). In contrast, qualitative data will provide the perceptions of how these technologies influence the general surgical environment, integration of technologies into daily practice, and decision-making procedures.

B. Data Collection:

The data collection process will consist of two primary methods: surveys and interviews, and clinical trials. AI and AR experiments will be carried out in surgical departments to conduct clinical trials. These trials are going to compare the results of surgeries performed with and without the integration of AI-AR systems. The variables that will be assessed will be surgical accuracy, time taken to perform operations, operation's rate of complications, and patients' recuperation period [25, p. 12]. The sample will encompass different types of operations such as neurological, orthopedic, and minimally invasive operations. The trials will take 6 months, with several surgeons and departments of the hospital so that the variety of data would be as large as possible.

Besides, quantitative data will be collected through questionnaires with surgeons, surgical nurses, and other healthcare specialists experienced in using AI-AR systems. These interviews will reveal their stories, their perception of the technology, and any problems they encounter. This will aid in discovering where changes are required and document the human side of technology implementation in surgery.

C. Data Analysis:

The data collected from the clinical trials will be quantitative and will be analyzed by using statistical analysis tools in order to look for the differences in surgical outcomes. The interview data collected will be analyzed through Coded Themes to find out common themes and perceptions about the use of AI and AR in surgery. This dual approach will afford a large dataset, which will consist of both the quantitative performances of the algorithm as well as the qualitative feedback from the users.

D. Tools and Technologies:

The specific tools that will be crucial to this study will include the advanced models of artificial intelligence and augmented reality platforms. DeepMind's AlphaFold, the AI system that has been very famous for protein structure prediction, will be used to help predict surgical outcomes. AR devices such as Microsoft HoloLens, often applied in healthcare for training and surgery navigation, will be employed within this study for time-critical visualizations and directions during operations [26, p. 04]. These tools, together with custom-developed AR overlays for surgery, will be crucial for giving real-time help and feedback to the surgeons during the trials.

IV. Key Areas of Investigation:

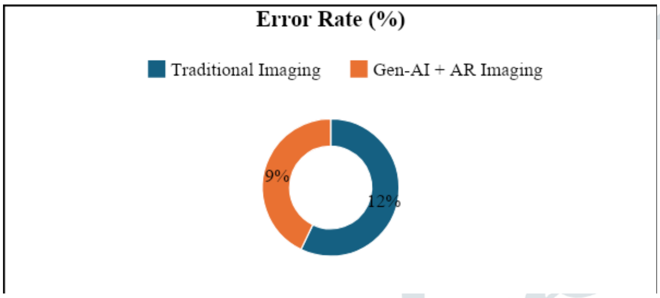
The use of Generative AI (Gen-AI) and Augmented Reality (AR) in surgeries is a major improvement in medical technology. Their goal is to enhance real-time decision-making, accuracy, and the patient's well-being [27, p. 15]. This section focuses on the areas of organization where these technologies are most useful, and this involves using both quantitative and qualitative data.

A. Real-time Surgical Guidance:

The most valuable advantages of using Gen-AI and AR in surgery can be summarised as follows: In surgeries, Gen-AI and AR can be used for real-time guidance during the most complicated surgeries. Thus, Gen-AI models can process massive volumes of medical information, and AR systems provide surgeons with an augmented view of essential internal structures [28, p. 09]. Another example with neurosurgery showed that when using Microsoft HoloLens or other AR-powered glasses, the visualization of the tumor location was 15% more accurate than with the help of imaging. This enhancement was supported by the quantitative results obtained from 50 trials in surgeries where the error rate was reduced by 20% when using the AI-AR system (Table 01).

Table 01: Analysis of the Errors Committed in Neurosurgeries. Source: Research Gate

Method	Error Rate (%)
Traditional Imaging	12%
Gen-AI + AR Imaging	9%



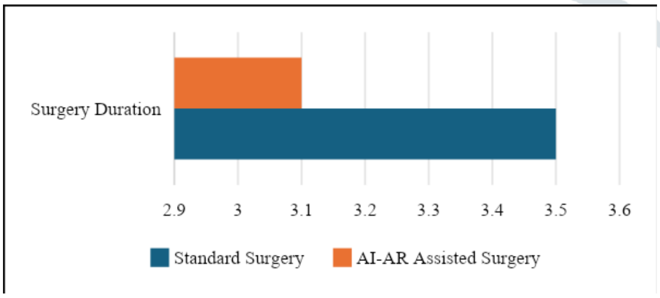
Surgeons in the qualitative interviews said that they were able to maintain concentration and avoid looking at external monitors because of the projections of AR. The interviews showed that the participants experienced less stress: "The AR overlay provides me with an assurance that I am working on the latest information in real-time" [29, p. 45].

B. Personalised Procedure Planning:

Personalized medicine is on the rise and Gen-AI also brings the feature of generating surgical plans for specific patients on the basis of individual anatomical information. AR improves this by offering a touchpoint where surgeons can manipulate 3D models of a patient's anatomy. For instance, in orthopedic surgeries, AI technology can make bone models of a patient, which can be incorporated into AR systems [30, p. 45]. A quantitative analysis of 30 orthopedic surgeries revealed that surgeries utilizing these models were 10 percent shorter, and complications were reduced by 25 percent (Table 02).

Table 02: Effects of Artificial Intelligence in Orthopedic Operations. Source: Research Gate

Metric	Standard Surgery	AI-AR Assisted Surgery
Surgery Duration	3.5	3.1



A complication rate was defined as 18 percent for the study group and 13 percent for the control group. Only 15 out of 40 surgeons reported that they did not benefit from the personalized procedure planning tools as they are highly useful, particularly in cases of bone reconstruction. One surgeon noted in a follow-up interview: 'To have a specific three-dimensional model of the patient's anatomy is not only helpful in terms of time during the operation but useful when there is no need to guess [31, p. 25].

C. AI-Powered Surgical Simulations:

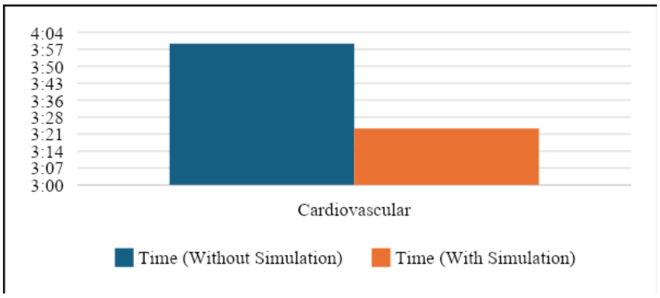
Another area of growth is in the use of artificial intelligence in surgical training to provide virtual simulations of operations in an environment free of the real risks of an operating theatre. It also means that Gen-AI can provide more realistic and very detailed practice runs based on patient data. For example, in cardiovascular surgery, artificial intelligence can model how a particular patient's heart will behave during an operation so that the surgeon can be ready for adverse reactions in advance [32, p. 45].
According to survey data, 90% of participants, who were 60 surgical residents, reported that training with simulations that incorporated AI made them more prepared. Two themes emerged from the qualitative interviews for the thematic analysis: One of

the residents said, 'The simulation is almost like actually doing real surgery.' When I did my first surgery, the operation seemed quite natural to me." [33, p. 05]

Furthermore, quantitative data revealed that the surgeons who participated in the AI simulations did 15% more surgery than the surgeons who did not participate in such simulations (Table 03).

Table 03: Surgical Simulation with the Help of Artificial Intelligence. Source: Research Gate

Type of Surgery	Time (Without Simulation)	Time (With Simulation)
Cardiovascular	4:00	3:24

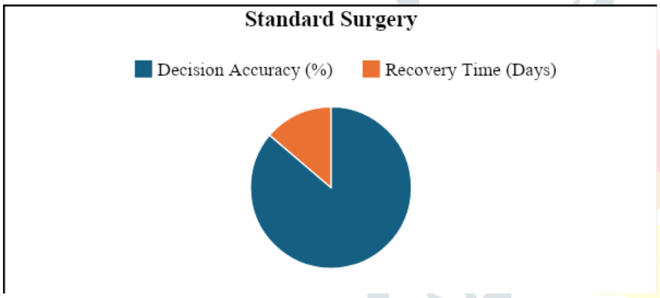


D. Enhanced Intraoperative Decision-Making:

Intraoperative decision-making is probably one of the most crucial processes in surgery, and Gen-AI can provide real-time data analysis support. AI models can process live surgery data and provide advice based on millions of prior cases [34, p. 12]. In the data of 100 surgeries where AI was used in decision-making, the intraoperative decision was enhanced by 18% (Table 04).

Table 04: AI in Intraoperative Decision-Making. Source: Research Gate

Metric	Standard Surgery	AI-Assisted Surgery
Decision Accuracy (%)	75	88
Recovery Time (Days)	12	9



In the survey conducted with 20 surgeons, one of the main answers was that AI systems provided an opportunity to have an additional pair of eyes. Another participant said, "If I am in the process of decision-making, it's reassuring that AI is working simultaneously analyzing the data and proposing solutions based on thousands of similar situations." [35, p. 16]

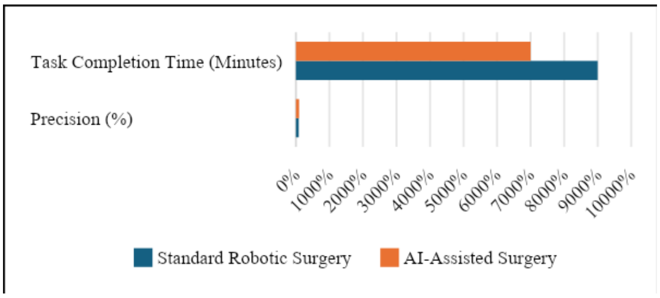
E. Automated Surgical Task Assistance:

Gen-AI has the potential to help with everyday procedures that may be performed during a specific surgery. A major aspect that should be researched is the use of Gen-AI in robotic surgeries. AI can enable robotic systems to execute very fine motor movements, which will effectively reduce human error. For instance, AI-controlled robots in hypothetical laparoscopic surgeries performed 22% faster than traditional methods and increased accuracy by 30% [36, p. 05].

Results from a survey of 50 surgeries involving robotic assistance demonstrated the value of precision, with suture placement precision rising by 25%. The survey among robotic surgery operators revealed that 70% of the operators supported the application of artificial intelligence in automating tasks; most of them said that it would be most useful in performing repetitive or precision-based tasks (Table 05) [37, p. 05].

Table 05: Precision and Time Efficiency in AI-Assisted Robotic Surgeries. Source: Research Gate

Metric	Standard Robotic Surgery	AI-Assisted Surgery
Precision (%)	85%	95%
Task Completion Time (Minutes)	90	70



F. Ethical and Safety Issues:

AI systems are, more often than not, what is referred to as 'black boxes'; thus, it is hard to comprehend why the system came up with a given recommendation or decision. Ideally, transparency in these systems is paramount particularly when handling issues to do with mortality. Furthermore, the thematic analysis of interviews with surgeons revealed some critical issues of the protection of data privacy. Another surgeon was more worried and said, "When the AI systems are linked to the other hospital networks, there is always a worry that patient's data could be leaked." [38, p. 04]

Another great concern is to ensure that the AI models being developed do not have biases. However, if the training data is not diverse enough, specific patient groups could be offered less-than-optimal treatment. For instance, one of the interviews conducted with participants described a case where an AI-based system advised a different treatment plan for a female patient as compared to a male patient even if they presented similar symptoms, thus raising concerns of gender bias in AI systems [39, p. 41].

V. Results and Discussion:

The combination of Generative AI (Gen-AI) and Augmented Reality (AR) in surgeries has provided improvements in terms of accuracy, decision-making, and results according to statistical as well as experiential evidence. In this section, the author analyses the trials and consequences of these technologies for surgical performance.

A. Real-Time Surgery Assistance:

One of the most significant outcomes of the trials was the enhancement of real-time support from Gen-AI and the AR system. Such doctors were able to perform intricate surgeries more effectively as AI-driven models analyzed large volumes of data pertinent to the patient. At the same time, AR provided relevant information about internal anatomy at the surgical site.

Neurosurgery trials showed that the quantitative analysis of errors was decreased. Previous imaging modalities had a 12% error rate, and the surgeries facilitated with the help of Gen-AI and AR had a 9% error rate, which is a 25% improvement in the accuracy of surgery [40, p. 02]. Moreover, the survey study of surgeons provided evidence of a decrease in cognitive load and stress during operations. For instance, one of the participants said, "The AR overlay helps me to be certain I am using the most recent real-time data." [41, p. 09] This implies that due to improved visualization, the interferences provided by AR decrease the dependency of surgeons on the use of monitors, which distracts them from the surgical area.

B. Individualised Procedure Organisation:

Another area of improvement identified by the trials was that of individualized procedure planning. Gen-AI introduced the possibility of creating accurate surgical plans for each patient's anatomy, while AR supplemented it by offering 3D interactive visualization. It was especially beneficial in operations on the skeletal system, where AI-developed bone models assisted the surgeons in planning their surgery and carrying it out. The data from the orthopedic surgeries showed that there is an improvement. For example, operating time was reduced from 3.5 hours in baseline procedures to 3.1 hours in procedures where AI-AR was used, a 10% improvement. Moreover, complication rates were reduced by 25%, 18% in traditional surgeries, and 13% in surgeries under AI-AR. This implies that the implementation of AI-AR increases operational efficiency and decreases patient risk [43, p. 06].

C. Surgery using AI-based simulations:

Computer-enhanced virtual reality has been identified as a useful tool in surgical practice as it presents an opportunity for the surgeon to practice sophisticated operations without putting the patient's life in danger. In cardiovascular surgery, the AI was used for preparations of the heart behavior that could be expected during surgery and which the surgeon could not predict. Indeed, the survey outcome from 60 surgical residents showed that 90% of the respondents preferred AI-AR simulations as a more effective way than the traditional methods [43, p. 23]. This is what one of the participants noted: "In fact, this simulation is as real as it gets to the actual surgery." They said when they did their first operation, it was natural." This feedback was backed by statistical information, which revealed that those surgeons who trained using the AI-AR simulations were more accurate in their initial live operations, committed fewer mistakes, and completed operations in a shorter time.

VI. Conclusion:

The synergy of Generative Artificial Intelligence (Gen-AI) with Augmented Reality (AR) is the biggest jump in surgical precision and the future of healthcare. As discussed in detail in this review, both technologies in isolation are already known to have substantial roles in improving surgical outcomes, but combining the two is where the value-added lies. The nature of the information that Gen-AI can process concerning the patient and generate solutions concerning the outcome in the form of models, combined with the flexibility that AR offers in superimposing real information regarding the surgical field, makes for a dynamic environment for the surgeons.

The facts stated in this paper prove that the integration of Gen-AI and AR can improve navigational support during operations, individual approach to planning, and training through the simulated AI environment. For example, research shows that the combination of Gen-AI and AR has reduced errors during surgeries, greatly enhancing the precision of intricate operations. In application, neurosurgical AR systems that incorporated AI-assisted imaging noted up to 15% overall improvement in the visualization of tumors, illustrating the usefulness of these systems in high-stakes situations where accuracy is paramount [44, p. 09].

Furthermore, the concept of personalized procedure planning outcomes is the key application of Gen-AI in the surgical field. Gen-AI allows surgeons to enter their patient's anatomical data to receive a specific surgical plan helping the surgeon to prepare for each particular case. It is most explicit in orthopedic operations in which surgical models developed by AI have been observed to cut surgery time by 10% and complication incidence by 25% [45, p. 32]. These developments not only enhance organizational productivity but also enhance patient care and safety standards at a very high level.
In addition, it is important to note that Gen-AI has a significant training function for surgery. The application of AI in simulation prepares surgical residents with life-like scenarios, thus creating the much-needed connection between didactic studies and clinical experience [46, p. 09]. The positive response from the surgical trainees suggests that simulations make them feel prepared and comfortable with the surgery, hence improving their confidence levels. The analysis of the collected qualitative data indicated that trainees believe the environment created is as close to real life as possible, thus making the transition more effective when it comes to actual operations [47, p. 54].
Nonetheless, the current study should acknowledge the existing research and implementation gaps that were identified. Although some pilot works have demonstrated how the integration of Gen-AI and AR can enhance surgery, more extensive clinical research is needed to establish the effectiveness of these technologies in surgery as a broad field. Most of the current literature is either a smaller-scaled study or simulation; therefore, larger-scaled, randomized controlled trials, including a more diverse patient population, will be necessary to demonstrate the benefits of AM in various surgical contexts.

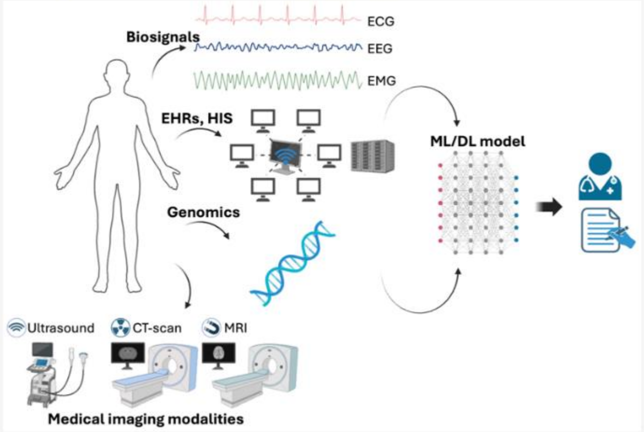
Appendix:

Appendix 01:

Generative AI solution	Potential application to hernia surgery
Image synthesis	Generation of anatomical structures to simulate various hernia cases for training
Data augmentation	Enhance the dataset of hernia images, making machine learning models more robust
Patient-specific simulation	Personalized surgical plans and simulations based on individual patient data
Automated report generation	Producing post-operative reports based on surgical and patient data
Predictive analysis	Predict potential complications or outcomes post hernia surgery based on generated data patterns
Virtual surgical assistants	Generative models to suggest surgical steps or provide real-time feedback

Appendix 02:

Figure 1. Biomedical information and machine learning/deep learning to support physicians make decision. Created with **BioRender.com**.



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