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Review Article

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The Power of Artificial Intelligence in Surgery: A Systematic Review

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Abstract

Background: Artificial intelligence (AI) in surgery has evolved significantly improving surgeon's cognitive capabilities. Natural Language Processing (NLP), Machine Learning (ML) and Computer Vision (CV) are some technologies utilized for effective training and surgical outcomes. Aim and Objective: The primary aim of the study was to answer the question: "How far AI is helping a surgeon to demonstrate his skills in teaching in future?". Methods: Fourteen studies dealing with AI applications in surgery were selected from Pubmed, Embase and Scopus for the period 2016 to 2024 and were analysed by throwing light on various techniques and their accuracy in surgical skill evaluation affecting outcomes for patients and impacting surgical education. Results: The overall accuracy percentage for the role of AI in skill evaluation and training for surgery was 91.26%. ML and DL (Deep Learning) techniques showed promising results in improving intraoperative guidance and surgical training. Conclusion: Challenges like availability of data, ethical considerations and robust validation need remain to linger. AI has revolutionized surgery with provision of enhanced support for decision with better training outcomes by enabling surgical actions autonomous in nature. There is a need for the community of surgeons to embrace AI technologies in future keeping associated challenges in mind and ensuring patient safety with much emphasis on treatment strategies.

Keywords: ***Artificial Intelligence, Surgery, Machine learning, Deep learning, Natural language processing, Computer vision, Surgical skill assessment, Surgical training.***

Introduction

Artificial Intelligence (AI) nowadays is transforming the field of surgery especially in training and skill evaluation (Iftikhar M et al, 2024). The more complex the surgeries become, the need for extremely skilled surgeons arises. Conventional techniques of training are outdated due to over-reliance on subjective evaluation. The data-driven insights by AI technology excels in performance. To enhance performance metrics, technologies such as deep learning and machine learning algorithms are most commonly utilized. AI offers real time decisions, precision and targeted training approaches and objective assessment using advanced stimulation interventions (Saravi B et al, 2022). Augmented reality (AR) and virtual reality (VR) help trainees improve their skills in risk free environment. AI-driven simulations help the trainees in complex surgical circumstances in development of skills related to decision making providing technical proficiency along with the emergence of robotic surgery (Moglia A et al, 2021). It interprets historical information for prediction of outcomes. However, it has its own challenges in surgical training such as algorithmic bias and breach of data. Finally, AI developers should collaborate with surgeons to develop tools that are user friendly, ensure patient safety and lend effective outcomes. The aim of the study is to review past literature on ML, DL, NLP and CV and its accuracy to promote the use of AI in future in skill training and evaluation among surgeons and trainees to overcome current obstacles in the field of surgery.

Methodology

This systematic review and meta-analyses followed the Preferred Reporting Item for Systematic Review and Meta-Analyses (PRISMA) guidelines (Figure 1) (Page MJ et al, 2020). The risk of bias was analysed (Figure 2)

Literature search

A comprehensive literature search was done to find out studies published between 2016 to 2024 on the role of AI in surgery and accuracy. Electronic database search was done in PubMed, Scopus and Embase using the keywords "Artificial Intelligence", "Surgery", "Training and Skill Assessment" and "Accuracy".

Inclusion criteria

- Cases available with complete data for the role of AI techniques (ML, DL, NLP and CV) in training and skill assessment in surgical practices
- Published in English
- Studies with quantitative data on AI accuracy in surgery and area under curve reported percentage

Exclusion criteria

- Case series, reports
- Studies not reporting AI technologies

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- Studies that comprised of non-surgical AI applications in various other fields of health sciences
- Studies published before 2016

No ethical approval was required since the study conducted was a review and did not include any patient data. Fourteen studies from 2016 to 2024 were selected from various databases and analyzed.

Data extraction and analyses

The eligibility of the article based on criteria search was completed by 2 authors (A.S and S.H) and the full text of the studies was analysed by using Microsoft Excel 2016. The two authors assessed the methodology and the quality of the articles by using the New Castle Ottawa assessment scale (Norris JM et al, 2021). Finally, a total of 14 studies met the quality of assessment.

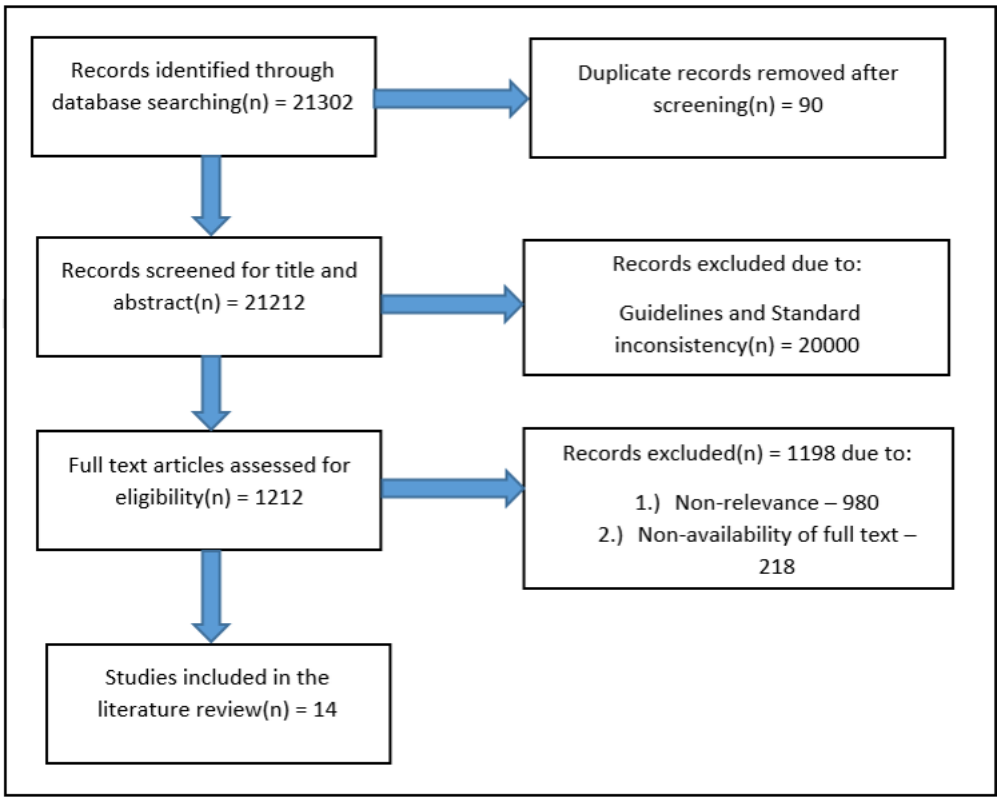

Figure 1: Flow chart for literature review on accuracy of AI in skill assessment and training for surgery

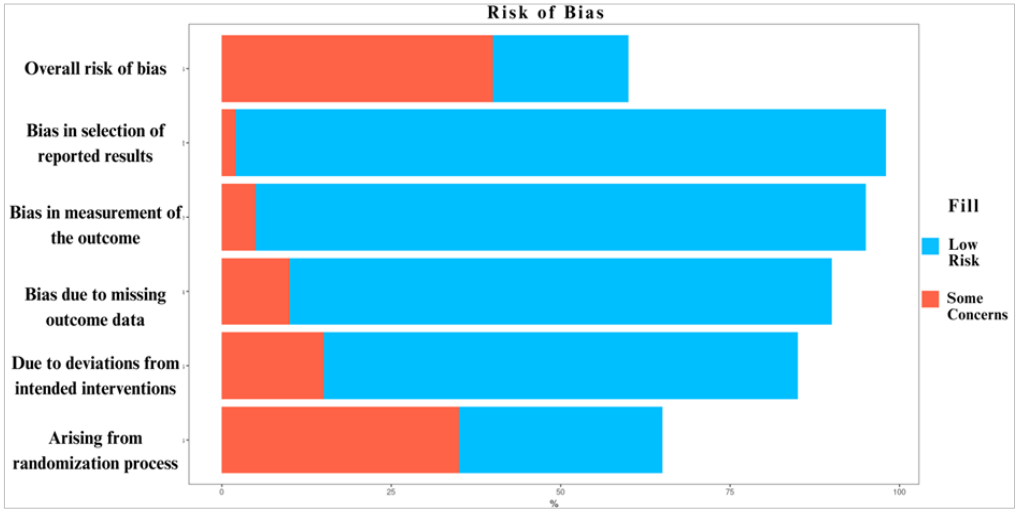

Figure 2: Risk of bias chart

Results

Screening flow

A total of 21302 articles were retrieved from PubMed, Scopus and Embase from 2016 to 2024. During duplicate removal, 90 articles were excluded. From 21212 articles, during the title and abstract screening, 20000 articles were excluded after which a total of 1198 articles were removed from the remaining 1212 articles during the full text screening phase.

Ultimately, the review analysed 14 studies meeting the inclusion criteria showing various applications of Artificial Intelligence in the field of surgery. The study varied on basis of design and involved articles from multiple countries including Canada, USA, UK, Italy and India.

AI technologies depicted high accuracy rates in numerous surgical approaches (Table 1). The results for accuracy of AI in skill evaluation and training in the field of surgery were tabulated for each author (Table 1 and Figure 3). The framework for AI skill assessment was depicted (Figure 4). The overall accuracy turned out to be 91.26%. One author mentioned sensitivity of 79% and specificity of 92% (Hashimoto DA et al, 2018).

Table 1: Characteristics of each study

S No	First Author (year)	Country of Study	Study Design	Features	Accuracy (%) of AI in Surgery
1	Fard et al (2016)	USA	Review Article	AI in surgical performance evaluation	85% accuracy in performance metrics
2	Hashimoto et al (2018)	USA	Review Article	Applications of AI in Surgery	79% sensitivity, 92% specificity
3	Schwartz et al (2019)	USA	Review Article	AI in surgical skill assessment	92.8% accuracy in skill classification
4	Mirchi et al (2020)	Canada	Review Article	AI in video analysis for surgical training	90% accuracy in video assessment
5	Andras et al (2020)	Romania	Review Article	AI in surgical workflow optimization	85% accuracy in workflow predictions
6	Gumbs et al (2021)	Italy	Review Article	Ai in autonomous actions	Not specified
7	Lam et al (2022)	UK	Systemic Review	66 studies analysed	91%
8	Nema et al (2022)	India	Review Article	AI in intraoperative decision support	97% accuracy in decision-making
9	Yanik et al (2022)	Turkey	Review Article	AI in surgical error reduction	98% accuracy in error detection
10	Chadebecq et al (2023)	France	Review Article	AI in surgical training	30% improvement in accuracy of instrument placement
11	Strong et al (2023)	Canada	Systemic Review	AI in robotic surgery	Not specified
12	Nagaraj et al (2023)	India	Review Article	AI in enhancing surgical outcomes	Not specified
13	Hamilton et al (2024)	USA	Review Article	AI in surgical guidance	Not specified
14	Jogan et al (2024)	Australia	Review Article	AI in predictive analytics for surgery	Not specified

Table 2: Important findings in each study

S No	First Author (year)	Important Findings
1	Fard et al (2016)	The potential of AI in improvement in surgical performance was demonstrated
2	Hashimoto et al (2018)	Surgical decision can be vividly analysed and predict patient outcomes
3	Schwartz et al (2019)	Objective evaluation and assessing surgical skills was accurately performed by AI
4	Mirchi et al (2020)	AI played a key role in video analysis for surgical training and teaching purpose
5	Andras et al (2020)	AI played a crucial role in surgical workflow, decreasing delay and improving surgical efficiency
6	Gumbs et al (2021)	Autonomous surgical practices were supported by AI with increased accuracy
7	Lam et al (2022)	Machine learning methods like neural networks and vector machines enhanced surgical skills improving training techniques
8	Nema et al (2022)	Live data analysis provided full information for decision making by surgical professionals
9	Yanik et al (2022)	Chances of surgical errors were reduced with provision of accurate feedback due to AI
10	Chadebecq et al (2023)	The learning curve for surgical trainees was enhanced with the aid of AI driven stimulations
11	Strong et al (2023)	Reduced operation time and increased surgical precision in robotic surgery was successfully achieved with AI
12	Nagaraj et al (2023)	Complications were reduced and recovery period was shortened with the help of AI
13	Hamilton et al (2024)	Anatomical landmarks were mapped by AI to enhance intraoperative guidance
14	Jogan et al (2024)	Prior forecasts for complications in surgery were predicted by AI providing effective management approaches

Table 3: Merits and gaps for each study

S No	First author (year)	Merits	Gaps
1	Fard et al (2016)	The role of AI in surgical training was vividly depicted	Surgical workflows were however not clearly explained
2	Hashimoto et al (2018)	Improved decision making with the help of AI	Lack of longitudinal study
3	Schwartz et al (2019)	Objective evaluation provided by AI improved training methods	Small sample size
4	Mirchi et al (2020)	Video analysis with vivid feedback to trainees helped in skill enhancement with the help of AI	However, quality and method variations may affect results
5	Andras et al (2020)	Optimized workflows enhanced efficiency	Ethical consideration and safety of patients were not stressed upon
6	Gumbs et al (2021)	Autonomous surgical actions in the field of surgery were discussed	Lack of clinical trial for evaluation
7	Lam et al (2022)	Comprehensive study on machine learning methodologies	certain surgical specialities were omitted
8	Nema et al (2022)	Real-time decision in intraoperative surgery was shown.	This limited the effectiveness of AI applications in practice.
9	Yanik et al (2022)	Easy error detection	Lack of comprehensive studies
10	Chadebecq et al (2023)	Improvements in training methodologies depicted	Lack of longitudinal studies
11	Strong et al (2023)	Vivid explanation of robotic surgery outcome with high precision through AI	Potential bias

12	Nagaraj et al (2023)	Decreased complication and shortened recovery period due to AI application	Ethical implications omitted
13	Hamilton et al (2024)	High anatomical landmark accuracy	Lack of generalizability
14	Jogan et al (2024)	Effective predictive analysis of surgical outcome	Lack of diverse data

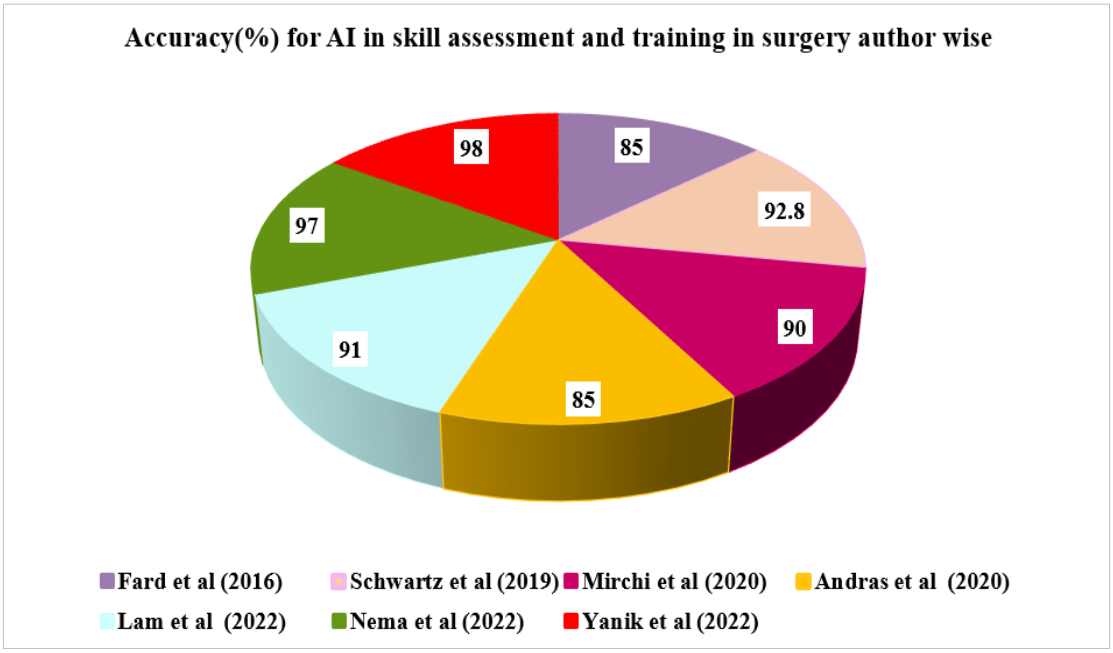

Figure 3: Accuracy (%) for skill evaluation and training in surgery for AI for each authority

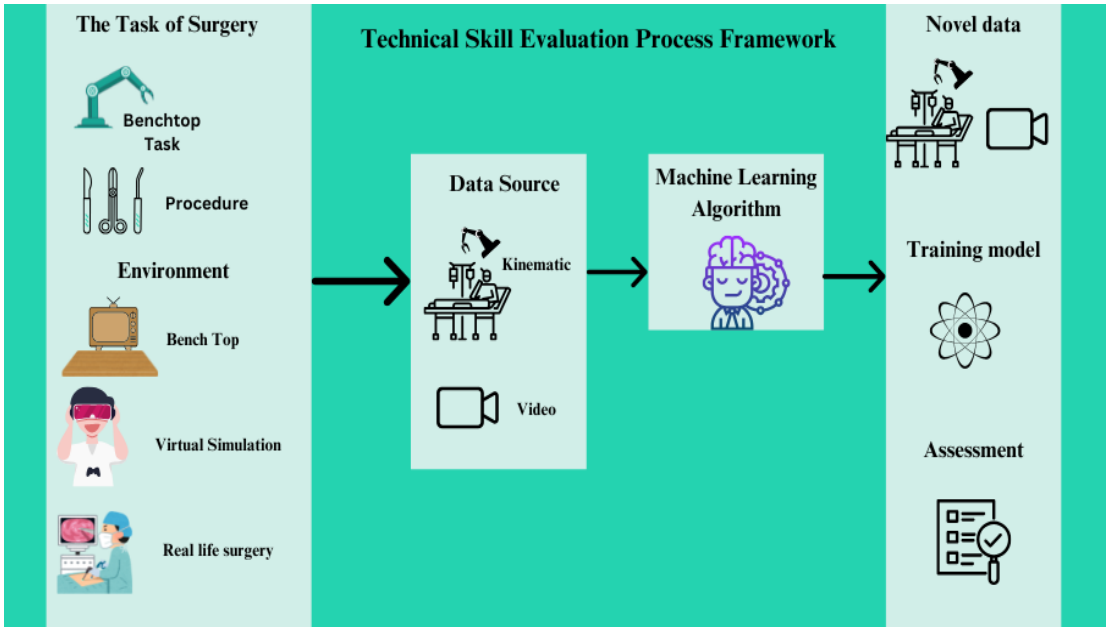

Figure 4: AI Skill assessment framework

Discussion

The role of AI was discussed in surgical performance evaluation by an author of our study (Fard MJ et al, 2016). This was supported by another study (Zhang Y et al, 2022).

Sensitivity and specificity analysis of AI applications was conducted by another author of our study enhancing decision making in the field of surgery (Hashimoto DA et al, 2018). This was depicted by another study (Lex JR et al, 2023).

Another author from our study pointed out the efficacy of classification of surgical skill improving assessment and training methods (Winkler-Schwartz A et al, 2019). In fact, this was corroborated on by another author (Liu D et al, 2021).

Yet another study of our review examined AI's crucial role in video analysis in surgical training assisting the trainees by providing deep learning experience (Mirchi N et al, 2020). Similar findings were noted by another author (Hameed MS et al, 2023).

Yet another study of our review showcased the optimization of workflows for surgical practices by AI with overall improvement in surgical settings (Andras I et al, 2020). This was further evaluated by another study (Jellouli WE et al, 2023).

AI's effectiveness in conducting autonomous actions were depicted by one of the authors of our study specifically in the categorization of lesions of skin showcasing its ability in aiding critical surgeries (Gumbs AA et al, 2021). This was reported by another author (Taher H et al, 2022).

The role of AI in enhancement of surgical practices was stressed upon by an author of our study (Lam K et al, 2022). The

findings align with another author's study (Abbasi N, Hussain HK, 2024).

The crucial role of AI in support of decision intraoperatively aiding in real time assistance of surgeons was depicted by an author of our study (Nema S, Vachhani L, 2022). This was elucidated upon by another author (Madani A et al, 2022).

Surgical error reduction was addressed being essential for improvising patient safety. This was highlighted by one of the authors of our study (Yanik E et al, 2022). Another study depicted similar findings (Colborn K et al, 2023).

The impact on surgical training by AI was observed by another author of our study by assessing its capability in provision of valuable feedback to the trainees being crucial for skill development (Chadebecq F et al, 2023). This was showcased by another author (Shahrezaei A et al, 2024).

With keen focus on robotic surgery another author of our study showed promising results with improvement in efficiency and great precision in robotic aided procedures (Strong JS et al, 2024). This was highlighted by another author (Kwok KW et al, 2022).

AI's contribution in enhancement of surgical outcomes in the surgical field was well addressed by another author of our study (Nagaraj MB et al, 2023). This was indicated in another study (Kitaguchi D et al, 2022).

Ultimately, the importance of AI in guidance for surgeries was much stressed upon with depiction of achievement of anatomical landmarks by an author of our study who also highlighted how this could help in decreasing procedural errors (Hamilton A, 2024). Another study showcased similar findings (Smithmaitrie P et al, 2024).

AI's predictive capabilities were explored by an author of our study in anticipation of outcomes for patients and various complications that are the hallmark for surgical success (Jogan M et al, 2024). This was further elucidated upon by another author (Elfanagely O et al, 2021).

All these studies showcase the crucial advancements brought about by AI in the field of surgery with enhancement of patient safety, precision of procedures and above all training enkindling the desire in the current researchers to undertake this topic for further future innovations. The important findings, strengths and gaps for each author were tabulated (Table 2 and 3).

Conclusion

The integration of Artificial Intelligence(AI) with surgical practice promises for a significant advancement in the field of surgery with close alignment with the foremost aim of enhancement of outcomes for surgery and training. The collective findings from the studies taken for review depicted the improvement in decision making, skill evaluation and intraoperative guidance with the aid of AI technologies. AI not only produces better patient outcomes with improved recovery period and decrease in complications but also is successful in enhancing efficiency in training surgical professionals forming the crucial pillars for success of surgery. An overall high accuracy supporting better outcome was demonstrated in our study indicating that the teaching and training skills can be improved by laying trust on AI solving our primary aim.

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Conflicts of interests

The authors report no conflict of interest.

Author contributions

Conceptualization and methodology, A.R.K., A.S., and S.H..; Formal analysis, S.H., and J.H.; Visualization and writing – original draft A.R.K., A.S., S.H.; Writing – review and editing, A.S., A.R.K., S.H. and J.H. All authors have read and agreed to the final version of the manuscript.

Ethical approval

Not required since the study conducted was a review and did not include any patient data. Fourteen studies over a period

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