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The Role of Artificial Intelligence in Plastic Surgery: Review, Applications, and Future Prospects to Revolutionize Patients Outcomes, Safety and Satisfaction

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ABSTRACT

The integration of artificial intelligence (AI) in plastic surgery holds immense potential for transforming the field, improving outcomes, and enhancing patient satisfaction. This article examines the application of AI in pre-operative planning, intra-operative decision making, and post-operative monitoring. AI tools leverage patient images to provide valuable insights into surgical outcomes, aiding in visualization and communication. Real-time guidance during surgery is facilitated by AI's analysis of intra-operative images, ensuring accurate execution and enhancing safety. In post-operative monitoring, AI analyzes patient data to predict outcomes, detect complications, and optimize wound healing assessment. Despite challenges, the future of AI in plastic surgery looks promising, with advancements in augmented reality, mobile applications, computer vision, and robotically assisted treatments driving progress and strengthening patient-physician relationships.

KEYWORDS: artificial intelligence, plastic surgery, pre-operative planning, intra-operative decision making, post-operative monitoring, virtual surgical planning, deep learning algorithms, augmented reality, surgical navigation, wound healing assessment, personalized care, patient-reported outcomes, challenges, future perspectives.

ARTICLE DETAILS

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INTRODUCTION

In the first half of the 20th century, science fiction familiarized the world with the concept of artificially intelligent robots. We may recall how it began with the "heartless" Tin Man from the *Wizard of Oz*, and by the 1950s, the world witnessed a generation of scientists, mathematicians, and philosophers with the concept of artificial intelligence (or AI) culturally assimilated in their minds. One such person was Alan Turing, a young British polymath who explored the mathematical possibility of artificial intelligence. Turing suggested that humans use available information as well as reason in order to solve problems and make decisions, so why can't machines do the same thing? This was the logical framework of his 1950 paper, *Computing Machinery and Intelligence* in which he discussed how to build intelligent machines and how to test their intelligence.[1] The proof of concept was initialized through Allen Newell, Cliff Shaw, and Herbert Simon's *Logic Theorist*, a program to act out the problem solving skills of a human, funded by Research and Development (RAND) Corporation and presented at the Dartmouth Summer Research Project on Artificial Intelligence (DSRPAI) in 1956.[2]

Since its birth in the 1950's, artificial intelligence has been revolutionizing many industries and services. However, several limitations in early models prevented widespread acceptance and application to medicine. In the early 2000s, many of these limitations were overcome by the advent of deep learning and artificial intelligence has been rapidly growing in recent years, transforming various fields of medicine,[3] including plastic surgery, with objective of improving outcomes, reducing errors, and enhancing patient satisfaction. AI-powered technology can help plastic surgeons with tasks such as pre-operative planning, intra-operative decision-making, and post-operative monitoring.

Artificial intelligence tools for pre-operative planning

Artificial intelligence (AI) can provide valuable assistance to plastic surgeons in pre-operative planning by analyzing patient pre-existing images and providing insights into surgical outcomes.[4] The first and most obvious function artificial intelligence can provide is **virtual surgical**

planning: artificial intelligence tools create 3D models of the patient's anatomy and simulate different surgical approaches. This can help the surgeon choose the best approach and anticipate potential complications. Plastic surgeons can utilize to evaluate patient pre-existing clinical images/photographs as well as radiographs, computerized tomographs or magnetic resonance images (see **Image 1**), and to request detailed information about anatomical structures and tissue properties which later help the surgeons plan the surgical approach, choose the appropriate surgical instruments, and anticipate potential complications.[5-7] In doing so, artificial intelligence can create three-dimensional models of the patient's anatomy and simulate different surgical approaches which in turn assist the surgeons to visualize potential outcomes, choose the best approach, and communicate the plan to the patient.[8,9] Not only these applied technology help surgeons visualize potential outcomes and optimize surgical plans, but also facilitate easier and more improved communication with patients during pre-operative consultation.

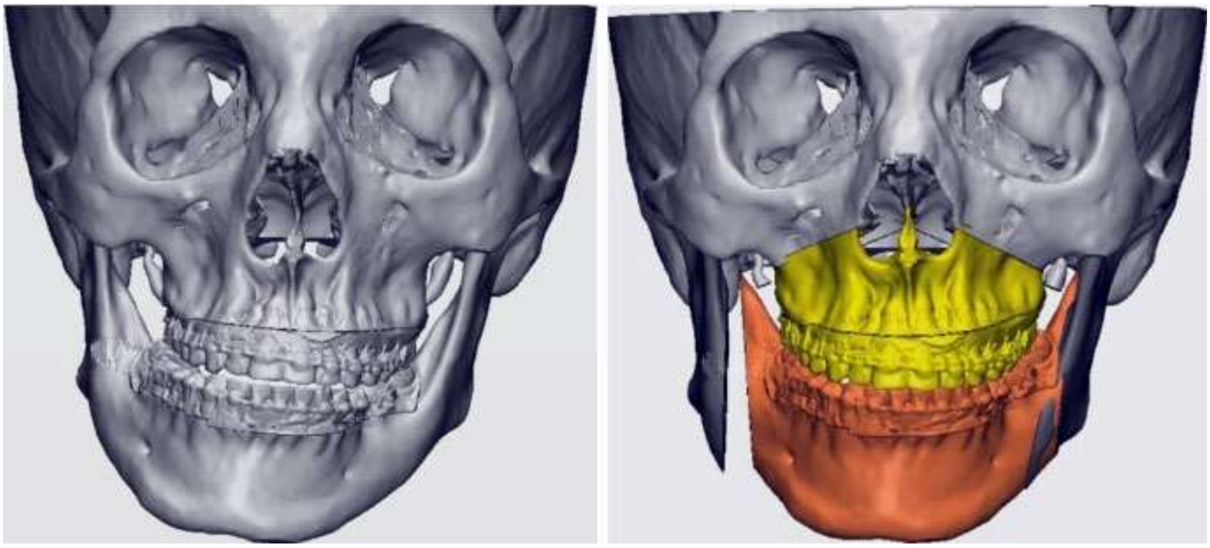

Image 1. Virtual surgical planning

Artificial intelligence use **deep learning algorithms** to analyze patient images and provide insights into potential outcomes, for example: deep learning algorithms analyze facial images to predict potential aesthetic outcomes or identify areas of asymmetry, or in identifying skin cancer (see **Image 2**). These deep learning algorithms are the power behind data analysis provided by its human users. Every provided anatomical and clinical data, such as anatomical measurements, images, etc., will later be useful as reference for analysis of certain anatomical unit to identify areas of abnormality or to predict potential aesthetic outcomes. With its deep learning, artificial intelligence explore, compare, evaluate, and utilize patient data and algorithms to auto-generate optimized surgical plans. This algorithm-based surgical plan will theoretically save time and reduce risk of human bias compared to manual planning methods. Furthermore, enhancing the algorithm-based surgical plans with three-dimensional modelling of the patients' anatomical structure will create excellent virtual surgical planning as well as surgical simulation.[10,11]

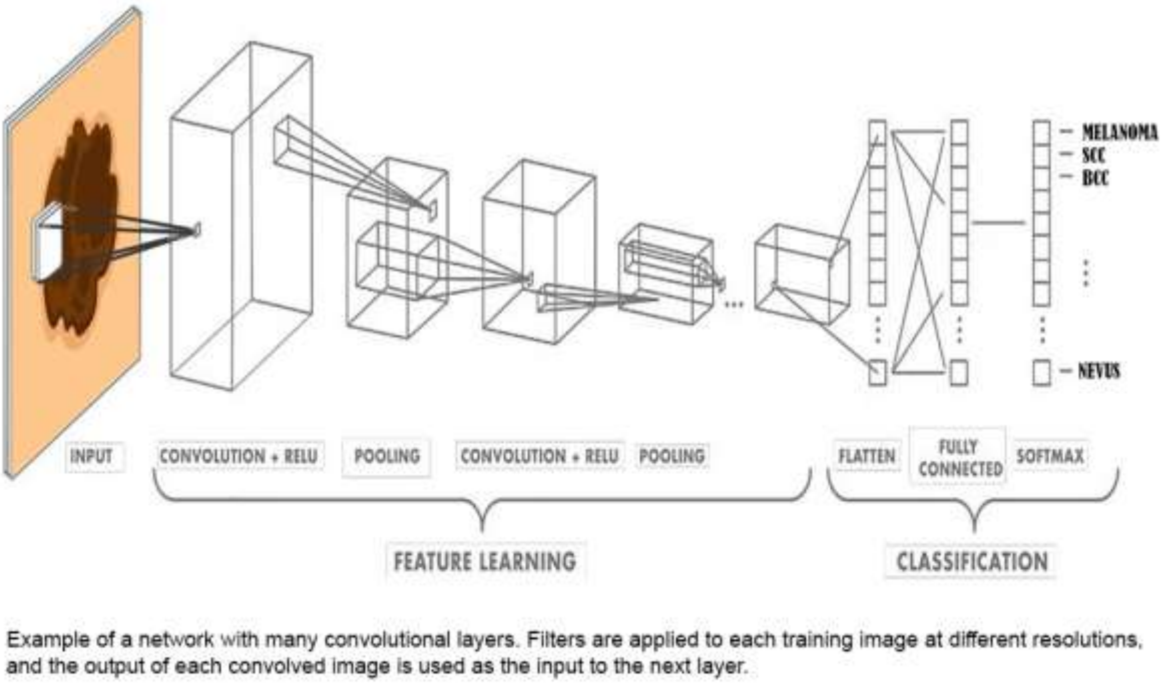

Image 2. A deep learning algorithm (Convolutional Neural Network) to identify skin cancer.

The more advanced evolution is **augmented reality visualization**. Now artificial intelligence can present augmented reality to overlay patient images or clinical appearance onto the procedural process, allowing the surgeon (and the patient as well) to visualize the planned approach in real time (see **Image 3**). This can improve accuracy and reduce errors during the procedure.[12,13]

Image 3. One of the application using augmented reality is Crisalix® that help future plastic surgery clients to visualize the outcomes of their breast surgery procedures.

Artificial intelligence tools for intra-operative decision making

The first and simplest function an artificial intelligence tool can provide during the surgery itself by providing **real-time information and guidance**, for example: analyzing intra-operative images, such as fluoroscopy or endoscopic images, to identify anatomical landmarks or structures, to measure tissue properties, and to provide feedback on surgical technique –for example: artificial intelligence can assist in identifying critical structures like nerves or blood vessels, ensuring their protection during surgery. Artificial intelligence may also provide warnings if the surgeon deviates from the planned procedure, helping to reduce errors and improve safety.[14,15]

AI-powered **surgical navigation** systems use real-time imaging data to provide visual guidance during the procedure. These systems can help surgeons accurately track the position of marked surgical instruments, verify the intended trajectory, and alert the surgeon to deviations from the planned path. In doing so, artificial intelligence will also provide **real-time guidance and augmentation** during surgery, for instance: augmented reality overlays can project critical information, such as pre-operative plans or patient-specific anatomical landmarks, onto the surgeon's field of view, aiding in precise instrument placement and ensuring accurate surgical execution. [14,15]

Artificial intelligence tools for post-operative monitoring

Artificial intelligence can play a valuable role in post-operative monitoring by analyzing patient data, providing predictive models for outcomes, identifying potential complications, facilitating early detection of complications (such as infection or blood clots), optimizing wound healing assessment, and enhancing personalized post-operative patient care.

Artificial intelligence can analyze and **assess post-surgery wound healing process** by automatically detecting wound characteristics such as discoloration, texture, and tissue viability, then provide quantitative measurements and evaluate wound healing over time. By analyzing patient data, including physiological parameters, laboratory results, and patient-reported outcomes, interpreting and integrating them to the surgical procedure, artificial intelligence algorithms can **detect and predict post-operative complications**, such as infections, hematomas, or necrosis. This can assist in early identification of complications and guide appropriate and timely interventions.[16-18]

Artificial intelligence can leverage patient-specific data to develop personalized care plans and provide tailored recommendations. By considering factors such as patient demographics, medical history, and procedure-specific variables, artificial intelligence tools can help optimize post-operative management, pain control strategies, and recovery plans, leading to improved patient outcomes.[18,19]

Examples of artificial intelligence tools or applications for post-operative monitoring in plastic surgery include remote monitoring and telemedicine, machine learning-based risk stratification and patient-reported outcomes analysis. AI-powered systems can enable remote monitoring of patients' post-operative progress. By leveraging wearable devices or mobile applications, artificial intelligence algorithms collect and analyze real-time data, provide patient education, and facilitate virtual consultations, enhancing patient convenience and reducing the need for in-person visits.[20] By analyzing large datasets to identify risk factors and patterns associated with post-operative complications, artificial intelligence tools can also generate risk stratification models to help surgeons identify high-risk patients who require closer monitoring or proactive interventions.[21] Patient-reported outcomes analysis: AI can analyze patient-reported outcomes, such as pain scores or satisfaction surveys, to assess post-operative recovery and treatment effectiveness. By identifying trends, correlations, and predictors of patient satisfaction and quality of life, AI tools can aid in refining surgical techniques and optimizing patient care pathways. (PubMed: "Artificial Intelligence in Patient-Reported Outcomes: A Scoping Review")

The challenge and concerns

Artificial intelligence has kept up with, and even in some ways surpassed clinicians, for example in skin cancer detection or in proposing post-operative outcomes. However, plastic surgery still lags behind –let us say—radiology, or even dermatology in its broader adoption. Creating and utilizing artificial intelligence applications are becoming increasingly accessible, however, complex cases may still require specialized medical expertise for design and deployment.

Some challenges stifling artificial intelligence adoption to daily plastic surgery practice are the lack of standardization of images and privacy concerns. Other major challenges in using artificial in medicine are the need for large datasets to train the deep learning algorithms and the potential for bias in the deep learning algorithms. As artificial intelligence algorithms require large amounts of data to learn and improve, to obtain enough diverse and high-quality data to develop accurate algorithms requires hard and diligent effort. Clinicians have to participate in standardizing data collection, curating data for machine learning, clinically validating artificial intelligence solutions, and ultimately adopting this paradigm shift that is changing the way they practice. If the algorithms are trained on datasets that are not diverse enough, they may produce biased results that may lead to incorrect diagnoses or treatments.

The future

The potential of artificial intelligence models for plastic surgery –especially in aesthetic plastic surgery field— for better patient experience and plastic surgeon aptitude to manage patients will determine the future. The development and utilization of the handheld mobile application showing actual pre-procedural clinical images and proposed post-procedural clinical outcomes will certainly upsurge appropriately and improve the patient-physician relationship as that technology facilitates and enhances patient active participation in their choices. The trend of in-depth computer vision technologies will also grow accordingly, and they have the potential to educate and streamline treatment protocols. Office-based software will complement the physical examination with a thorough study of the patient's anatomy and a built-in library of surgical techniques and implant materials to meet every need for surgery information. Automated and robotically assisted treatments may be on the way, however more study is necessary before implementing it. In order to better inform their patients and advance their clinical practices, all current and future plastic surgeons should equip themselves with enough knowledge about these cutting-edge, emerging technologies.

SUMMARY

The application of artificial intelligence (AI) in plastic surgery has the potential to revolutionize the field by improving outcomes, reducing errors, and enhancing patient satisfaction. In pre-operative planning, AI tools can analyze patient images and provide insights into surgical outcomes, aiding in visualization, surgical approach selection, and communication with patients. Intra-operatively, AI can provide real-time information and guidance, analyzing images to identify anatomical landmarks and structures, ensuring surgical technique accuracy and safety. For post-operative monitoring, AI can analyze patient data to predict outcomes, detect complications, optimize wound healing assessment, and personalize post-operative care. Challenges include standardization of clinical images, privacy concerns, the need for large datasets, and potential algorithm bias. Despite these challenges, the future of AI in plastic surgery holds promise, with potential advancements in augmented reality, mobile applications, computer vision, and robotically assisted treatments.

Conflict of Interest

Authors declared no conflicts of interest during the research and the writing of article.

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