# Artificial Intelligence in Facial Plastic Surgery: A Review of Current Applications, Future Applications, and Ethical Considerations

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Facial Plast Surg 2023;39:454–459.

## Abstract

From virtual chat assistants to self-driving cars, artificial intelligence (AI) is often heralded as the technology that has and will continue to transform this generation. Among widely adopted applications in other industries, its potential use in medicine is being increasingly explored, where the vast amounts of data present in electronic health records and need for continuous improvements in patient care and workflow efficiency present many opportunities for AI implementation. Indeed, AI has already demonstrated capabilities for assisting in tasks such as documentation, image classification, and surgical outcome prediction. More specifically, this technology can be harnessed in facial plastic surgery, where the unique characteristics of the field lends itself well to specific applications. AI is not without its limitations, however, and the further adoption of AI in medicine and facial plastic surgery must necessarily be accompanied by discussion on the ethical implications and proper usage of AI in healthcare. In this article, we review current and potential uses of AI in facial plastic surgery, as well as its ethical ramifications.

**Keywords**
- artificial intelligence
- ethics
- machine learning
- patient care

In the 21st century, artificial intelligence (AI) has become synonymous with the bulk of modern technology, where advancements in programming and computer science have expedited change in numerous sectors of society. In the healthcare industry, AI will have an impact on the tripartite missions of patient care, education, and research. For example, it is being used to support clinician decision making,[1,2] engage patients as virtual conversational agents,[3] and predict surgical outcomes[4,5]; most recently, the March 2023 release of OpenAI's latest AI system Generative Pretrained Transformer 4 (GPT4) has demonstrated abilities ranging from transcribing clinical encounters into physician notes to correctly answering exam questions from the US medical licensing examination.[6]

It is unsurprising that radiology, the specialty based on advanced digital imaging, is at the forefront of AI innovation in medicine. Smarter machines programmed with intelligent models have the potential to provide high-quality images with less artifactual distortions, decrease the amount of radiation emitted during imaging, and assist in image interpretation by providing automated measurements of tumor scans.[7] Similar to and separate from these exciting prospects, other fields have found their own niche applications of the newest technology: Esteva et al[8] developed a model that successfully identified skin cancers from medical images with an accuracy rate on par with multiple dermatologists; Bertsimas et al[4] developed a tool that, within 4 to 11

**article published online** June 23, 2023

**Issue Theme** The Cutting Edge in Facial Plastic Surgery; Guest Editor: Lamont R. Jones, MD, MBA, FACS


Thieme Medical Publishers, Inc., 333 Seventh Avenue, 18th Floor, New York, NY 10001, USA

**DOI** https://doi.org/10.1055/s-0043-1770160.
**ISSN** 0736-6825.

questions, accurately predicted the risk of mortality and other postoperative complications following emergency surgery. Given that the amount of data in electronic health records (EHRs) is proposed to grow by nearly 50% every year,[9] increased development of such AI-powered models would make possible the ability to harness incredible amounts of information to a degree unachievable by manpower alone. Understandably, such seemingly limitless potential raises ethical questions including, but not limited to, the infringement of AI on patient privacy, the accountability of computers (versus physicians) for errors, and the development of biased algorithms by using data that underrepresents certain demographics, like race or gender.[9–11]

In facial plastic surgery, the potential applications and ethical considerations of AI are likewise widespread: from research to workflow and patient evaluation, the high digital visibility of this field—via "before" and "after" pictures, for example—and the demand for flawless aestheticism lend itself well for implementation of precise, AI-supported care. Ironically, these same characteristics also produce unique ethical concerns. The purpose of this article is to provide an overview of AI and discuss current uses, future possibilities, and ethical implications of AI in facial plastic surgery.

## What Is AI?

AI is broadly used to describe computer programs or machines designed to complete processes that mimic human intelligence, such as learning or problem solving.[1,2] These programs are composed of algorithms—sets of rules that produce a given output from input data—that have the ability to recognize patterns in large data sets.[12,13] In one category of AI called machine learning (ML), developing an algorithm requires initial "training" via some amount of input information, where the algorithm uses one of three types of learning styles to identify specific features or patterns within the data. Once trained, the algorithm is tested on a new dataset to ensure that it is able to maintain its accuracy when applied to unseen data.[1,12] Depending on the learning style employed, the algorithm is better equipped to perform a specific type of function, whether that be categorizing medical images into clinical outcomes or finding subtle similarities between genetic sequences.[12] In short, ML can be described as programs that generate desired outputs (i.e., predict an outcome) by using algorithms that find patterns in large datasets.

Subfields of ML include deep learning (DL), natural language processing (NLP), and computer vision.[1,12] Briefly, DL is a type of ML that utilizes algorithms inspired by the human brain. These algorithms are called neural networks, where multiple layers of processing allow for self-directed learning and complex problem solving.[1,14,15] Facial recognition technology is one example of DL. NLP refers to language detection and analysis—both speech and text—exemplified by medical chart interpretation and chatbots, or virtual conversational agents.[3,12] Computer vision is defined as image and video analysis using various algorithms for object detection, image classification, and segmentation of regions of interest (such as human faces).

## Current Applications

### Workplace Efficiency

One of the most simple and direct applications of AI in transforming medical care lies in optimizing nonclinical tasks such as documentation. The EHR was one of the most influential changes to medical care[16]; however, due to significant regulatory changes, much of clinicians' workloads are spent interacting with EHR.[17] To relieve some of this burden, AI may be used for documentation of patient-physician communications in the form of a medical scribe. Using speech recognition and speech to text conversion algorithms, transcribing communications via AI during a patient visit can lead to enhanced workplace efficiency and less administrative time,[18,19] and companies like Augmedix and Deepscribe already offer such services.[20,21] As an interesting example, Patel and Lam[22]—recognizing the challenges of proper discharge summary documentation—demonstrated the ability of ChatGPT (an AI chatbot that utilizes NLP technology) to write a discharge summary for a theoretical postsurgical patient after it was given a basic prompt. However, caution must be exercised when increasing adoption of AI in the setting of documentation, as automation bias may ensue if clinicians develop an overreliance on such technologies. For example, accepting documentation without confirmation of its accuracy can lead to errors in the EHR.[23] Bearing this in mind, incorporation of AI into EHRs has the potential to help providers optimize their workflow by allowing for more efficient and timely medical documentation.

Additionally, conversational agents utilizing NLP have been used to assist patients for other purposes including appointment management, triage, or medical advice, and patient perceptions of the effectiveness and usability of these technologies are generally positive.[3] Baker et al[24] compared the diagnostic accuracy and the appropriateness of recommendations of an AI-based triaging system with multiple physicians using clinical vignettes similar to those used for simulation-based learning in medical education. Although there was no statistical analysis, the system was able to diagnose conditions and provide recommendations comparable to that of human doctors; in fact, the AI system's recommendations were generally found to be safer than those provided by the physicians.

### Preoperative Decision Making

Facial plastic surgery is unique in that the face is among the most distinct structures of the human body. Pre- and postoperative pictures are already common practice and large databases can be created to categorize facial anatomy and model outcomes.[25] While research using AI in aesthetic and facial reconstructive surgery is still in the early phases, AI systems can take advantage of these databases to inform preoperative decision making. For example, ML programs are able to make independent associations using large datasets to identify patterns and trends, where the Google search engine is one of many algorithms that use ML to predict a user's preferences. Borsting et al[25] created a DL-based program called "RhinoNet" that, using data from thousands of before and after images, was trained to predict whether the image depicted an individual who had undergone rhinoplasty. The program successfully estimated rhinoplasty status in 85% of the test images, where it performed better (although not statistically significant) compared to expert opinions. Similarly, Phillips et al[26] demonstrated the ability of an AI-based detection algorithm to accurately identify melanoma with performance similar to dermatologists.

Such algorithms could be used in facial plastic surgery in various ways; for example, AI may analyze large sets of pictures and videos of patients to create prediction models to categorize favorable versus unfavorable patient anatomy. Formeister et al[27] showed the ability of an ML algorithm to identify chief factors (i.e., flap ischemic time, smoking) involved in complications for head and neck free flap tissue transfer, which differed from factors emphasized by traditional statistical models (i.e., flap type). However, it should be noted that one difficulty with developing models in facial plastic surgery is the significant variation in facial anatomy between individuals, which necessitates a large number of sample images to train AI-based algorithms.

### Postoperative Outcomes

A major limitation of assessing postoperative outcomes in plastic surgery is the lack of objective evaluation, especially considering the inherently subjective qualities of aesthetic surgery.[28] Currently, patient satisfaction and surgeon-based perception assess outcomes. However, because patient satisfaction is influenced not only by the actual surgical results, but also by personal expectations, AI may assist in creating more objective methods of evaluation. A study examined the accuracy of an AI algorithm to predict perceived age reduction after facelift,[29] where neural networks were very accurate in predicting preoperative age. Such programs can provide validated methods of determining postoperative results for plastic surgeons. With the advent of generative AI (including generative adversarial networks and diffusion models) such as DALL-E, one can create various types of synthetic images using AI. This is very useful for simulating postsurgery result images virtually even before the procedure. Surgeons can virtually try out different interventions and both surgeons and patients can look at the AI-simulated result face images to evaluate and score them. This process helps the surgeon fine tune the actual procedure preemptively and aim for the best outcome.

### Surgical Training and Research

Plastic surgeons require expertise in technical ability, anatomy, surgical planning, and clinical knowledge. Oftentimes, surgical performance is difficult to assess objectively and most metrics are not validated with evidence.[30] In this regard, AI-based simulation is another application that is gaining attention, as algorithmic analyses of video-recorded surgeries can help trainees identify technical weaknesses and predict outcomes of different surgeries.[30,31] For example, with the use of wearable sensors, an ML algorithm was able to identify movement patterns that were associated with the skill level of a surgeon.[32] As these algorithms mature, there is great promise for these programs to be utilized as tools that enhance the quality of surgical training. Finally, AI may also be utilized as a supplemental resource when conducting research. Gupta et al[33,34] prompted ChatGPT to produce novel ideas for systematic reviews across various topics in plastic surgery, and its results were subsequently compared to literature searches of multiple databases. While the overall accuracy of proposing truly novel ideas for systematic reviews was only 55%, this software may provide a useful starting point for those wishing to contribute to research.

## Future Applications

The horizons of AI implementation in the future are broad, where continuous advancements in technology may make it possible to consider opportunities and applications that cannot currently be imagined. While one group used AI to predict which patients may be more likely to develop a postoperative surgical site infection,[35] further advances with image processing, interpretation of symptoms, and vital sign assessment may eventually allow for patients to triage any concerns surrounding their surgical site. AI tools can also help monitor and forecast postsurgery wound healing times and potential issues with that. Moreover, computer vision AI-based systems can also be used to coach and monitor patients and caregivers for optimal postoperative behavior and care, such as exercises for muscle movement. Such software could assist in decision making that may prevent unnecessary presentations to the emergency room or give medical recommendations to patients who may not have access to timely healthcare or are unsure of what care to seek. Additionally, future applications of cosmetic surgeries may utilize predictive software; for example, a program may learn individual surgeons' particular "styles" through before-and-after pictures and inform patients wishing to undergo similar procedures, with the patients' outcome preferences driving the program's output. In addition, AI could be used to develop patient-specific treatment plans that combine surgical and nonsurgical procedures to improve reconstructive or rejuvenation outcomes. For example, one patient may benefit from deep plane facelift with fat grafting, while another may benefit from mini-face lift, laser, and filler.

## Ethics

Proponents of AI in patient care agree that any use of AI should be informed by the same ethical principles dictating traditional human-provided care; however, this is complicated by the fact that the increasing involvement of advanced technology in healthcare presents unique questions that may not be completely answered by traditional ethical principles. Relatedly, there have been concerns regarding the possibility that AI may eventually replace, rather than assist, healthcare practitioners. This may be especially true in technologically-based subspecialties and when considering the development of an AI-driven robotic surgical device that can successfully perform basic surgical skills.[11] However, years of physician expertise and the sanctity of the patient-provider relationship, along with other inherently human qualities like empathy and compassion, cannot be digitally replicated and should not be undermined. When considering its additional limitations, it does not appear that AI will overtake physicians anytime soon.[1,11,36,37] Indeed, Pinto Dos Santos et al[38] found that, in a survey of 260 medical students, a vast majority (96%) disagreed that physicians could be replaced by AI and agreed that AI should be incorporated into medical training (71%). Thus, the inclusion of AI in medicine should not be feared, but approached with careful excitement and curiosity for the ways that AI may, when used appropriately, contribute to efficient, accurate, and patient-centered care. Consequently, there is a need to dissect the ethical intersection between human thought and virtual processing when considering the proper implementation of AI as a tool that may augment physicians' abilities to provide care, educate, and innovate.

### Legal Liability

One important consideration is the liability of AI-based medical recommendations, especially the point at which a physician's recommendations may be discordant with AI. Loftus et al[39] used DL to evaluate the over-triaging and under-triaging of postoperative patients and whether they should be treated in an ICU setting or a ward setting with regard to resource utilization and acuity of care. Though this data was analyzed in a retrospective setting, studies like this will be used to inform development of real-time decision-making tools to aid surgeons in determining the most appropriate disposition for postoperative management. As described by Morris et al[40] in the event of patient harm, there remains to be a discussion as to whom the liability falls upon: the surgeon overriding a ML-based prediction or the developer of the technology. Future considerations for implementation of such technology into patient care would necessitate continued shared decision-making and an informed consent process in which detailed risks and benefits to AI-augmented care should be discussed with patients.

### Bias

Another important ethical consideration with the increased prevalence of AI in surgery is the amplification of racial, socioeconomic, or gender biases. If the data used to teach automated neural networks is based on preexisting documentation, then the systems are inherently prone to the biases of the provider documenting such information.[41] Additionally, patients of lower socioeconomic status—who are more likely to seek care at multiple institutions—may be perpetually disserviced if records of their care are spread across multiple, noncommunicating EHRs, possibly resulting in over-testing or undertreatment.[42] Parikh et al[41] proposed methods to reduce such bias including training AI models with populations mirroring those most affected by a particular condition rather than from the general population. They also suggested flagging patients for whom a predictive model has limited EHR data to indicate that the algorithmic outputs should be reviewed in greater detail. In order for these technologies to guide patient care, it would be crucial to ensure aggregation of medical records for accurate information processing.

For supervised ML, different experts may label the same data point or image differently, based on their experience. This causes interobserver variability, and the AI system needs to be cognizant of and gracefully handle this issue with ground truth uncertainty. Bias in data collection may cause degradation of the AI model when deployed in new settings (a different hospital or location). Data to train AI may also be lacking for certain races causing AI bias.

AI fairness is an important and growing topic. To mitigate bias, various metrics such as group parity have been developed. Facial plastic surgery would need to use such fair AI models, even at the possible cost of lower overall accuracy.

Specific to facial plastic surgery is the concept of beauty, the pursuit of which drives many patients' decisions to pursue cosmetic procedures. ML programs have been taught to interpret the attractiveness of faces from photographs and recommend surgical plans for patients wishing to undergo aesthetic surgeries.[43] Computer systems that—by nature—rate beauty as an objective measurement and leave no room for subjective preference would elevate certain qualities as superior to others; in other words, they would define the "perfect face." This is problematic when perfection is based on a narrow set of beauty standards derived from specific cultures (i.e., Western countries), where such bias leads to the undervaluing of qualities that may be considered beautiful in other races or ethnicities. Consequently, AI may contribute to decreasing diversity in perceptions of beauty,[11,14,44] and would only serve to inform the goals of individuals who have beauty ideals similar to those that are standardized within the algorithm. As such, surgeons using predictive software during patient consultations for aesthetic procedures should bear this in mind and minimize the risk of coercion in pursuing an outcome misaligned with the patient's goals. Again, this emphasizes the role of AI as a tool that aids patient decision making, not as a primary decision maker itself.

### AI Model Explainability

AI models have become more complex over the years. However, it is crucial that the AI models are interpretable, especially in a healthcare setting. One needs to understand what is triggering the AI to make a certain decision. For this, explainability is a growing and important topic. This process takes a complex black box model and helps the user (doctor and/or patient here) gain insights into the AI decision making process. One concrete example in medical imaging AI is when the AI calls a particular patient's X-ray as suspicious (say, for cancer), then the explainability module will generate a "heatmap" showing which regions of the image caused the AI to call cancer, most likely because those image regions had lesion like objects. This is also crucial for plastic surgery. Consider a scenario where the plastic surgeon is trying to evaluate a surgical outcome. Using explainable AI, they can predict and identify specific parts of the face that may be affected adversely due to the procedure (resulting in an overall poor outcome) and prioritize these areas accordingly.

### Data Security

Implementation of third-party AI software into patient care would require stringent policies on patient data usage and storage held to the standards outlined by the Health Insurance Portability and Accountability Act (HIPAA). One consideration unique to surgery involves the use of video-based AI learning models. Prigoff et al[45] highlighted several ethical recommendations regarding the use of video recording in operating rooms, including a clearly stated purpose for recording, informed consent, the ability to opt-out of data retention, and for video recordings to be held with the same security standards as other medical records. Further standards regarding the timeline of data retention for applications such as preoperative-to-postoperative predictive software would also need to be developed. Distributed storage and federated ML can be used to train AI with the data still residing on the patient's phone or computer, reducing the risk of data loss or breach. AI can also be used to identify and mask out personal identifying information and other sensitive information before patient data is stored on the cloud, to ensure patient privacy.

## Conclusion

The applications of AI in healthcare are numerous and will likely continue to grow as advancements are made in the quality and accuracy of AI-based models. AI shows great promise in the field of plastic surgery, where collections of facial profiles and the need for objective assessment of surgical outcomes serve as unique points of application. When used carefully and in alignment with physician judgment, AI programs may provide important contributions to efficient healthcare workflow and delivery in facial plastic surgery. This review provides a glimpse into the current applications and potential future directions of these intelligent technologies, as well as an important discussion regarding the ethical implications of nonhuman, computer influences on a field that, while based on scientific objectivity and biological fact, is equally driven by inimitable human character.

**Conflict of Interest**
None declared.

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