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Insights on Applications, Considerations and Future of Artificial Intelligence in Facial Plastic Surgery

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Abstract

Artificial intelligence (AI) is often hailed as the technology that will continue to transform this generation. Among widely adopted applications in other industries, its potential use in medicine is becoming increasingly explored, owing to the extensive amount of data present in electronic health records and the need to improve patient care and workflow efficiency. AI is playing an increasingly important role in facial plastic surgery. By studying technical skills and pathways, and their impact on patient outcomes and error rates, specialists are able to gain a more precise and efficient understanding of our technical skills and pathways. A number of algorithms have been developed to enhance pre-operative assessment, surgical planning, outcome simulation, and post-operative monitoring. In spite of these benefits, there are currently limitations, including the ethical acquisition of large datasets, human biases, and trust in new technologies. It is important to consider how AI may influence the patient-surgeon relationship in the near future. A number of tasks related to documentation, image classification, and surgical outcome prediction have already been assisted by AI. Specifically, facial plastic surgery is a field where this technology lends itself well to specific applications due to its unique characteristics. There are limitations to AI, however, and further adoption of AI in medicine and facial plastic surgery must necessarily be accompanied by discussions on its ethical implications and proper application. A review of the current and potential uses of AI in facial plastic surgery, along with its ethical implications, is presented in this article.

Keywords: Artificial intelligence, AI, Machine learning, Facial plastic surgery

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Introduction

Today, AI is synonymous with the bulk of modern technology, where advancements in programming and computer science have accelerated change. AI will have a significant impact on the tripartite missions of patient care, education, and research in the healthcare industry. In addition to supporting clinician decisions, it is being used to engage patients as virtual conversational agents and predict surgical outcomes; most recently, OpenAI's latest AI system has demonstrated abilities ranging from translating clinical encounters into physician notes to answering US medical licensing exam questions correctly. In medicine, radiology is at the forefront of AI innovation due to its reliance on advanced digital imaging [1]. Using smarter machines that are programmed with intelligent models, high-quality images with fewer artifactual distortions can be obtained, radiation levels during imaging can be decreased, and tumor scans can be automated and analyzed more easily. Similarly, and separately from these exciting prospects, other fields have found their own niche applications of the newest technology. With an accuracy rate comparable to multiple dermatologists, researchers developed a model that identified skin cancers from medical images. Additionally, a tool was developed that predicted the risk of mortality and other postoperative complications after emergency surgery in a few questions [2]. As EHR data is expected to increase by nearly 50% yearly, increased development of AI-powered models would enable enormous amounts of information to be harnessed to a degree unattainable by human hands alone. Obviously, such seemingly limitless potential raises ethical concerns, such as the infringement of AI's privacy on patients, the accountability of computers vs physicians for errors, and the development of biased algorithms based on data that underrepresents certain demographics [3]. It is also widely recognized that AI has potential applications and ethical considerations in facial plastic surgery: from research to workflow and patient evaluation, the high level of digital visibility in this field-via "before and after" pictures, for example-and the demand for flawless aesthetics make it a good candidate for AI-supported care implementation. These same characteristics, however, also raisesome ethical issues. We will also explore current uses, future possibilities, and ethical implications of AI in facial plastic surgery in this article [2].

Importance of AI

A computer program or machine that mimics human intelligence,

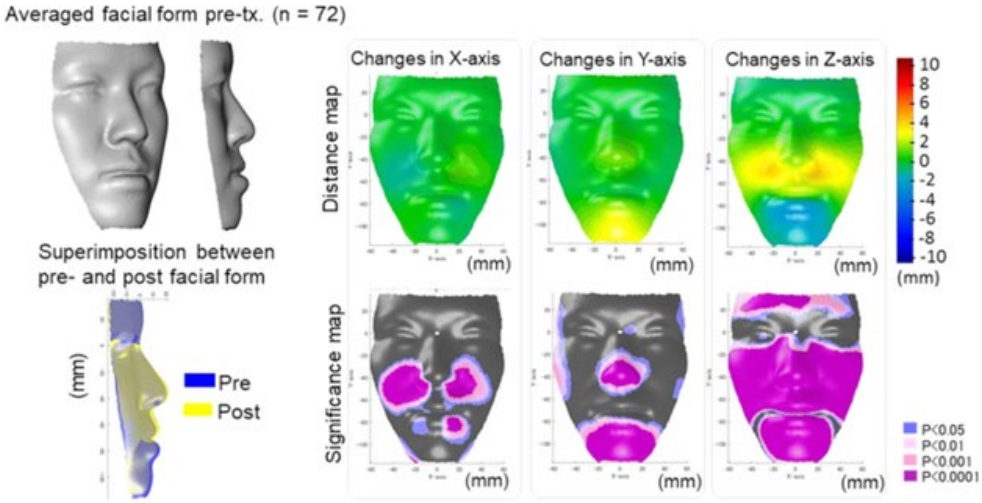

Figure 1: Surgery group average facial changes for pre-treatment (top-left) and the superimposition of pre-treatment and post-treatment [11].

such as learning or problem-solving, is considered AI [4]. Algorithms form the basis of these programs and have the ability to recognize patterns in large datasets through sets of rules. In machine learning (ML), an algorithm must be trained by some amount of input information to develop a specific pattern or feature within the data. There are three types of learning styles used in ML. In order to determine whether the algorithm can maintain its accuracy when applied to unknown data, it is tested on a new dataset once trained. The algorithm can be tailored to perform specific functions, such as classifying medical images based on clinical outcomes or finding subtle similarities between genetic sequences, depending on the type of learning method used [5]. A ML algorithm is a program that uses algorithms to find patterns in large datasets to generate desired outputs (e.g., predictions). There are three subfields of ML: deep learning (DL), natural language processing (NLP), and computer vision. In short, DL is a type of ML that uses algorithms inspired by the brain. Algorithms with multiple layers of processing are called neural networks, which can solve complex problems by self-directing. A good example of DL is facial recognition technology. A chatbot, or virtual conversational agent, is an example of NLP as it relates to language detection and analysis-both speech and text [6]. A computer vision system analyzes images and videos to detect objects, classify images, and segment regions of interest.

New Applications on the Horizon

Surgeons may be able to monitor outcomes using AI in a novel way. The learning ability of neurons is mimicked by DL algorithms such as convolutional neural networks (CNN) that recognize, differentiate, and allocate value to specific signals in data [2, 7]. In order to detect subtle changes in facial proportions and symmetry, CNNs use more than a million facial images to recognize lines, shapes, colors, and textures. Slight changes to nasal structures can have significant aesthetic and functional impacts in FPS rhinoplasties. Following cosmetic rhinoplasty, ML models can identify that larger nasofrontal and nasolabial angles are associated with increased attractiveness. By combining this information with 3D modeling, surgical planning can be enhanced. In the same way, ML algorithms can be trained to recognize and simulate different surgical techniques. AI may also be used to model rhinoplasty healing. By understanding precisely how their techniques work, surgeons can make better decisions, and patients can be more involved in the decision-making process [8].

The monitoring of free-flaps after reconstructive microsurgery is a resource-intensive procedure as an ultrasound doppler probe is needed, along with a practitioner familiar with its use. With ML models that analyze post-operative free flap viability in reconstructing facial skin cancers, resources may be better allocated. A prediction model developed by can detect arterial and venous insufficiency in clinical photographs of free-flaps with 99% accuracy [9]. It would allow initial assessments to be conducted at centers with less equipment and fewer specialized staff, thereby reducing the use of portable dopplers. It is possible for NLP algorithms to recognize and understand language in text and voice recordings. It is possible to analyze large quantities of data through text recognition in order to make conclusions based on existing electronic patient records. Understanding timelines, benefits, and complication rates quickly enables surgeons to improve their practices. In this way, high risk patients can be identified for certain surgical procedures, augmenting the preoperative assessment process and allowing a more informed decision to be made [10].

Efficacy at Work

Documentation optimization is one of the simplest and most direct applications of AI in medical care. Medical care has been transformed by the electronic health records (EHR); however, due to significant regulatory changes, clinicians spend much of their time interacting with EHRs. As a medical scribe, AI can help relieve some of this burden by documenting patient-physician communications. By utilizing speech recognition and speech-to-text algorithms during a patient visit, AI can enhance workplace efficiency and reduce administrative workloads. In addition, clinicians should exercise caution when adopting AI in documentation settings, as automation bias may result if clinicians rely too heavily on such technologies. By incorporating AI into EHRs, providers can optimize their workflow by documenting medical information in a more efficient and timely manner [10].

Conversational agents that utilize NLP have also been used to assist patients with appointment management, triage, or medical advice, and patients generally rate these technologies as effective and user-friendly. Researchers compared an AI-based triaging system with multiple physicians using clinical vignettes similar to those used in simulation-based learning in medical education in order to determine the diagnostic accuracy and appropriateness of recommendations. Despite the absence of statistical analysis, the AI system was able to diagnose

conditions and make recommendations that were comparable to those made by doctors; in fact, the AI system's recommendations were generally considered safer than those of doctors [12].

Preoperative Decision Making and Postoperative Outcomes

Among the most distinctive structures in the human body, the face makes facial plastic surgery unique. A large database can be created to categorize facial anatomy and model outcomes based on pre- and postoperative pictures. Even though AI systems are in the early stages of research for aesthetic and reconstructive surgery, they can be used to inform preoperative decision-making [13]. A Google search engine, for instance, uses ML to provide users with predictions of their preferences using large datasets to make independent associations. Using data from thousands of before and after photographs, Borsting et al. [25] developed a DL-based program called "RhinoNet" to predict whether an image depicted someone who had undergone a rhinoplasty. In 85% of the test images, the program correctly estimated rhinoplasty status, beating expert opinion by a small margin (though it was not statistically significant). According to an AI-based detection algorithm performed similarly to dermatologists in detecting melanoma [14].

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. ML algorithms can identify chief factors involved in complications for head and neck free flap tissue transfer, which differ from factors emphasized by traditional statistical models [15, 16]. It should be noted, however, that developing facial plastic surgery models is difficult due to the considerable variation in facial anatomy between individuals. This requires training AI-based algorithms using thousands of samples.

Postoperative outcomes are difficult to assess in plastic surgery because there is no objective evaluation, especially when aesthetic surgery is inherently subjective. The current method of assessing outcomes is based on physician perception and patient satisfaction [4]. In spite of this, AI may help create more objective methods of evaluating patient satisfaction, since patient satisfaction is influenced not only by the actual surgical results, but also by personal expectations. Researchers examined the accuracy of AI algorithms to predict perceived age reduction after facelifts, and neural networks predicted preoperative age very well. Plastic surgeons can use such programs to determine postoperative results in a validated manner. The advent of generative AI (including generative adversarial networks and diffusion models) such as DALL-E has enabled the creation of a variety of synthetic images [17]. A virtual post-surgery result image can be simulated even before the surgery has been performed using this method. As well as evaluating and scoring the AI-simulated results, surgeons and patients can virtually try out different interventions. By aiming for the best outcome, the surgeon is able to fine-tune the actual procedure preemptively [18].

Surgical Research and Training

An experienced plastic surgeon must possess technical skill, an understanding of anatomy, the ability to plan surgeries, and clinical knowledge. Surgery performance is often difficult to assess objectively, and most metrics are not supported by evidence. Consequently, AI-based simulation is another application that is gaining attention, since algorithmic analyses of videoed surgeries can aid trainees in identifying technical weaknesses and predicting outcomes. In one study, a ML algorithm determined that movement patterns were associated with a surgeon's skill level with the use of wearable sensors. There is great potential for these algorithms to be used as tools to enhance surgical training as they mature. Additionally, AI can be used as a supplementary resource when conducting research.

AI and FPS Limitations

A high-volume data set is required for AI systems to produce accurate and representative results. Over 500 hospitals in western countries participate in the collaborative National Surgical Quality Improvement program. When obtaining informed consent for the storage and distribution of personal data, several ethical considerations must be taken into account. Data protection legislation in the European Union, called general data protection regulation (GDPR), does not preclude the use of big data in AI. Due to the complexity and evolution of data handling for use in AI, as well as the constant evolution of GDPR policy, politicians have a larger role to play in outlining stakeholder responsibilities. AI requires human input, naturally introducing bias. According to researchers CNNs were used to calculate improvements in facial attractiveness following FPS. Racial and gender biases affect perceived social attractiveness, and ethnically diverse facial features are likely to be underrepresented in facial recognition and ML models of AI due to preexisting socioeconomic and cultural barriers. Despite cultural influences and different aesthetic ideologies, cosmetic facial plastic populations include a disproportionately low number of black patients. Despite its usefulness for some populations, it is subject to the bias caused by current trends and the differences in beauty standards among cultures and races [3].

New Ideas and Dimensions

As evidenced by its many applications in surgery, AI is a powerful tool. Using NLP and ML, clinicians can provide more detailed preoperative counseling to patients. It is possible to provide automated and personalized post-operative simulations to patients perioperatively, thus reducing the mystery and anxiety surrounding surgery. Scaffolds for reconstructive procedures could be manufactured using personalized simulations and 3D printing. Medical burnout is a result of the increasing burden of administrative tasks. The power of AI can be harnessed to improve this, thus improving the wellness, efficiency, and retention of our doctors. A patient-surgeon relationship should not be affected by technology, however. As a specialty such as reconstructive plastic surgery, where trust is crucial to achieving positive patient outcomes, this is especially important [19]. AI proponents agree, however, that any use of AI for patient care should follow the same ethical principles as traditional human-provided care; however, this is complicated by the fact that the increasing use of advanced technology in healthcare poses unique questions that traditional ethical principles may not fully address. A related concern has been raised about the likelihood of AI eventually replacing healthcare professionals rather than assisting them. Particularly relevant in technologically-based subspecialties and when considering the development of a robot that can successfully perform basic surgical tasks. Nevertheless, AI's inclusion in medicine should not be feared, but approached with curiosity and excitement for the ways in which AI can contribute to effective, accurate, and patient-centered care when it is used appropriately. Consequently, when evaluating the proper implementation of AI as a tool that may enhance physicians' ability to provide care, educate, and innovate, there must be an examination of the ethical intersection between human thought and virtual processing.

Future Applications

AI implementation in the future may offer opportunities and applications that are currently unimaginable due to continuous advances in technology. AI was used by one group to predict the likelihood of patients developing a surgical site infection after surgery, but further advances in image processing, interpretation of symptoms, and vital sign assessment may eventually allow patients to triage any concerns relating to their surgical site on their own. It is also possible to monitor and forecast postsurgical wound healing times and potential issues with them using AI tools. Furthermore, computer vision-based AI-based systems are useful for coaching and monitoring patients and caregivers during postoperative care, such as exercise routines. By using such software, clinicians may be able to prevent unnecessary presentations to emergency rooms or make medical recommendations to patients who may not have access to timely healthcare or are unsure what to seek. A predictive software application for cosmetic surgeries may also emerge in the future; for example, a program could learn individual surgeons' unique "styles" by analyzing before-and-after pictures and inform patients who wish to undergo similar procedures, based on their preferences for outcome. Moreover, AI could be used to develop patient-specific treatment plans that combine surgical and nonsurgical procedures to improve the results of reconstructive or rejuvenative surgery. One patient may benefit from a deep plane facelift with fat grafting, whereas another may benefit from a mini-facelift with laser and filler [20].

Legal Liability and Bias

The liability of AI-based medical recommendations must be considered, especially when a physician's recommendation is discordant. Researchers evaluated whether postoperative patients were over-triaged or under-triaged and whether they should be treated in an intensive care unit or in a ward based on the utilization of resources and the level of care provided. Using studies like this, surgeons can determine the most appropriate disposition for postoperative management using real-time decision-making tools. Considering the implementation of advanced technologies into patient care would require continued shared decision-making and an informed consent process in which patients would be informed about the risks and benefits of AI-augmented care [21]. As the prevalence of AI in surgery increases, racial, socioeconomic, and gender biases may be amplified. When automated neural networks are trained based on preexisting documentation, the systems are naturally biased by the provider who documented the data. It is also possible to over-test or under-treat patients of lower socioeconomic status if their records are spread across multiple, noncommunicating EHRs, resulting in those patients being perpetually disservice. The researchers propose methods for reducing such bias, including training AI models on populations that mirror those most affected by a particular condition rather than the general population [2, 22]. Additionally, they recommended flagging patients with limited EHR data for predictive models to indicate that the algorithmic outputs need to be reviewed further. This technology can guide patient care only if medical records are aggregated for accurate information processing. In facial plastic surgery, patients are often driven to undergo cosmetic procedures by the pursuit of beauty [23]. It has been shown that ML can be used to determine the attractiveness of faces based on photographs, providing surgical plans to patients who wish to undergo aesthetic procedures. AI may result in a decrease in diversity of perceptions of beauty, and will only influence the goals of those who share standardized beauty ideals [24]. Predictive software is commonly used by surgeons in consultations with patients for aesthetic procedures, so they should be aware of this and minimize their risks of coercion.

Conclusion

AI in healthcare has numerous applications and is likely to continue to grow as AI-based models improve in quality and accuracy. A unique application of AI in plastic surgery is to collect facial profiles and evaluate surgical outcomes objectively. The use of this therapy should be carefully considered and aligned with the physician's judgment. Clinical practitioners should understand how AI may impact their practice in the early stages of its use in FPS. By working with data scientists, surgeons can optimize surgical time and patient outcomes, and possibly reduce the burden of repetitive administrative tasks. In order to take shared decisions and decide on its role in the surgical journey, it will be necessary to gain patient perspectives and improve awareness of AI's increasing capabilities in FPS. The use of AI should continue to advance the capabilities of surgeons and not replace their expertise. There is a possibility that AI programs could make a significant contribution to improving healthcare workflow and delivery in the field of facial plastic surgery. An important discussion regarding the scientific objectivity and biological fact is equally driven by the unique characteristics of humans, as well as the current applications and potential future directions of these intelligent technologies are also included in this review.

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Conflict of Interest

None.

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