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Future of outcomes research in plastic surgery: Artificial intelligence generated synthetic data and predictive models

Berk B. Ozmen ^a, Eugene Pinsky ^b, Graham S. Schwarz ^{a,*}

^a Department of Plastic Surgery, Cleveland Clinic, Cleveland, OH, USA

^b Department of Computer Science, Metropolitan College, Boston University, Boston, MA, USA

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Recent advancements in artificial intelligence (AI) offer groundbreaking potential to enhance personalized care, precision, and safety in plastic surgery.¹ However, current AI applications face limitations in our specialty due to the scarcity of large, diverse surgical outcomes datasets needed to train robust predictive models.² We propose an innovative solution integrating Generative Adversarial Networks (GANs) with AI to generate synthetic data, enabling the development of highly accurate, patient-specific outcome prediction models.

The proposed approach begins with the compilation of single or multi-institutional surgical outcomes datasets containing granular data points and long-term follow-up. These

datasets are then augmented using GANs to generate realistic synthetic data, capturing a broad spectrum of patient profiles and surgical scenarios. This allows training AI models on more comprehensive, representative data. Subsequently, AI predictive models are trained on the GAN-enriched datasets to forecast individualized surgical outcomes and potential complications with high accuracy. To ensure model accuracy, reliability, and generalizability across patient populations and surgical techniques, extensive external validation is performed using data from diverse institutions. Finally, trials are conducted to integrate validated models into clinical workflows and electronic medical records for real-time, point-of-care predictive insights. While this approach holds great promise, careful consideration must be given to the quality, diversity, and representativeness of the generated data to ensure the resulting AI models are reliable, unbiased, and generalizable to real-world clinical scenarios.

* Correspondence to: 9500 Euclid Avenue, A60, Cleveland, OH 44195, USA.

E-mail address: schwarg@ccf.org (G.S. Schwarz).

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This robust approach can be illustrated through two clinical examples. In craniofacial surgery, GANs generate synthetic cases spanning variations in defect size, location, patient age, and comorbidities.³ AI models trained on this data can provide surgeons precise predictions of cosmetic and functional outcomes, guiding optimal reconstructive strategies for each unique patient. Similarly, in breast reconstruction surgery, it is possible to generate synthetic data that captures the full spectrum of patient features, tumor characteristics, and treatment variables. Resultant AI models can predict oncologic outcomes, complications, and esthetic results, empowering highly personalized surgical planning and patient counseling.

Generating high-quality synthetic data requires careful design of GAN architectures (e.g., conditional GANs, Wasserstein GANs) tailored to the statistical properties and complexities of surgical data.⁴ Techniques have evolved from simpler approaches like Monte Carlo sampling to powerful frameworks like Variational Autoencoders (VAEs) and GANs that capture intricate data distributions. The choice of technique depends on data modality, dimensionality, and available sample size. Importantly, models trained on synthetic data offer greater interpretability by allowing the generation of representative samples, identification of salient predictive features, and provision of clear explanations of model behavior to clinicians, facilitating trust and adoption.⁵

Leveraging AI tools for predictive modeling while integrating techniques such as synthetic data generation can unlock the ability to gain insight from limited datasets and, hence, improve precision and personalization in plastic surgery. These powerful generative techniques can be applied to augment data in textual, tabular, image, and video formats. However, to fully harness the potential of this approach, it is crucial to understand the implications, limitations, and complexity inherent in data augmentation with synthetic data. A collaborative approach among computer, data and surgeon scientists is necessary to ensure safe, accurate and clinically actionable output from models trained and validated with synthetic data.

Ethical Approval

Not required.

Financial Disclosure Statement

The authors have no financial interests to declare in relation to this article's content.

Conflict of Interest

None.

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