Artificial Intelligence in Diagnostic Dermatology: Challenges and the Way Forward

Abstract

Artificial Intelligence (AI) has emerged as a transformative force in the field of diagnostic dermatology, offering unprecedented capabilities in image recognition and data analysis. Despite its promise, the integration of AI into clinical practice faces multifaceted challenges that span technical, ethical, and regulatory domains. This article provides a narrative overview of the current state of AI in dermatology, tracing its historical evolution from early diagnostic tools to contemporary hybrid supervised models. We identify and categorize six critical challenges: data quality and quantity, algorithmic development and explainability, ethical considerations, clinical workflow integration, regulatory frameworks, and stakeholder collaboration. Each challenge is dissected from the perspectives of academia, industry, and healthcare providers, offering actionable recommendations for future research and implementation. We also highlight the paradigm shift in AI research, emphasizing the potential of transformer architectures in revolutionizing diagnostic methodologies. By addressing the challenges and harnessing the latest advancements, AI has the potential to significantly impact diagnostic accuracy and patient outcomes in dermatology.

Keywords: *Artificial intelligence, dermatology, diagnosis*

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Introduction

Artificial intelligence (AI) has been making significant strides in various fields of medicine, including dermatology. AI's ability to analyze vast amounts of data and extract meaningful patterns has led to its application in diagnosing skin conditions, especially through image recognition and machine learning algorithms. These advancements have the potential to revolutionize the field of dermatology, enabling faster, more accurate, and cost-effective diagnostics for a range of skin diseases.

The purpose of this review article is to provide a narrative overview of the current state of AI in diagnostic dermatology, along with its challenges and how recent developments can pave the road for the future. We will discuss the challenges and the current approach towards them. At the end, we will briefly discuss how the latest developments in AI can solve some of the pressing problems, but may also create new challenges in the future.

Previous Works on AI Diagnostics in Dermatology

Attempts to diagnose skin disorders through AI can be traced back to the early 1990s, when MelaFind[1] (now archived by Emory University) was developed for melanoma detection. In the last few decades, there have been hundreds of attempts that became gradually more sophisticated as the algorithms became better, more computational powers were available, and more data could be used for training. While traditional machine learning models like k-nearest neighbors (KNN), support vector machines (SVM), random forest, etc., were also tried from time to time,[2] the mainstream focus was on deep learning as manual feature extraction was not necessary. Some of the attempts were on individual diseases (most notably melanoma, but also on psoriasis, atopic dermatitis, acne, rosacea, and many others), and some of them were attempting to diagnose a broad range of dermatological disorders; recently reviewed by Li *et al*.[3] Among all the models studied for accuracy, the highest accuracy (93%) was seen in

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Access this article online

Website: https://journals.lww.com/idoj

DOI: 10.4103/idoj.idoj_462_23

Quick Response Code:

How to cite this article: Sengupta D. Artificial intelligence in diagnostic dermatology: Challenges and the way forward. Indian Dermatol Online J 2023;14:782-7.

Received: 13-Jun-2023. **Revised:** 07-Aug-2023. **Accepted:** 17-Aug-2023. **Published:** 17-Oct-2023.

a hybrid supervised model (combining SVM with deep learning)[4] built on a proprietary image dataset; among the models assessed for area under the curve (AUC), highest score (0.98) was achieved by a model to diagnose onychomycosis which performed significantly better than dermatologists.[5]

However, most models only served an academic purpose; with few developing into real-life applications.[6-9] At the time of writing this review, as per TRACXN data, there are around 44 active startups around the world that utilize AI for skin disorder diagnosis and incorporate that technology into their business model.[10] However, most commercially successful applications do not have a corresponding publication, indicating a disparity between academia and the industry. A recent study also showed the lack of diagnostic accuracy among popular dermatological symptom checkers available in the virtual market.[11]

Recent Developments and Future Directions

The most obvious reason for the limited success of AI models in diagnostic dermatology is that they lack background knowledge (versus human dermatologist who has extensive domain knowledge in the field) along with the fact that for an individual team or group of scientists, the resource is always limited to build larger models with foundational knowledge. Without the foundational knowledge, researchers are forced to focus on any narrow or specific domain (individual models become discrete and cannot be combined into a broader general model). This problem is felt across every domain of AI research, and it was only possible for large technology companies to build high-quality AI models. However, a paradigm shift is being seen in AI research worldwide, along with a new business model empowering small resource-poor teams. The revolution started in 2017 when a group of scientists published a new state-of-the-art architecture known as transformers, which performed better than convolutional neural networks (CNN), recurrent neural network (RNN), and all ensemble (combined) methods.[12] The basic principles are shown in Figure 1, though a full discussion is beyond the scope of this review. However, afterward, it gave rise to multiple foundational models (e.g., Generative Pre-trained Transformer 3 (GPT-3), Bidirectional Encoder Representations from Transformers (BERT), DALL-E, flamingo, etc.), which are trained on massive amounts of data and can perform a wide variety of tasks.[13] The public interest, however, peaked after the release of ChatGPT (a chatbot by openAI based on GPT-3.5 architecture), which set a record by acquiring 100 million users within 2 months of its release.[14] Apart from these general foundational models, attempts have also been made to create foundational models specifically for the medical domain.[15] Readers can refer to the primer by Goodman *et al.* written for doctors regarding how foundational models work and their possible impact on our field.[16]

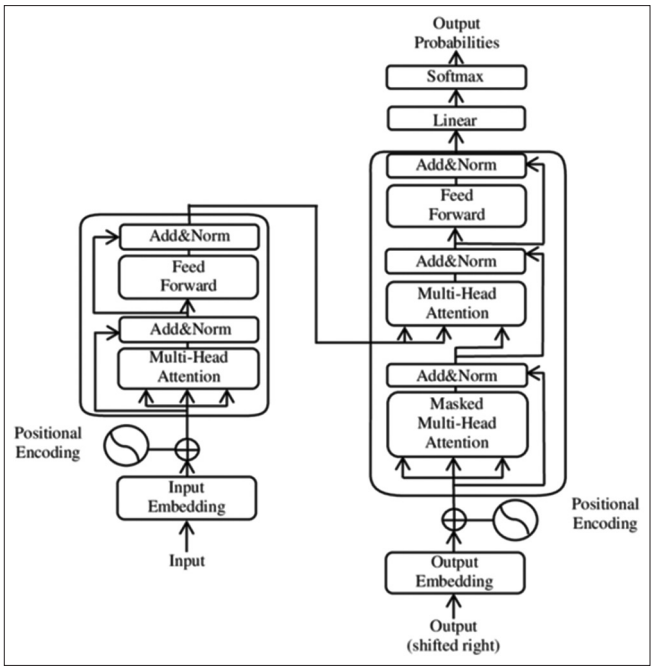

Figure 1: Basic model of a transformer architecture. Source: Yuening Jia (https://commons.wikimedia.org/wiki/File: The-Transformer-model-architecture.png), The-Transformer-model-architecture", https://creativecommons.org/licenses/by-sa/3.0/legalcode. Permission from original source to be obtained

The business model for most such foundational models is that they let developers use their application programming interface (API), on a pay-per-usage basis and let them build custom applications with their own dataset but on top of a foundation of background knowledge. It, however, remains to be seen how much these foundational AI models can address the issue of lack of data in adequate quality and quantity (we will describe this separately later in this article) and what new challenges and opportunities they pose to the new generation of developers.[13,16]

Current Challenges

When two complex fields like dermatology and technology intersect, there are many challenges that need to be overcome. It is, therefore, highly important that each stakeholder clearly understands its limitations and the point of view of other stakeholders as well to build a sustainable ecosystem. Unfortunately, most available literature usually focuses on only one aspect, depending on the nature of the document (academic articles, policy papers, market research documents, etc.). In this review, we will try to understand the complex interdependencies of various challenges and how to improve collaboration among stakeholders to build a thriving ecosystem. We will discuss these under six categories, summarised in Table 1.

Data Quality and Quantity

This is the first and major challenge faced by developers. Clean, properly, and consistently annotated, high-quality, and adequate amounts of data are not easy to acquire,

Table 1: Current challenges in AI diagnostics in dermatology – Analysis from multiple stakeholders' perspectives

Major challenge segment	Who is having the problem	Who can solve it and how
Access to high-quality, diverse, and representative data	Developers	Developers, startups, academia: Collaborate on data collection
Ensuring explainability and interpretability of AI models	Developers, clinicians	Developers: Adopt explainable AI techniques
Developing algorithms with strong generalizability	Developers	Developers, academia: Collaborate on research and validation
Addressing ethical concerns	Government, developers	Developers: Follow ethical guidelines, reduce bias
Adapting to regulatory frameworks	Developers, startups	Developers: Collaborate with government, ensure compliance
Navigating complex regulations	Startups, industry	Startups, government: Collaborate on policy development
Building trust among clinicians and patients	Startups, industry	Startups, developers: Demonstrate clinical validity and utility
Ensuring data privacy and security	Startups, patients	Startups, developers: Implement robust security measures
Scaling AI solutions to meet market demands	Startups, industry	Startups: Optimize algorithms, collaborate with academia
Attracting funding and investments	Startups, industry	Startups: Demonstrate potential impact, collaborate with partners
Integrating AI tools into existing workflows	Clinicians	Developers, startups: Design user-friendly and adaptable tools
Gaining trust in AI-driven diagnoses	Clinicians, patients	Developers, startups: Transparent evaluation, clinician education
Acquiring AI training and education	Clinicians	Startups, academia, Government: Offer education and training
Ensuring AI does not compromise patient care	Clinicians, patients	Developers, clinicians: Focus on human-AI collaboration
Developing regulatory frameworks for AI in healthcare	Government	Government, developers, startups: Collaborate on policy
Ensuring ethical use of AI in dermatology	Government, developers	Government, developers: Establish and enforce ethical guidelines
Balancing AI innovation and patient privacy	Government	Government, developers, startups: Collaborate on policy
Encouraging collaboration between stakeholders	Government	Government, developers, Startups, academia: Foster partnerships
Allocating resources and funding for AI in dermatology	Government	Government: Support AI research and development initiatives

AI=artificial intelligence

especially when funding or external support is limited. For an image-based model, the quality and associated parameters in images[17] are arguably the strongest predictors of any model's success. A large dataset is also required to ensure representativeness for different demographics and different conditions (it would be easier to build a model for skin cancer detection, rather than inflammatory skin conditions). The problem is known as the "curse of dimensionality".[18]

The most logical and fair solution is to build large open-source, anonymized, representative, and regularly updated datasets that will be available for all developers. Though dozens of such efforts exist (most notably the Society for Imaging Informatics in Medicine (SIIM)-ISIC (International Skin Imaging Collaboration),[19] most data is still protected by individual institutions or electronic medical records (EMR) software vendors. Low usage of EMR or poor digital adoption makes it more challenging for developing countries like India.[20] However, a stopgap solution in the meantime can be developing generative algorithms to artificially create representative images using special techniques.[21]

Algorithm Development and Explainability

This is another foundational challenge for AI developers because, by default, modern machine learning algorithms are like "black boxes"; that is, they cannot explain why they took some specific decision or recommended a particular approach.[22] This can create valid concerns and mistrust among dermatologists and patients, especially when legal compliance is still a grey zone, so by default, clinicians are responsible for any unintended consequences.[23] To overcome this challenge, developers need to collaborate with academia and take a multidisciplinary approach.

Explainable artificial intelligence (XAI) is a large field, and detailed discussion is beyond the scope of this review. The most common and traditional approaches are "post hoc"; that is, the interpretation is made after the result is obtained and can be categorized into four main approaches – interpretable local surrogates, occlusion analysis, integrated gradient, and layerwise relevance propagation (LRP).[24] However, in the recent transformer-based models, the attention mechanism can itself be interpreted as a form of explainability, though

recently, new techniques have been proposed beyond simple attention visualization.[25] Multimodal approaches are also being developed primarily for skin disorders[26] and have recently been reviewed by Hauser *et al*.[27]

Ethical Considerations and Trust Building

The issue of ethics in healthcare is multifaceted, challenging, and evolving continuously. Ideally, every stakeholder should participate in building an ethical framework for the use and development of AI in direct patient care. The Indian Council of Medical Research (ICMR) has recently issued an ethical guideline regarding AI that developers need to follow.[28] This is also intrinsically linked with the trust that is currently lacking among both dermatologists (national survey[29]) and the general population.[30]

However, at present, we are witnessing a watershed moment in AI acceptance among the general public after the phenomenal success of ChatGPT and other generative AI tools. As per a recent consumer-facing survey, more than 70% of participants say that they would consider an AI-generated answer at least credible,[31] a huge leap from the previous data points. However, for a sensitive field like healthcare, this would always be a work in progress that requires continuous and deliberate efforts from all stakeholders.

Integration into clinical workflow

Along with trust, many other factors turn out to be equally, if not more, important for the proper integration of AI into the clinical workflow of a practicing dermatologist. Start-ups or institutions should work closely with dermatologists to identify their needs, keep the switching cost low by making the process easy to use, and gain their trust by using updated and validated algorithms. All of these are nice-sounding terminologies but difficult to deploy in real-life settings.[32] We recommend a modern lean approach to systematize such transformational shifts in any sector, including dermatology.[33]

Regulatory frameworks and compliance

How much regulation is ideal for a certain market is a debatable topic in the field of economics or political sciences, and rightfully so.[34] When public or a large community (like doctors) interests are involved, it is essential that the government or representative associations keep proper regulatory frameworks in place (versus the "free" market in a neoliberal ideology) to ensure community interests in the long run. Examples of broad regulatory frameworks are AI ethics guidelines by the European Commission[35] and ICMR,[28]; however, there are also specific guidelines, such as a 9-point checklist created by an Australian research group specific for AI in skin cancer diagnosis,[36] and guidelines for image-based AI development and assessment by an international working group.[37]

While the importance of regulations cannot be ignored, on the other hand, over-regulation can hinder AI research and development and may not always be practical to implement (the inner working of most AI model is complex and proprietary), as pointed out by an expert group in Pew Research Center.[38] At the time of writing this article, ChatGPT was temporarily banned in Italy over privacy concerns[39], whereas virtual private network (VPN) searches skyrocketed, indicating positive public sentiment towards AI usage over privacy risks in Italy.[40]

Collaboration, Funding, and Resource Allocation

As most challenges in AI are multisided, that is, involving multiple stakeholders, collaboration from different stakeholders is often required to create a complete and thriving ecosystem. However, AI research is currently a heavily funded (more than 16 billion dollars in the last 3 months[41] up to April 19, 2023) and highly competitive sector because of the potential profit opportunities. On the other hand, we have witnessed some spectacular failures in the last decade alone, ranging from small skin cancer detection startups[42] to big tech companies like IBM Watson[43] and the diabetic retinopathy project by Verily[44] (owned by Google).

AI in dermatology diagnosis is a promising sector but requires collaboration among multiple disciplines/industries. Startups and companies should closely work with academia and scientists to understand the potential and limitations of various available technologies and also with dermatologists (and possibly other healthcare workers) to understand the needs and opportunities. Finally, government and private funds should be able to identify promising projects and ensure they grow to their full potential. The Indian government recently launched a program to provide financial assistance of up to 50 Lakhs (5,000,000 INR) to promising startups.[45]

Imagining the Future – The Road Ahead of Us

While just a few years ago, AGI (artificial general intelligence) seemed like a distant dream, today, we are closer to it more than ever, as few researchers claimed that GPT-4 might have shown early signs of AGI.[46] As AI develops at an exponential pace, we can only predict how some of the above challenges will be addressed in the near future.

- Generative AI and advanced data synthesis techniques could enable the creation of high-quality, diverse, and representative training data for AI models in dermatology. Large foundational models will act as background knowledge bases to reduce the need for massive datasets.
- AI advancements, especially large language models, will lead to improvements in explainability and interpretability, making AI-driven decisions more transparent and trustworthy. GPT-4 is already multimodal,[47] though that feature is not yet available to

the public at the time of writing this review. An obvious benefit of multimodal AI models would be the ability to incorporate meta-data from patients to improve diagnostic accuracy.

- AI systems will incorporate ethical guidelines by design, minimizing biases and building trust among clinicians, patients, and other stakeholders.
- Enhanced AI technologies will facilitate the seamless integration of AI-driven tools into clinical workflows, fostering human-AI collaboration and improved patient care.
- Adaptive regulatory frameworks, developed in collaboration with AI stakeholders, will balance innovation and patient safety while AI systems will ensure compliance by design.
- Increased collaboration among academia, industry, and governments, fuelled by AI advancements, will lead to greater funding and resource allocation for AI research in diagnostic dermatology.

Conclusions

In this review, we have explored the current state, recent developments, and challenges in diagnostic dermatology with AI and our current approach to solving them. However, we also discussed upcoming developments and what they could potentially mean to our field. We are looking forward to a world of large foundational models with potential AGI (artificial general intelligence) on the horizon, giving rise to new challenges and opportunities for physicians, patients, and mankind at large.

Acknowledgements

GPT-4 (accessed through the ChatGPT interface) was used to arrange the content in a more logical and coherent format.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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