Artificial intelligence: Its role in dermatopathology

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Abstract

Artificial intelligence (AI), a major frontier in the field of medical research, can potentially lead to a paradigm shift in clinical practice. A type of artificial intelligence system known as convolutional neural network points to the possible utility of deep learning in dermatopathology. Though pathology has been traditionally restricted to microscopes and glass slides, recent advancement in digital pathological imaging has led to a transition making it a potential branch for the implementation of artificial intelligence. The current application of artificial intelligence in dermatopathology is to complement the diagnosis and requires a well-trained dermatopathologist's guidance for better designing and development of deep learning algorithms. Here we review the recent advances of artificial intelligence in dermatopathology, its applications in disease diagnosis and in research, along with its limitations and future potential.

Key words: Artificial intelligence, dermatopathology, convolutional neural networks

Introduction

Artificial intelligence/machine intelligence, a major area of research, is likely to have a tremendous impact on various aspects of healthcare. The advent of artificial intelligence could lead to a paradigm shift in our clinical approach and make it essential for dermatologists to have knowledge of artificial Intelligence.[1] With a large clinical, dermoscopic and pathological image database, dermatology has also taken a prime position in artificial intelligence implementation.[2] Pathology has been traditionally restricted to microscopes and glass slides, but with recent advancements, it has transitioned into a digitally oriented branch.[3] Whole slide imaging in surgical pathology and dermatopathology has proven to be on par with traditional microscopes for most diagnostic classes except melanocytic lesions.[4] In addition to whole slide imaging, free-hand smartphone photography has facilitated digital image capturing[5] and archiving of large numbers of tissue slides.[6] Whole slide imaging is expensive and not readily available in all laboratories, hence artificial intelligence using free-hand smartphone photography may be a feasible option. However, the accuracy of artificial intelligence in whole slide imaging may outweigh the use of AI for the interpretation of smartphone images, as whole slide imaging utilises a high-resolution trinocular microscope with robotic control of the intensity of illumination and unlike smartphone images, whole slide imaging scanners capture sequential images to get an exact replica of the glass slide. However when whole slide imaging is not feasible, artificial intelligence using smartphone photography can facilitate digital image capturing and aid in diagnostic dermatopathology. Compilation of digital pathological images is a source not only for education but also for machine learning research. A study by Schaumberg[7] *et al.* on artificial intelligence in dermatopathology demonstrated the first machine learning based pan-disease and pan-tissue image database for disease diagnosis and immunostaining. In this review, we provide an overview of the applications of artificial intelligence in dermatopathology, its challenges and limitations.

Artificial intelligence and deep learning

AI is defined as a field of computer science that aims to mimic human intelligence with a computer system.[8] Machine learning is a subset of artificial intelligence that aims to teach machines to learn tasks automatically by inferring from data patterns. This type of learning can be supervised, semi-supervised and unsupervised.[2,9] Neural networks are flexible mathematical models that use multiple algorithms comprising input, hidden

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and output layers to identify complex relationships within a large database.[10] Neural networks are currently the most popular technique of machine learning, especially the two subtypes called deep learning and convolutional neural networks. Data fed through the input layer is processed in the hidden multiple layers of algorithmic processes and the processed data is displayed in the output layer. In a simple neural network, there are only one or few layers of nodes between the input and the output layers. However, with growing computational power, it is possible to infinitely increase the number of hidden layers making the machine more sensitive and specific. This process of outcome estimation with multiple numbers of hidden layers, where each layer can recognise specific information from the database, is called deep learning.[8] Deep learning utilises this cascade of numerous layers with nonlinear processing units for data extraction and analysis. A combination of deep learning, powerful graphic processing and increased application of digital images has helped to explore the effects of deep learning.[11]

Convolutional neural networks are a subclass of neural networks in which the inputs are passed through infinite hidden layers, which analyse the image. The image is broken down into a collection of pixels and each node or 'neuron' is assigned a characteristic feature like colour, size and shape and finally the output is generated.[12] A type of convolutional neural network known as the region-based convolutional neural network or R-convolutional neural network can identify a particular object within an image; for example, in dermatology it can determine the location of cutaneous lesions using various algorithms.[13] Based on their capability to extract a complex image and make analyses or predictions without any help from humans, convolutional neural networks may be considered an ideal tool in dermatopathology.

Artificial intelligence in dermatopathology

The concept of artificial intelligence in dermatopathology dates back to 1987, when a text-based system TEGUMENT[14] was used on a personal computer. It was designed to identify 986 histopathological diagnoses using light microscopic images and had a diagnostic accuracy of 91.8% compared to a qualified dermatopathologist.[14] Significant discordant and non-classifiable diagnoses were recorded, respectively in 4.8% and 3.4% of cases only. However, it required traditional medical information to be re-organised in the system, making it more of a computer-aided human diagnosis than primarily a machine-based analysis. During that period, due to the lack of equipment/technologies needed to capture whole slide imaging, the concept of human-independent image analysis was presumed to be non-feasible. However in recent times, it is a reality for machine-based accurate classification of routine diagnosis.[15]

Artificial intelligence in diagnostic dermatopathology

In a study model,[11] deep learning algorithms were designed to recognise the whole slide imaging of dermal nevus, seborrheic keratoses and nodular basal cell carcinoma. The images were disintegrated into pixels and data was analysed. In comparison to the diagnostic accuracy of light microscopy by a pathologist, the accuracy of deep learning algorithms was 99.3% for dermal nevus, 99.5% for nodular basal cell carcinoma and 100% for seborrheic keratoses. Ianni[16] *et al.* designed a deep learning algorithm in pathology taking into account haematoxylin and eosin stained whole slide imaging and classified them into four diagnostic classes: basaloid, squamoid, melanocytic and other. This system incorporated three convolutional neural networks that work sequentially to arrive at the most probable diagnosis. These convolutional neural networks assist in image adaption and then identify the region of interest so that eventually the third or the final convolutional neural networks can process or diagnose the image based on histological characteristics. Though it could only classify them into these four categories, it was successful in the diagnosis of routine images even with an artefact, poor staining or varying pathological evidence. A limitation was the requirement of digital computational resources. However, it can be overcome by the use of smartphones. This highlights the potential use of artificial intelligence in resource-limited areas with high incidence or prevalence of skin cancers. Artificial intelligence implementation in tumour pathology is mainly involved in tumour diagnosis, grading, staging and prognostic prediction as well as in identifying genetic (gene mutations or HLA associations) or pathological features.[17]

Artificial intelligence in melanoma diagnosis

It is most important for dermatopathologists to distinguish malignant from benign lesions as there is a significant difference in therapeutic decisions thereafter. In order to differentiate melanoma from nevus, Hekler *et al.*,[18] used 695 melanocytic neoplasms and classified them into nevus or melanoma. All the stages of melanoma and all types of nevi like compound, junctional and congenital nevi were represented. All the haematoxylin and eosin stained sections were scanned and a convolutional neural network was trained using this image database. In this study, the convolutional neural network significantly (P - 0.016) outperformed the pathologists in accurate of histopathological diagnosis of nevi and melanoma. The diagnostic discordance between a dermatopathologist and artificial intelligence was 20% for nevi, 18% for melanoma and 19% overall. This was similar to the discordance of 25–26% described among dermatopathologists.[18] Inter-observer variability can result in a false positive diagnosis of melanoma, especially in cases of Spitz nevus. However, this can be overcome by the ability of the dermatopathologist in selecting representative images, which has a profound effect on the accuracy and efficacy of validation and adequate training of convolutional neural networks. In other words, deep learning algorithms are capable of overcoming the misdiagnosis of Spitz nevi when efficiently trained by dermatopathologists[19]. These neural networks can also predict the recurrence rate of distant metastases and evaluate the survival rate in the early stages of melanoma.[20] A study by Logu *et al.*,[21] developed an artificial intelligence to recognize histopathological images of cutaneous melanoma. Here, biopsies of 791 patches of normal skin and 1122 patches of pathological tissue were used for testing the diagnostic accuracy, sensitivity and specificity of convolutional neural networks and comparing it with expert dermatopathologists as reference. The results showed a high diagnostic accuracy of 96.5%, sensitivity of 95.7%, specificity of 97% and concluded that a deep learning system trained to recognise melanoma achieves higher accuracy compared to experts (91.4% accuracy).

Artificial intelligence in non-melanoma skin cancers diagnosis

A study by Olsen *et al.*,[11] to determine the accuracy of a deep learning algorithm in the diagnosis of three dermatopathological conditions using whole slide imaging concluded that AI could accurately classify 99.5% of nodular BCC (n = 200), 99.4% of dermal nevi (n = 125) and 100% of seborrheic keratoses (n = 125). In contrast to diagnosing of melanoma and differentiating it from pigmented nevi, which is a simple binary classification, diagnosis of non-melanoma skin cancers (squamous cell carcinomas, basal cell carcinomas) is a more difficult task due to their complex classification and as the differential diagnoses include various benign and malignant diseases as well as inflammatory dermatoses. Tschandl[22] *et al.* conducted a study to demonstrate the accuracy of convolutional neural networks in identifying and accurately diagnosing non-pigmented lesions using clinical and dermoscopic images and compare it with the diagnoses done by 95 clinicians with 62 qualified dermatologists. Convolutional neural networks did not achieve a higher percentage of accurate diagnosis (37.3%) compared to the experts (40%) and it was more accurate in the diagnosis of common skin cancers like basal cell carcinoma, actinic keratoses, squamous cell carcinoma and keratoacanthoma but it was less accurate than the clinicians in the diagnosis of rare non-pigmented malignancies like amelanotic melanoma. This study emphasised the importance of data input in determining accurate results and also concluded that artificial intelligence, at present, needs more extensive training and data inputs, for it to be more accurate in the diagnosis of non melanoma skin cancers.

Artificial intelligence in other dermatological diseases

A deep learning algorithm has been used in the diagnosis of various dermatological diseases like psoriasis, atopic dermatitis, onychomycosis and rosacea.[13,23] However, compared to skin neoplasms, there is still a paucity of research on the use of artificial intelligence in these inflammatory dermatoses based on clinical and pathological images. In dermatopathology education, artificial intelligence has great potential in being used for visual diagnosis and for diagnostic reporting. Artificial intelligence is able to diagnose psoriasis and differentiate it from atopic dermatitis and other dermatoses based on clinical images; however, there is a paucity of literature as well as a lack of artificial intelligence training in histopathological differentiation of common inflammatory dermatoses like psoriasis or psoriasiform dermatoses.

Publicly available datasets for skin cancers include DERMOFIT IMAGE LIBRARY, DERMNET-NZ, CANCER GENOMA ATLAS.

Attitude of dermatopathologists towards artificial intelligence

Polesie *et al.* conducted an anonymous voluntary online survey among dermatopathologists and found that they were optimistic about implementation of artificial intelligence and concluded that there is a strong need for artificial intelligence education and its application in dermatopathology.[3] Artificial intelligence is ideally beneficial in assisting difficult tasks like the evaluation of human epidermal growth factor receptor-2 expression by immunohistochemistry, that are prone to human error. Convolutional neural networks are trained to differentiate seborrheic keratoses from keratinocytic tumours, and nevi from melanomas both clinico-dermoscopically and histopathologically with sensitivity and specificity equal to those of well-trained dermatologists and dermatopathologists. Hence, artificial intelligence plays an integral role in diagnostic dermatopathology and provide pathologists with new tools to accelerate workflow (by reducing the burden on pathologists by increasing the speed of screening the slides and improving the efficiency of dermatopathologists by accurately diagnosing benign and malignant skin lesions), enhance diagnostic accuracy and reduce errors.

Limitations

Although artificial intelligence has promise in the field of dermatopathology, there is still a narrow classification system in diagnosis which limits the use of artificial intelligence in the accurate diagnosis of various dermatological conditions, as artificial intelligence is not used extensively in clinico-pathological diagnosis of various dermatoses.[24]

Dermatopathologists are well trained to recognise as well as exclude a wide variety of differential diagnoses, but most convolutional neural networks can only indicate if the image is positive or negative for a specific disease.

There is also a wide inter-observer variability among pathologists, which makes it a challenge to efficiently train the artificial intelligence. Further, the current image database is insufficient and image sharing among sources is limited, which again affects the efficient functioning of artificial intelligence.

Artificial intelligence has a major technical component and requires interdisciplinary participation to build effective algorithms in order to improve workflow efficiency.

At present, artificial intelligence can recognise only a very few specific conditions but the patients can present with varied clinical manifestations and pathological presentations; hence diagnosis can be a challenge. Dermatological artificial intelligence is trained at identifying only one or group of specific dermatoses and sometimes, patients can present with multiple dermatoses and unusual manifestations of a typical dermatoses, which the artificial intelligence is not yet trained to identify. Hence, image data and patient information need to be integrated so that artificial intelligence can comprehensively analyse the data, thereby playing a greater role in diagnosis, decision making and prognosis of a disease.

A lot of legal, ethical and data privacy issues (in terms of maintaining anonymity of the slides) need to be effectively tackled.

Finally, artificial intelligence is not a substitute for communication between doctors and patients and it cannot provide holistic patient care.

Challenges for artificial intelligence in dermatopathology

Digital pathological images consist of millions of pixels with higher magnification. This can lead to technical challenges like incorrect labelling, and need for high quality training to avoid errors due to inter-class similarities and intra-class dissimilarities.[25]

In comparison to a clinician who has access to appropriate medical history and clinical information, a histopathological image-based deep learning algorithm may not perform on par. A multimodal approach would be needed for accurate diagnostic predictions, with clinical and imaging data combined to develop fusion algorithms.

Conclusion

With the advent of digital pathology and advanced computational resources, artificial intelligence in dermatopathology has made encouraging progress and gained attention in recent years. Artificial intelligence is well-trained in simple binary classification in dermatopathology like in melanoma diagnosis, however diagn osis of non-melanoma skin cancers with complex classification and significant inter-class similarities and intra-class dissimilarities, is a more difficult task. With advances in research, data augmentation and a multi-disciplinary approach, artificial intelligence has the potential to outperform dermatologists and pathologists not only in the diagnosis of skin cancers but also for various other dermatoses.

In conclusion, it is essential to embrace artificial intelligence, but it is developed and trained by human experts ; it is dependent on clinicians and cannot replace humans in providing humanistic care.

Declaration of patient consent

Patient consent not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

References

1. Eapen BR. Artificial intelligence in dermatology: A practical introduction to a paradigm shift. Indian Dermatol Online J 2020;11: 881–9.
2. De A, Sarda A, Gupta S, Das S. Use of artificial intelligence in dermatology. Indian J Dermatol 2020;65:352–7.
3. Polesie S, McKee PH, Gardner JM, Gillstedt M, Siarov J, Neittaanmäki N, *et al.* Attitudes towards artificial intelligence within dermatopathology: An international online survey. Front. Med 2020;7:591952.
4. Kent MN, Olsen TG, Feeser TA, Tesno KC, Moad JC, Conroy MP, *et al*. Diagnostic accuracy of virtual pathology vs traditional microscopy in a large dermatopathology study. JAMA Dermatol 2017;153:1285–91.
5. Morrison AS, Gardner JM. Smart phone microscopic photography: A novel tool for physicians and trainees. Arch Pathol Lab Med 2014;138:1002.
6. Madabhushi A, Lee G. Image analysis and machine learning in digital pathology: Challenges and opportunities. Med Image Anal 2016;33:170–5.
7. Schaumberg AJ, Juarez-Nicanor WC, Choudhury SJ, Pastrián LG, Pritt BS, Prieto Pozuelo M, *et al*. Interpretable multimodal deep learning for real-time pan-tissue pan-disease pathology search on social media. Mod Pathol 2020;33:2169–85.
8. Gomolin A, Netchiporouk E, Gniadecki R, Litvinov IV. Artificial intelligence applications in dermatology: Where do we stand? Front Med (Lausanne) 2020;7:100.
9. Yu K, Syed MN, Bernardis E, Gelfand JM. Machine learning application in the evaluation and management of psoriasis: A systematic review. J Psoriasis Psoriatic Arthritis 2020;5:147–59.
10. Eapen BR. ‘Neural network’ algorithm to predict severity in epidermolysis bullosa simplex. Indian J Dermatol Venereol Leprol 2005;71:106–8.
11. Olsen TG, Jackson BH, Feeser TA, Kent MN, Moad JC, Krishnamurthy S, *et al*. Diagnostic performance of deep learning algorithms applied to three common diagnoses in dermatopathology. J Pathol Inform 2018;9:32.
12. Nichols JA, Herbert Chan HW, Baker MAB. Machine learning: Applications of artificial intelligence to imaging and diagnosis. Biophys Rev 2019;11:111–8.
13. Chan S, Reddy V, Myers B, Thibodeaux Q, Brownstone N, Liao W. Machine learning in dermatology: Current applications, opportunities, and limitations. Dermatol Ther (Heidelb) 2020;10:365–86.
14. Potter B, Ronan SG. Computerized dermatopathologic diagnosis. J Am Acad Dermatol 1987;17:119–31.
15. Wells A, Patel S, Lee JB, Motaparthi K. Artificial intelligence in dermatopathology: Diagnosis, education, and research. J Cutan Pathol 2021;48:1061–8.
16. Ianni JD, Soans RE, Sankarapandian S, Chamarthi RV, Ayyagari D, Olsen TG, *et al*. Tailored for real-world: A whole slide image classification system validated on uncurated multi-site data emulating the prospective pathology workload. Sci Rep 2020;10:3217.
17. Jiang Y, Yang M, Wang S, Li X, Sun Y. Emerging role of deep learning-based artificial intelligence in tumor pathology. Cancer Commun (Lond) 2020;40:154–66.
18. Hekler A, Utikal JS, Enk AH, Berking C, Klode J, Schadendorf D, *et al*. Pathologist-level classification of histopathological melanoma images with deep neural networks. Eur J Cancer 2019;115:79–83.
19. Hart SN, Flotte W, Norgan AP, Shah KK, Buchan ZR, Mounajjed T, *et al*. Classification of melanocytic lesions in selected and whole-slide images via convolutional neural networks. J Pathol Inform 2019;10:5.
20. Kulkarni PM, Robinson EJ, Pradhan JS, Gartrell-Corrado RD, Rohr BR, Trager MH, *et al.* Deep learning based on standard H&E images of primary melanoma tumors identifies patients at risk for visceral recurrence and death. Clin Cancer Res 2020;26:1126–34.
21. De Logu F, Ugolini F, Maio V, Simi S, Cossu A, Massi D, *et al*. Recognition of cutaneous melanoma on digitized histopathological slides via artificial intelligence algorithm. Front Oncol 2020;10:1559.
22. Tschandl P, Rosendahl C, Akay BN, Argenziano G, Blum A, Braun RP, *et al*. Expert-level diagnosis of nonpigmented skin cancer by combined convolutional neural networks. JAMA Dermatol 2019;155:58–65.
23. Marka A, Carter JB, Toto E, Hassanpour S. Automated detection of nonmelanoma skin cancer using digital images: Asystematic review. BMC Med Imaging 2019;19:21.
24. Li CX, Shen CB, Xue K, Shen X, Jing Y, Wang ZY, *et al*. Artificial intelligence in dermatology: Past, present, and future. Chin Med J (Engl) 2019;132:2017–20.
25. Goyal M, Knackstedt T, Yan S, Hassanpour S. Artificial intelligence-based image classification methods for diagnosis of skin cancer: Challenges and opportunities. Comput Biol Med 2020;127:104065.