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SPECIAL ARTICLE

# Harnessing artificial intelligence for advancing early diagnosis in hidradenitis suppurativa

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## ABSTRACT

This perspective delves into the integration of artificial intelligence (AI) to enhance early diagnosis in hidradenitis suppurativa (HS). Despite significantly impacting Quality of Life, HS presents diagnostic challenges leading to treatment delays. We present a viewpoint on AI-powered clinical decision support system designed for HS, emphasizing the transformative potential of AI in dermatology. HS diagnosis, primarily reliant on clinical evaluation and visual inspection, often results in late-stage identification with substantial tissue damage. The incorporation of AI, utilizing machine learning and deep learning algorithms, addresses this challenge by excelling in image analysis. AI adeptly recognizes subtle patterns in skin lesions, providing objective and standardized analyses to mitigate subjectivity in traditional diagnostic approaches. The AI integration encompasses diverse datasets, including clinical records, images, biochemical and immunological data and OMICs data. AI algorithms enable nuanced comprehension, allowing for precise and customized diagnoses. We underscore AI's potential for continuous learning and adaptation, refining recommendations based on evolving data. Challenges in AI integration, such as data privacy, algorithm bias, and interpretability, are addressed, emphasizing the ethical considerations of responsible AI deployment, including transparency, human oversight, and striking a balance between automation and human intervention. From the dermatologists' standpoint, we illustrate how AI enhances diagnostic accuracy, treatment planning, and long-term follow-up in HS management. Dermatologists leverage AI to analyze clinical records, dermatological images, and various data types, facilitating a proactive and personalized approach. AI's dynamic nature supports continuous learning, refining diagnostic and treatment strategies, ultimately reshaping standards of care in dermatology.

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KEY WORDS: Hidradenitis suppurativa; Artificial intelligence; Machine learning.

Hidradenitis suppurativa (HS) stands as a chronic autoinflammatory skin condition, marked by the recurrent formation of painful nodules, abscesses, and tunnels beneath the skin, primarily occurring on sites exposed to enhanced friction.[1] Despite its profound impact on the quality of life for those affected, HS frequently poses diagnostic challenges, leading to delays in the initiation of treatment.[2] The intricate and heterogeneous nature of the disease, coupled with its varied clinical presentation, presents a formidable task for healthcare professionals in achieving accurate and early diagnosis.[3]

In recent years, the integration of artificial intelligence (AI) into healthcare systems has introduced new possibilities to enhance diagnostic accuracy and efficiency across various medical disciplines.[4] The transformative potential of AI, particularly in dermatology, holds the key to revolutionizing the early diagnosis of HS. Here, we delve into the evolving landscape of AI applications in dermatology, with a specific emphasis on its role in augmenting precision and promptness in HS diagnosis.[5]

The clinical diagnosis of HS relies primarily on physical examination, medical history, and characteristic lesion

morphology. However, the variability in disease presentation often leads to misdiagnosis or delayed diagnosis, impacting patient outcomes and the initiation of appropriate therapeutic interventions.[6]

The imperative for a more precise and early diagnostic approach is evident, and AI emerges as a transformative solution.

AI, encapsulating machine learning and deep learning algorithms, has showcased remarkable capabilities in image analysis and pattern recognition. In dermatology, AI applications have gained traction for their prowess in processing extensive datasets of skin images, aiding dermatologists in diagnosing various skin conditions with heightened accuracy. The fusion of AI and dermatology proves particularly beneficial in streamlining the diagnostic process and overcoming human limitations in pattern recognition. AI algorithms excel in discerning subtle patterns and variations in skin lesions that might elude the human eye, a critical capability in HS where early lesions can be inconspicuous.[7]

AI provides an objective and standardized analysis of skin images, mitigating subjectivity inherent in traditional diagnostic approaches. This objectivity is pivotal for achieving consistency and accuracy in HS diagnosis. AI integration facilitates the efficient processing of vast datasets, including images, clinical data, and genetic information. This enables a holistic approach to HS diagnosis, considering multifactorial aspects of the disease. AI's ability to detect subtle changes allows for the identification of early-stage HS lesions, crucial for preventing disease progression, minimizing complications, and improving overall outcomes.[8]

Machine learning algorithms, trained on diverse skin image datasets, can learn to distinguish between different skin conditions, including HS. These algorithms continually refine their diagnostic accuracy through exposure to a wealth of data. Deep learning models, inspired by the human brain's structure, excel in recognizing intricate patterns. Neural networks, a subset of deep learning, are invaluable for analyzing dermatological images related to HS.

The integration of AI into dermatological practices has the potential to redefine the landscape of HS diagnosis. Collaborative efforts involving dermatologists, AI developers, and regulatory bodies are essential to validate and refine AI algorithms for HS diagnosis. As the technology evolves, the aim is to seamlessly integrate AI tools into routine dermatological assessments, empowering healthcare professionals to make more accurate and timely diagnoses.[9]

The synergy between dermatology and AI represents a paradigm shift in the diagnosis of skin conditions, including HS. The ability of AI to enhance pattern recognition, provide objective analysis, and enable early detection aligns seamlessly with the unmet needs in HS diagnosis. As research progresses and ethical considerations are addressed, the future promises an AI-powered era in dermatology, where precision and efficiency converge to transform the lives of patients affected by HS. This exploration of AI's role in HS diagnosis sets the stage for a dynamic and transformative journey toward more accurate, timely, and patient-centered care.

## Hidradenitis suppurativa: clinical diagnosis state of the art

The diagnosis of HS currently relies on a combination of clinical evaluation, medical history, and visual inspection of skin lesions. However, despite the presence of these tools, the problem of late diagnosis remains a significant challenge in the management of this disease.[10] Clinicians typically assess patients for the characteristic features of HS, including painful nodules, abscesses, and sinus tracts, often occurring in intertriginous areas. Yet, the clinical presentation of HS can be highly variable, and the early stages of the disease may manifest as subtle symptoms that are easily overlooked or misattributed. This variability and the often-insidious onset contribute to delays in accurate diagnosis, impeding timely intervention and management.

One of the primary issues with the current diagnostic approach is the reliance on visible symptoms, which often only become apparent in later stages of the disease when significant tissue damage has occurred. The late diagnosis of HS is associated with prolonged suffering for patients due to the recurrent nature of abscess formation, leading to pain, scarring, and a negative impact on their quality of life. Moreover, delayed diagnosis hampers the initiation of appropriate therapeutic interventions, contributing to disease progression and complications.[11]

There is a pressing need for more sophisticated clinical tools and algorithms to aid in the early diagnosis of HS.[12] Research efforts are underway to develop imaging techniques, such as ultrasound and magnetic resonance imaging (MRI) and to visualize the subclinical manifestations of HS in its early stages. These tools aim to detect inflammatory changes and structural abnormalities in the affected skin before the emergence of overt symptoms. Implementing such imaging modalities into routine clinical practice could significantly enhance the diagnostic

accuracy of HS, allowing for earlier and more effective interventions.[13]

In addition to imaging, efforts are being made to incorporate machine learning algorithms and AI into the diagnostic process. These advanced technologies can analyze vast datasets, including clinical information and imaging results, to identify patterns associated with HS. Machine learning models have the potential to recognize subtle changes in the skin that may precede the development of overt lesions, enabling early diagnosis and intervention. This approach not only addresses the problem of late diagnosis but also holds promise for improving the overall management and outcomes of HS.[14]

Despite these advancements, challenges persist in integrating these tools into routine clinical practice. The accessibility and cost-effectiveness of imaging modalities, as well as the standardization and validation of AI algorithms, remain areas of active research and development. However, as these technologies continue to evolve,[15] there is optimism that they will play a crucial role in overcoming the diagnostic challenges associated with HS. Early and accurate diagnosis is pivotal for optimizing patient care, minimizing the impact of the disease, and improving the overall quality of life for individuals living with this condition.

## Unlocking the potential of artificial intelligence for tailored diagnosis and treatment in hidradenitis suppurativa

The incorporation of AI into the realm of HS diagnosis and treatment planning entails the amalgamation of diverse datasets, ushering in a comprehensive and individualized approach. Multiple types of data serve as the cornerstone in nourishing AI algorithms, empowering them to craft precise and customized diagnoses for individuals afflicted by HS. Within this expansive dataset:

- clinical records – patient medical histories, encompassing details about prior treatments, disease progression, and concurrent medical conditions, constitute a fundamental component. AI undertakes an in-depth analysis of these records to unveil patterns and correlations, contributing to a nuanced comprehension of individual cases;
- images – dermatological images, including meticulously captured high-resolution photographs of affected areas, emerge as indispensable for AI applications in dermatology. The algorithm's scrutiny of these images enables the recognition of lesion characteristics, severity assessment, and the tracking of temporal changes. This visual data proves vital for the timely detection and continuous monitoring of HS;
- biochemical exams – data derived from biochemical examinations, such as skin swabs or biopsies, furnish invaluable insights into the molecular and cellular dimensions of HS. AI engages in the analysis of this data to pinpoint specific biomarkers associated with disease activity and severity;
- blood exams – routine blood tests furnish systemic information pertaining to inflammation, immune response, and overall health. AI interprets these results within the HS context, correlating systemic factors with the dermatological manifestations of the disease;
- immunology tests – specialized immunological tests, encompassing cytokine profiling and immune cell analysis, contribute to understanding the immune dysregulation that underlies HS. AI navigates this intricate immunological data to identify aberrations that may inform personalized treatment strategies;
- OMICs data – the integration of various OMICs data, including genomics, transcriptomics, and proteomics, presents a multi-layered comprehension of HS at the molecular level. AI deciphers intricate molecular interactions, identifies key pathways, and reveals potential therapeutic targets.

The holistic vision facilitated by AI in the context of HS proves transformative, synthesizing information from this diverse dataset. By considering the interplay between genetic/epigenetic factors, immunological responses, and clinical manifestations, AI unravels the complexities of HS in individual patients. The personalized diagnoses generated by AI meticulously account for the unique genetic makeup, disease history, and current biochemical status of each patient.

Furthermore, the dynamic nature of AI permits continuous learning and adaptation. As more data becomes available and treatment responses are documented, AI algorithms refine their recommendations, ensuring an evolving and tailored approach to each patient's journey with HS. This holistic integration of data types[16] not only elevates diagnostic accuracy but also opens avenues for personalized treatment strategies, optimizing outcomes for individuals grappling with the challenges of HS.

## AI methods to face the hidradenitis suppurativa diagnostic challenges

HS is typically diagnosed through clinical observation by dermatologists, which can lead to inconsistencies in

evaluations using manual scoring systems. There are various scoring systems, such as the Modified Sartorius Score and the Hurley Classification, for HS assessment. The widely used International Hidradenitis Suppurativa Severity Score System (IHS4) categorizes lesions into inflammatory nodules, abscesses, and draining tunnels, providing a graded evaluation of the disease's severity, which is recognized for its validity and is a valuable tool in both clinical research and daily practice.[17, 18] Although the availability of these scoring systems allows for HS to be standardized, their practical application can be challenging, and their validation is limited.[19] Globally, over a third of new HS patients are already at late stages, which may be attributed to a lack of knowledge about the disease among the general population and shame about a disfigured skin area. Meanwhile, recent studies have reported an increase in online searches for HS and questioned the content's readability, quality, and timeliness.[20] Although the advancement of telemedicine in dermatology, utilizing visual cues through smartphone cameras, and health informatics offering promising avenues for enhancing accessibility and patient care,[19] four articles were found through NCBI search using as key words Hidradenitis Suppurativa, and Artificial Intelligence.[19, 21-23]

The field of artificial intelligence in medicine (AIM), wearable electronics, and telemedicine have made considerable progress in recent years, with a surge in publications, media coverage, start-ups, and FDA-approved AIM products.[24] AI has become an integral part of healthcare, encompassing preventive medicine, disease management, and imaging. By tackling the unmet clinical needs that are otherwise unmanageable, AI is advancing medicine with robust technical tools, computational resources, and ongoing research. Our proposed framework aims to provide an integrated and comprehensive AIM platform for HS evaluation, assessment and management, catering to a diverse audience beyond patients and healthcare professionals. Indeed, the presented platform aims to integrate different data.

To succeed in data-driven machine learning for AI in HS, it is vital to have intelligent AI frameworks, innovative strategies, and the integration of diverse data types such as electronic health record (EHR), epidemiology, multi-omics, recent scientific advances, patient lifestyle, and concerns. Robust statistical evaluation methods are essential for model validation, particularly in handling heterogeneous data. Incorporating new machine learning techniques into multidisciplinary tasks can bridge the gap between AI and human intelligence. Therefore, the timely deployment and clinical integration of AIM tools are crucial in the current AI-driven era of medicine, ultimately enhancing patient care. This requires a profound understanding of clinical workflows and a clear roadmap for translating AIM research into clinical practice.

## Challenges and ethical considerations

The integration of AI into dermatology heralds a new era of possibilities, promising substantial benefits in the diagnosis and treatment of skin conditions. However, this transformative journey is not without its challenges. The first among them is the critical issue of data privacy. In the era of AI, vast amounts of patient data, including sensitive images and medical information, are processed and analyzed. Safeguarding this information against unauthorized access and ensuring compliance with privacy regulations become paramount. Striking a delicate balance between the potential insights AI can offer, and the protection of patients' personal data is an ongoing challenge that demands meticulous attention.[25]

Another challenge is the potential for algorithm bias, which can significantly impact the accuracy and fairness of AI-driven diagnoses. If the training data used to develop AI algorithms is not diverse and representative, the resulting model may demonstrate biases, leading to disparities in diagnosis across different demographic groups. Ensuring that AI systems are trained on comprehensive and unbiased datasets is essential to prevent perpetuating existing healthcare disparities and to foster equitable diagnostic outcomes for all patients.

Interpretability of AI decisions is another hurdle in the path of seamless integration into clinical settings. The so-called "black box" nature of many AI algorithms means that healthcare professionals may struggle to understand how the AI arrives at a particular diagnosis or recommendation. Establishing transparent and interpretable AI systems is vital for gaining the trust of clinicians and ensuring that AI complements, rather than replaces, human expertise. This interpretability also plays a role in addressing patient concerns and fostering a sense of confidence in AI-assisted diagnostics.

Ethical considerations form the bedrock of responsible AI deployment in dermatology. Transparency in AI decision-making is a key ethical principle, ensuring that clinicians and patients alike can understand the rationale behind AI-generated recommendations. Human oversight is another crucial aspect, emphasizing the need for healthcare professionals to remain actively involved in the deci-

sion-making process, using AI as a tool to enhance their capabilities rather than replace their expertise.[26] Striking the right balance between automation and human intervention is essential for ethical and responsible AI deployment in dermatological practices.

All in all, while the integration of AI in dermatology holds immense promise for improving diagnostic accuracy and efficiency, navigating the associated challenges is imperative. Addressing issues related to data privacy, algorithm bias, and interpretability is crucial for the ethical and responsible implementation of AI in clinical settings. By mitigating these challenges, the field can harness the full potential of AI to revolutionize dermatological care, providing more precise and timely diagnoses while upholding the highest standards of patient privacy and ethical practice.

## The dermatologists point view: how AI can be integrated in the routine clinical diagnosis and follow-up of hidradenitis suppurativa?

Dermatologists, at the forefront of diagnosing and managing complex skin conditions, are increasingly exploring the integration of AI into their routine clinical practices, with a specific focus on diseases like HS. This chronic skin condition poses unique challenges due to its varied clinical presentations and the need for personalized treatment plans. The utilization of AI in the realm of HS signifies a paradigm shift in the dermatologist's approach, enhancing diagnostic accuracy, treatment planning, and safe and effective long-term follow-up.

In the realm of diagnosis, AI offers a valuable ally to dermatologists by analyzing diverse datasets. Clinical records, a cornerstone of patient's information, can be systematically processed by AI algorithms to identify subtle patterns and correlations that may elude human observation. This is particularly crucial in HS, where the disease progression varies widely among individuals. Dermatologists can leverage AI's ability to process vast amounts of patient data, including medical histories, previous treatments, and comorbidities, to gain nuanced insights into the unique aspects of each case.

The integration of AI in the analysis of dermatological images brings an additional layer of precision to HS diagnosis. High-resolution photographs of affected areas, when fed into AI algorithms, empower dermatologists to

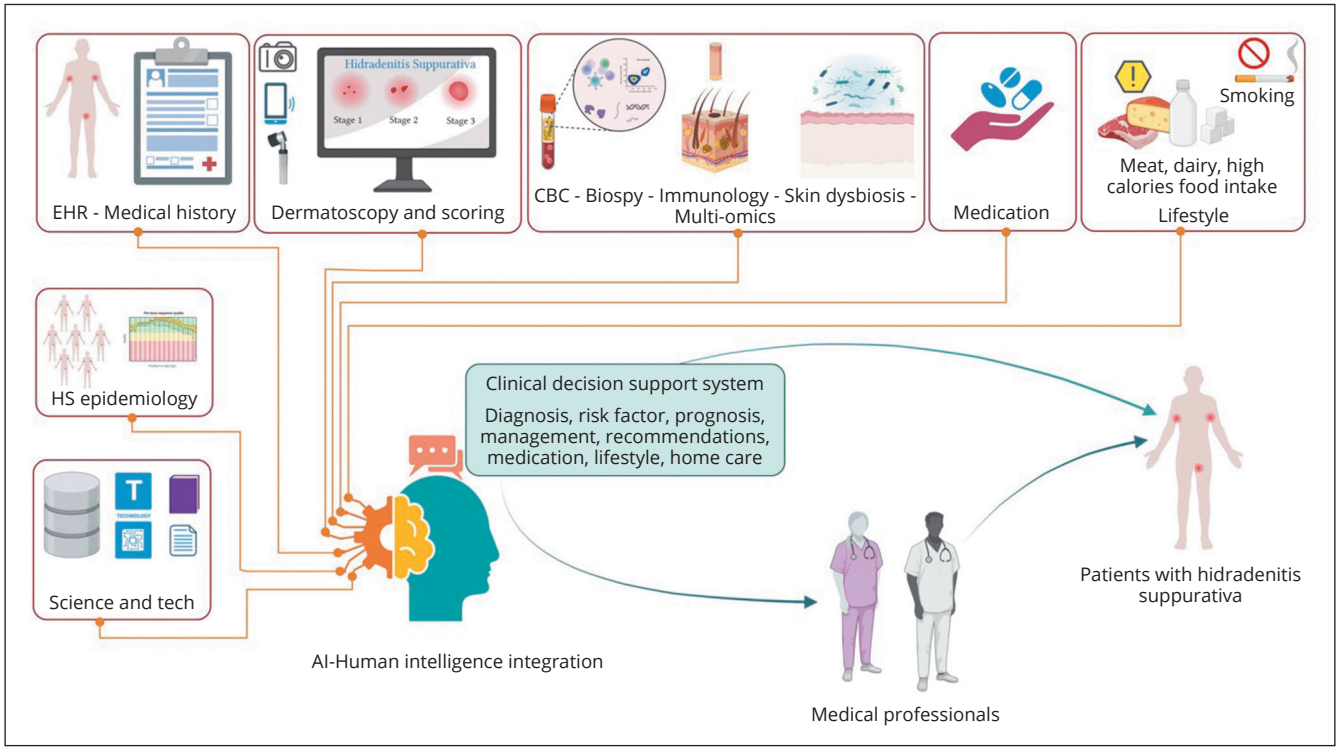


Figure 1.— Framework of AI-powered Hidradenitis Suppurativa Clinical Decision Support System Comprehensive Platform. Created with Biorender.com (credit Dr. Abdelfatteh El Omri).

recognize distinctive lesion characteristics, assess disease severity, and monitor changes over time. This visual data becomes invaluable for early detection and continuous monitoring, facilitating a more proactive and personalized approach to HS management.

Biochemical and immunological aspects of HS, traditionally intricate and time-consuming to analyze, find a streamlined solution in AI applications. By interpreting data from biochemical exams, such as skin swabs or biopsies, AI can pinpoint specific biomarkers associated with disease activity and severity. Specialized immunology tests, including cytokine profiling and immune cell analysis, contribute to understanding the immune dysregulation underlying HS. AI's capability to process complex immunological data enhances the dermatologist's ability to identify alterations that may inform personalized treatment strategies.

Genetic data, playing a pivotal role in understanding the hereditary aspects of HS, undergoes comprehensive analysis through AI algorithms. Dermatologists can benefit from AI-generated insights into genetic predispositions, risk factors, and familial patterns, contributing to a holistic understanding of the disease. The integration of various OMICs data, including genomics, transcriptomics, and proteomics, enriches this understanding by unraveling intricate molecular interactions, identifying key pathways, and uncovering potential therapeutic targets.

## Conclusions

In the routine clinical follow-up of HS, AI demonstrates its dynamic nature. As more patient data becomes available and treatment responses are documented, AI algorithms continuously learn and adapt. Dermatologists can rely on this evolving technology to refine their diagnostic and treatment strategies, ensuring a tailored approach for each patient's journey with HS (Figure 1). The amalgamation of clinical acumen with AI-driven insights empowers dermatologists to not only enhance diagnostic accuracy but also opens avenues for personalized and optimized treatment strategies, thereby improving outcomes for individuals grappling with the challenges of hidradenitis suppurativa. The dermatologist's point of view on AI integration in HS management is characterized by a commitment to precision, personalization, and ongoing learning, ultimately redefining the standards of care in dermatology.

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*Conflicts of interest*

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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*History*

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