Artificial Intelligence [AI] in Psoriatic Disease

Richard Barlow, Anthony Bewley, Maria Angeliki Gkini

Submitted to: JMIR Dermatology
on: June 30, 2023

Table of Contents

Artificial Intelligence [AI] in Psoriatic Disease

Richard Barlow[1]; Anthony Bewley[2] frcp; Maria Angeliki Gkini[2] PhD

[1]Department of Dermatology University Hospital Birmingham NHS Foundation Trust Birmingham GB
[2]Department of Dermatology Barts Health NHS Trust London GB

Corresponding Author:
Maria Angeliki Gkini PhD
Department of Dermatology
Barts Health NHS Trust
Whitechapel Rd
London
GB

Abstract

Background: Artificial Intelligence (AI) is an emerging tool with many applications in numerous medical fields, including dermatology.

Objective: Our objective is to provide an up-to-date literature review on the use of AI in psoriatic disease, including diagnostics and clinical management.

Methods: Literature review

Results: Although the majority of AI studies in dermatology focus on skin cancer, there is growing interest and applicability of AI models in inflammatory diseases, such as psoriasis. Psoriatic disease is a chronic, inflammatory, immune-mediated systemic condition with multiple comorbidities and a significant impact on patients' quality of life. Advanced treatments, including biologics and small molecules, have transformed the management landscape of psoriatic disease. Nevertheless, there are still huge unmet needs. Globally, delay in the diagnosis of the disease and its severity is common due to poor access to healthcare systems. Moreover, despite the abundance of treatments, we are unable to predict which is the right medication for the right patient.

Conclusions: Dermatologists can play a crucial role in the evolIn the future, AI and Machine Learning may be able to predict the clinical course of the disease and , in combination with molecular studies, may even be able to guide our choice of treatment.

(JMIR Preprints 30/06/2023:50451)
DOI: https://doi.org/10.2196/preprints.50451

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?
✔ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.
2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?
✔ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Artificial Intelligence [AI] in Psoriatic Disease

Barlow R[1], Bewley A[2], Gkini MA[2]
[1] Dermatology Department, University Hospitals Birmingham NHS Foundation Trust, UK
[2] Dermatology Department, Barts Health NHS Trust, UK

Corresponding author: Maria-Angeliki Gkini - gkinimargo@gmail.com
Department of Dermatology, Barts Health NHS Trust, Whitechapel Rd, London, E1 1FR

Keywords: artificial intelligence; machine learning; psoriasis; psoriatic arthritis; psoriatic disease; biologics; prognostic models

Abstract

Introduction
Artificial Intelligence [AI] has many applications in numerous medical fields, including dermatology. Although the majority of AI studies in dermatology focus on skin cancer, there is growing interest and applicability of AI models in inflammatory diseases, such as psoriasis. Psoriatic disease is a chronic, inflammatory, immune-mediated systemic condition with multiple comorbidities and a significant impact on patients' quality of life. Advanced treatments, including biologics and small molecules, have transformed the management of psoriatic disease. Nevertheless, there are still considerable unmet needs. Globally, delay in the diagnosis of the disease and its severity is common due to poor access to healthcare systems. Moreover, despite the abundance of treatments, we are unable to predict which is the right medication for the right patient, especially critical in resource-limited settings. AI could be an additional tool to address those needs. In this way, we can improve rates of diagnosis, accurately assess severity and predict outcomes of treatment.

Objective
Provide an up-to-date literature review on the use of AI in psoriatic disease, including diagnostics and clinical management as well as addressing the limitations in applicability.

Methods
We searched the databases Medline, PubMed and Embase using AI AND psoriasis or psoriatic arthritis or psoriatic disease, ML AND psoriasis or psoriatic arthritis or psoriatic disease, prognostic model AND psoriasis or psoriatic arthritis or psoriatic disease until 01.06.2023. Reference lists of relevant articles were also cross-examined for other relevant articles not detected in the initial search.

Results
AI has been identified as a key component to digital health technologies. Within this field, there is the potential to apply specific techniques such as machine learning and deep learning to address several aspects of managing psoriatic disease. This includes diagnosis, particularly useful for remote teledermatology via photographs taken by patients as well as monitoring and estimating severity. Similarly, AI can be used to synthesise the vast data sets already in place through patient registries which can help identify appropriate biologic treatments for future cohorts and those individuals most likely to develop complications.

Conclusion
There are multiple advantageous uses for AI and digital health technologies in psoriatic disease. With wider implantation of AI we need to be mindful of which datasets ML are derived from. This can

lead to limitations particularly with skin of colour.

1. Introduction

Artificial intelligence [AI] is generally regarded as the ability of machines to simulate human intelligence, and typically refers to computers or software. Although the term AI is used daily, a standard definition is lacking. In 1950, Alan Turing suggested a method to examine machine intelligence via an exercise now termed the Turing test. In this exercise an impartial observer deemed a machine intelligent if it was indistinguishable from a human in conversation(1). Nowadays, AI refers to the ability of a machine to communicate, reason and operate independently in both familiar and novel scenarios in a similar manner to a human, and not indistinguishable(2).

AI is distinct from machine learning [ML] although the two terms are often used interchangeably [Table 1] (2). ML is a subset of AI that is related to teaching machines to automatically learn tasks from data by recognising and inferring patterns within them(2). Due to the growth in available patients' medical data ML's potential to comprehend medical tasks has significantly increased. Algorithm can also learn via deep learning [DL] which can be performed without labelled datasets. DL refers to a neural network with multiple layers of 'neurons' that have adjustable weights [mathematical functions](2), with ML to train / test data across its network for improved accuracy and performance.

Table 1. Essential terminology in the field of machine learning and artificial intelligence(2)

Artificial Intelligence	The ability of machines, such as computers, to simulate human intelligence
Machine Learning	Algorithms and statistical models that are programmed to learn from data, therefore recognising and inferring patterns within them. This enables computers to perform specific tasks without explicit instructions from a human operator
Deep Learning	Refers to a neural network with multiple layers of 'neurons' that have adjustable weights [mathematical functions], with ML to train / test data across its network for improved accuracy and performance

Both the US Department of Health and Human Services(3) and the European Union(4) have outlined potential future roles and implementation of AI within healthcare.The National Health Service [NHS] in the United Kingdom has also identified AI as a current and future priority; the 2019 Topol review published by Health Education England includes AI as one of three key digital health technologies. The report also details how to prepare the healthcare workforce to deliver a digital future as a response to keeping up with the increasing demands of our expanding population [Box 1] (5).

BOX 1 Digital Health Technologies

1. *Genomics [reading the genome & writing the genome]*
2. *Digital medicine [telemedicine, apps, sensors & wearables, virtual reality]*
3. *Artificial intelligence [speech recognition, natural language processing (NLP), AI robotics]*

AI has broad applications within medical settings Box 2, all of which need careful consideration regarding appropriate clinical governance(6). Many of these applications naturally lend themselves to dermatology given the visual nature of the specialty and the large datasets already established, Box 3 (7,8). Further steps forward have been taken in screening and diagnosing of melanoma and non-melanoma skin cancers. Numerous applications and digital platforms, using dermoscopic or clinical images, have been already available although their sensitivity and specificity vary. More recently, there is growing interest in the use of AI in inflammatory skin diseases (9).

BOX 2 AI In Healthcare

- AI-assisted robotic surgery
- Virtual nursing assistants
- AI-assisted medical diagnoses
- Medical image analysis
- Drug discovery
- Automated workflow assistance
- Fraud detection
- Medical data security
- Medical risk prediction
- Clinical trials
- Personalise treatment
- Improve gene editing

BOX 3 Uses of AI In Dermatology

- Skin cancer diagnosis
- Onychomycosis assessment
- Ulcer assessment
- Predicting Skin Sensitization Substances
- Novel Applications in Pathology and Gene Expression Profiling
- Psoriasis disease and other inflammatory skin diseases

Psoriatic disease is a common, chronic, systemic inflammatory condition with a significant impact on patient's quality of life. Common comorbidities include psoriatic arthritis, cardiovascular disease, metabolic syndrome and psychiatric / psychosocial impact. More recently researched comorbidities such as liver fibrosis and renal disease also exist (10). Concerning is the fact that these comorbidities can be found also in the US paediatric population (11). Advanced systemic treatments, including biologics and small molecules can improve comorbidities(12).

Globally, the problem of delayed and or incorrect diagnosis of psoriasis remains. Long waiting lists and pressure to prioritise potential malignant lesions also prolongs patients accessing to appropriate specialist dermatology care. In areas of limited resources, access to dermatology can also be a challenge. Identifying the most appropriate treatment for each individual remains an unmet goal, although recently there are updates in the field of genomics and personalised medicine(13,14). Therefore, AI offers progress in both directions, diagnostics and management, Box 4.

BOX 4. Roles for AI in Psoriasis Evaluation Using Skin Images

- Identification and differential diagnosis of psoriasis lesions
- Assessment of severity

Clinical Management

Our objective was to provide an up-to-date literature review on the use of AI in psoriatic disease, including diagnostics and clinical management as well as addressing the limitations in applicability.

1. Methods

We conducted a literature search from the databases Medline, PubMed and Embase using the keywords AI AND psoriasis or psoriatic arthritis or psoriatic disease, ML AND psoriasis or psoriatic arthritis or psoriatic disease, prognostic model AND psoriasis or psoriatic arthritis or psoriatic disease until 01.06.2023. Reference lists of relevant articles were also cross-examined for other relevant articles not detected in the initial search. RB and MAG screened articles and discrepancies were reviewed by AB. Figure 1 demonstrates the flowchart of methodology.

2. Results

Diagnosis and Assessment of Severity

Correct, timely diagnosis is the first step of management in psoriasis; distinguishing it from other similar disorders can be particularly challenging for clinicians and AI alike.

Google has recently launched its own AI-tool for differentiating between 288 conditions and is undergoing validation. Users can upload three well-lit images of the skin, hair or nail of concern from different angles. The tool then asks questions related to personal history and combining this with the image, it suggests a list of possible causative conditions. The user is then signposted to similar matching images and dermatologist-reviewed information (15). This system is underpinned by a DL system formed from a dataset containing over 16,000 pictures of skin disorders. The system was shown to be non-inferior to 6 board-certified US dermatologists and superior to 6 general practitioners(16).

On the scalp, psoriasis and seborrheic dermatitis can look very similar. Multispectral imaging allows pictographic data to be collected from regions of the electromagnetic spectrum not visible to the human eye. Historically speaking, processing such vast data can be time-consuming, the equipment bulky and cumbersome. A smartphone-based multispectral imaging system in conjunction with ML has been used in South Korea to differentiate between psoriasis and seborrheic dermatitis of the scalp – allowing for swifter data interpretation and AI-based diagnosis. The authors used a small hand-held multispectral camera which displayed results on a smart phone screen for diagnosis and monitoring. Kim et al achieved a sensitivity of 65% to 75% and specificity of 70% to 80% in psoriasis diagnosis of the scalp versus seborrheic dermatitis (17). Moreover, the machine learning methods yielded better outcomes versus conventional methods.

Psoriasis can also be differentiated from other similar looking inflammatory disorders. Zhao et al classified 8,021 images of 9 skin conditions using convolutional neural networks into psoriasis versus non-psoriasis(18). Images included lichen planus, lupus erythematosus, basal cell carcinoma, squamous cell carcinoma, atopic dermatitis, pemphigus, seborrheic keratosis and psoriasis from a cohort of patients from a Chinese hospital. Their algorithm was superior to 25 Chinese dermatologists when tested on 100 new images. They reported a misdiagnosis rate of 3% compared to 27% by dermatologists.

Further to diagnosis, severity assessment is key to disease monitoring as well as determining which treatments are indicated. Shrivastava et al used ML to analyse 540 images of skin [270 affected images and 270 non-affected] in a cohort of 30 patients of Indian heritage with psoriasis. Principal component analysis was used to condense the data without losing important data points. This, in combination with computer-aided diagnosis was used to define 3 main components of each image; higher order spectra features, texture features and colour features. This type of ML, when combining the 3 features was proven to be highly effective with a classification accuracy of approximately 99% (19)

More sophisticated assessments such as psoriasis area and severity index [PASI] is widely used and presents an additional challenge for AI with textural changes and thickness featuring in the scoring. This is further complicated by the regional scores which require AI to determine which part of an image is unaffected as a percentage of overall body surface area. Huang et al used a database of 14,096 images from a cohort of 2,367 Chinese patients with psoriasis to estimate PASI. Multiview enhancement block [images from different angles] was implemented to allow all facets of the PASI score to be estimated. These images were then processed with convolutional neural network to extract specific features. Despite the large subjectivity of PASI scoring in clinical practice, the method of DL utilised by the authors were comparable to PASI scores calculated by 43 dermatologists and has been successfully used in 18 different sites via the use of an app (20). This has important ramifications for how we may deal with patients in more remote settings and those patients with less flexibility, where severity needs to be objectively scored.

Okamoto et al developed this concept further via a technique termed, “Single-Shot” PASI. The authors used 705 images of psoriasis, expanded with data augmentation techniques. Expert scoring was used as teacher data for the system to learn from. This DL system was then able to accurately assess psoriasis severity from a single photograph only, reducing inter-user variability and increasing efficiency(21).

Clinical Management

Despite an abundance of classic and novel treatments for psoriasis, including biologics and small molecules, there are vast unmet needs in the management of psoriatic disease. A significant number of patients may not respond to a specific treatment primarily or secondarily or may develop adverse events. Therefore, we are still unable to predict the right treatment for the right patient. Available guidelines can help us select an appropriate biologic agent (22), although understanding and predicting outcomes is much more challenging. Biomarkers that could predict response to biologic therapy would be ideal for clinical care, although a lack of robust experimental data means no consensus exists yet towards application in clinical practice(23). Use of AI to combine genotypic and phenotypic characteristics of psoriasis patients to identify the most appropriate treatment is starting to emerge.

Emam et al, a Danish group in 2020 analysed data from 681 patients with psoriasis from a national registry. Six different ML techniques were used to identify patterns from demographic and clinical data; generalized linear model [GLM], support vector machine, decision tree, random forest, gradient-boosted trees and DL. Treatment outcomes were able to be predicted with high accuracy and less than 18% classification error, with data that is routinely available to clinicians. The GLM was found to be the most accurate. Additionally, the model was able to identify characteristics associated with prolonged successful treatment including but not limited to; ≥ 23 years old at the time of diagnosis, baseline dermatology life quality index (DLQI) ≥ 16, baseline PASI ≥ 94, weight ≤ 98.9 kg (24). The study was limited by its retrospective nature and it did not take into account access to medication which could have limited duration of treatment.

Nielsen et al used the same registry to retrospectively predict the most suitable biological therapy for psoriasis patients. The authors found that gradient-boosted decision trees, a specific type of ML, performed significantly better than logistic regression for the prediction of specific biologic therapy. This technique was able to predict discontinuation of a given biologic within the first year of treatment with an accuracy of 62.9% - 67.6% (25).

AI is a natural fit to interpretation of the considerable amount of data that naturally accumulates as healthcare becomes more digitalised, which can often be dynamic through real-time capture. “Big data” is therefore well suited to interpretation via ML to draw patterns that may deepen our understanding of treatment trajectories and pathophysiology, taking healthcare one step closer to personalised medicine.

Bragazzi et al performed a systemic review to map the current use of ML for Big Data analysis in psoriatic disease; 26 papers met the inclusion criteria. ML algorithms were shown to accurately extract patterns on predicting psoriatic arthritis from epidemiological registries, molecular databases and different smart phone health applications. The authors did however highlight that we should be mindful of data protection, confidentiality and association biases (26).

Furthering genetic understanding of psoriasis paves the way for future treatment options as well as aiding in diagnosis and prediction of progression. Genetic medicine provides an enormous amount of data which can also benefit from ML interpretation. Using genetic markers to select those who at the most risk of developing PsA could have a large potential for reducing long-term morbidity. With each new gene identified comes possible new targets for therapy – more of these are being identified through increasingly sophisticated data analysis (27). Encouragingly, AI has also been shown to predict psoriasis highly accurately from microarray-based gene expression profiles(27).

Genome-wide association studies [GWAS] provide enormous amounts of complex data that can be swiftly interpreted via ML techniques. Patrick et al used ML [including random forest, conditional inference forest, shrinkage discriminant analysis, and elastic net regression] to identify 9 novel loci for psoriasis following evaluation of more than 7,000 genotyped psoriatic patients provided by GWAS (28). Love et al analysed data on 2,318 psoriatic arthritis patients to identify 31 psoriatic arthritis-related predictors. A single psoriatic arthritis code had a positive predictive value [PPV] of 57% [95% confidence interval 0.55 – 0.58], which increased to 90-93% following natural language processing(29).

We should be mindful that AI is susceptible to various bias and ethical aspects need to be considered with the patient as reference. Table 2 outlines broader disadvantages of AI applicable to psoriasis, and by contrast some of the advantages as well.

Table 2. Advantages & disadvantages of AI (39,40)

Advantages	**Disadvantages**
Use in repetitive and time-consuming tasks	Choice of Predictive Model
Use in tasks with poor interobserver reliability	Generalizability
Creative diagnostics via AI	Standardization
Applications for resource-limited settings	Interpretability
Interpretation of big data	Data Requirements
	Acceptance
	Liability

3. Discussion

In the future, AI will certainly take healthcare closer to personalised medicine. As research interests continue to grow, we will see an increase in application of AI and this will translate to greater benefits to our patients. As described in table 2, AI can be used to reach greater numbers of patients – particularly those in remote and or resource- limited settings.

Gaps do remain in the literature and there is a need for robust clinical governance when handling large volumes of patient data which limits AI's applicability to current clinical practice. Fortunately, the International Psoriasis Council [IPC] have agreed upon 36 statements around psoriasis and telemedicine relating to diagnosis and treatment which will continue to progress the frontier (30)**.**

Despite the advances in the field of AI and psoriatic disease, AI is still not the panacea. Further validated models are needed to assess its role in both the diagnosis and the management of psoriatic disease. Dermatologists can play a crucial role in the evolution of AI and relevant training is required as well as cooperation with other specialties, such as data scientists. In the future, AI and ML may be able to predict the clinical course of the disease and, in combination with molecular studies, may even be able to guide our choice of treatment although acceptance by patients will need to be considered.

Moreover, teledermatology has gained significant popularity after the Covid-19 pandemic. Combining teledermatology with AI in psoriatic disease could indeed transform our current practice, as suggested by the International Psoriasis Council in their statements concerning remote monitoring of patients (30)

4. Limitations

One of the challenges of AI in psoriatic disease resides with interpreting 3D aspects missed in imaging, such as thickness of plaques for calculating the PASI. Whilst multiview enhancement block may combat this to some extent, most algorithms only assess area, erythema and or scale (31), making an accurate PASI assessment difficult to achieve.

Additionally, AI diagnostics seem to be less accurate on skin of color than lighter skin, even when trained on equal numbers of images (32,33). More work is needed to optimize accuracy when using AI as a diagnostic tool for SOC. Of particular note, most datasets are based on European and Australian teaching sets, which limits the ability of ML to perform on SOC (34).

An Australian survey of over 4,000 individuals demonstrated that people felt accuracy was consistently the most important factor in utilizing AI and reducing costs the least important. Notably, 3,558 [80%] responders valued continued human contact more than other factors (35). Another international survey of dermatologists, found that only 292 [23%] had good knowledge on the subject whilst 116 of 680 [17%] of hospital-based dermatologist were fearful of the technology although most agreed that dermatology would provide benefit overall (36).

Further to the above, issues of choice regarding the right predictive model exist. These include small sample size of studies and variation in systems used which make comparisons of studies challenging.

There are multiple guidelines and recommendations in the literature which give suggestions on how to use AI safely, including methodologies for reporting on studies which use AI (37). Interestingly, there is little mention of any such adherence in many AI and ML studies, although this likely represents unawareness rather than poor methodology.

AI is coming to the forefront of governing bodies; in June 2023 The European Parliament begun negotiations on the AI act; a framework for incorporating AI safely into healthcare(38).

5. Conclusion

Future management of psoriatic disease will employ diagnostic and therapeutic tools that are tailored to a group of patients with common characteristics, taking healthcare closer to precision medicine. As dermatologists it is crucial to embrace these new technologies and familiarise ourselves with them, in order to provide the best possible care to our patients although we should be mindful that there remains a demand for human-human face-to-face interaction.

References:

1. Turing AM. Computing machinery and intelligence. Mind. 1950;59:433–60. Available from: http://www.loebner.net/Prizef/TuringArticle.html
2. Du-Harpur X, Watt FM, Luscombe NM, Lynch MD. What is AI? Applications of artificial intelligence to dermatology. Br J Dermatol 2020;183(3):423–30.
3. Artificial Intelligence (AI) | HHS.gov [Internet]. Available from: https://www.hhs.gov/about/agencies/asa/ocio/ai/index.html
4. Artificial intelligence in healthcare: Applications, risks, and ethical and societal impacts | Think Tank | European Parliament [Internet]. Available from: https://www.europarl.europa.eu/thinktank/en/document/EPRS_STU(2022)729512

5. The Topol Review [Internet]. Available from: https://topol.hee.nhs.uk/the-topol-review/
6. Reddy S, Allan S, Coghlan S, Cooper P. A governance model for the application of AI in health care. J Am Med Inform Assoc 2020;27(3):491.
7. Gomolin A, Netchiporouk E, Gniadecki R, Litvinov I V. Artificial Intelligence Applications in Dermatology: Where Do We Stand? Front Med (Lausanne) 2020;7.
8. Hogarty DT, Su JC, Phan K, Attia M, Hossny M, Nahavandi S, et al. Artificial Intelligence in Dermatology—Where We Are and the Way to the Future: A Review. Am J Clin Dermatol 2020;21(1):41–7.
9. De A, Sarda A, Gupta S, Das S. Use of Artificial Intelligence in Dermatology. Indian J Dermatol 2020;65(5):352.
10. Yeung H, Takeshita J, Mehta NN, Kimmel SE, Ogdie A, Margolis DJ, et al. Psoriasis severity and the prevalence of major medical comorbidity: a population-based study. JAMA Dermatol 2013;149(10):1173–9.
11. Kimball AB, Wu EQ, Guérin A, Yu AP, Tsaneva M, Gupta SR, et al. Risks of developing psychiatric disorders in pediatric patients with psoriasis. J Am Acad Dermatol 2012;67(4):651-657.e2.
12. Reid C, Griffiths CEM. Psoriasis and Treatment: Past, Present and Future Aspects. Acta Derm Venereol 2020;100(3):69–79.
13. Dalal G, Wright SJ, Vass CM, Davison NJ, Vander Stichele G, Smith CH, et al. Patient preferences for stratified medicine in psoriasis: a discrete choice experiment. Br J Dermatol 2021;185(5):978–87.
14. Al-Janabi A, Martin P, Khan AR, Foulkes AC, Smith CH, Griffiths CEM, et al. Integrated proteomics and genomics analysis of paradoxical eczema in psoriasis patients treated with biologics. Journal of Allergy and Clinical Immunology 2023
15. Google debuts AI-powered app to help consumers identify common skin conditions | Fierce Healthcare [Internet]. [cited 2023 Sep 10]. Available from: https://www.fiercehealthcare.com/tech/google-previews-ai-dermatology-tool-to-help-consumers-identify-skin-conditions
16. Liu Y, Jain A, Eng C, Way DH, Lee K, Bui P, et al. A deep learning system for differential diagnosis of skin diseases. Nature Medicine 2020;26(6):900–8.
17. Kim S, Kim J, Hwang M, Kim M, Jin Jo S, Je M, et al. Smartphone-based multispectral imaging and machine-learning based analysis for discrimination between seborrheic dermatitis and psoriasis on the scalp. Biomed Opt Express 2019
18. Zhao S, Xie B, Li Y, Zhao X, Kuang Y, Su J, et al. Smart identification of psoriasis by images using convolutional neural networks: a case study in China. J Eur Acad Dermatol Venereol 2020;34(3):518–24.
19. Shrivastava VK, Londhe ND, Sonawane RS, Suri JS. Computer-aided diagnosis of psoriasis skin images with HOS, texture and color features: A first comparative study of its kind. Comput Methods Programs Biomed 2016;126:98–109.
20. Huang K, Wu X, Li Y, Lv C, Yan Y, Wu Z, et al. Artificial Intelligence-Based Psoriasis Severity Assessment: Real-world Study and Application. J Med Internet Res 2023;25:e44932.
21. Okamoto T, Kawai M, Ogawa Y, Shimada S, Kawamura T. Artificial intelligence for the automated single-shot assessment of psoriasis severity. J Eur Acad Dermatol Venereol 2022;36(12):2512–5.
22. Smith CH, Yiu ZZN, Bale T, Burden AD, Coates LC, Edwards W, et al. British Association of Dermatologists guidelines for biologic therapy for psoriasis 2020: a rapid update. British Journal of Dermatology 2020;183(4):628–37.
23. Camela E, Potestio L, Fabbrocini G, Ruggiero A, Megna M. New frontiers in personalized medicine in psoriasis. Expert Opin Biol Ther 2022;22(12):1431–3.
24. Emam S, Du AX, Surmanowicz P, Thomsen SF, Greiner R, Gniadecki R. Predicting the long-term outcomes of biologics in patients with psoriasis using machine learning. Br J Dermatol 2020;182(5):1305–7. Available from: https://pubmed.ncbi.nlm.nih.gov/31778205/
25. Nielsen ML, Petersen TC, Maul JT, Wu JJ, Rasmussen MK, Bertelsen T, et al. Multivariable

Predictive Models to Identify the Optimal Biologic Therapy for Treatment of Patients With Psoriasis at the Individual Level. JAMA Dermatol 2022;158(10):1149–56.

26. Bragazzi NL, Bridgewood C, Watad A, Damiani G, Kong JD, McGonagle D. Harnessing Big Data, Smart and Digital Technologies and Artificial Intelligence for Preventing, Early Intercepting, Managing, and Treating Psoriatic Arthritis: Insights From a Systematic Review of the Literature. Front Immunol 2022;13.
27. Guo P, Luo Y, Mai G, Zhang M, Wang G, Zhao M, et al. Gene expression profile based classification models of psoriasis. Genomics 2014;103(1):48–55.
28. Patrick MT, Stuart PE, Raja K, Gudjonsson JE, Tejasvi T, Yang J, et al. Genetic signature to provide robust risk assessment of psoriatic arthritis development in psoriasis patients. Nat Commun 2018;9(1).
29. Love TJ, Cai T, Karlson EW. Validation of psoriatic arthritis diagnoses in electronic medical records using natural language processing. Semin Arthritis Rheum 2011;40(5):413–20.
30. Komy MHM El, Chiricozzi A, Kerkhof P van de, Armstrong A, Diamei V, Hsu C, et al. Telemedicine and psoriasis: A review based on statements of the telemedicine working group of the International Psoriasis Council. JEADV Clinical Practice 2023;2(1):19–31.
31. de Brito M, Stevens BR, Yiu ZZN. Can artificial intelligence be used for accurate remote scoring of the Psoriasis Area and Severity Index in adult patients with plaque psoriasis? Br J Dermatol 2021;185(6):1262–4.
32. 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(3):365–86.
33. AI Diagnostics Fall Short in Skin of Color [Internet]. [cited 2023 Sep 10]. Available from: https://www.dermatologytimes.com/view/ai-diagnostics-fall-short-in-skin-of-color
34. Guo LN, Lee MS, Kassamali B, Mita C, Nambudiri VE. Bias in, bias out: Underreporting and underrepresentation of diverse skin types in machine learning research for skin cancer detection-A scoping review. J Am Acad Dermatol 2022;87(1):157–9.
35. Isbanner S, O’Shaughnessy P, Steel D, Wilcock S, Carter S. The Adoption of Artificial Intelligence in Health Care and Social Services in Australia: Findings From a Methodologically Innovative National Survey of Values and Attitudes (the AVA-AI Study). J Med Internet Res 2022;24(8).
36. Polesie S, Gillstedt M, Kittler H, Lallas A, Tschandl P, Zalaudek I, et al. Attitudes towards artificial intelligence within dermatology: an international online survey. Br J Dermatol 2020;183(1):159–61.
37. Crossnohere NL, Elsaid M, Paskett J, Bose-Brill S, Bridges JFP. Guidelines for Artificial Intelligence in Medicine: Literature Review and Content Analysis of Frameworks. J Med Internet Res 2022;24(8).
38. A European approach to artificial intelligence | Shaping Europe’s digital future [Internet]. [cited 2023 Oct 22]. Available from: https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence
39. Al Kuwaiti A, Nazer K, Al-Reedy A, Al-Shehri S, Al-Muhanna A, Subbarayalu AV, et al. A Review of the Role of Artificial Intelligence in Healthcare. J Pers Med 2023;13(6).
40. Aung YYM, Wong DCS, Ting DSW. The promise of artificial intelligence: a review of the opportunities and challenges of artificial intelligence in healthcare. Br Med Bull 2021;139(1):4–15.

Supplementary Files

Figures

Untitled.

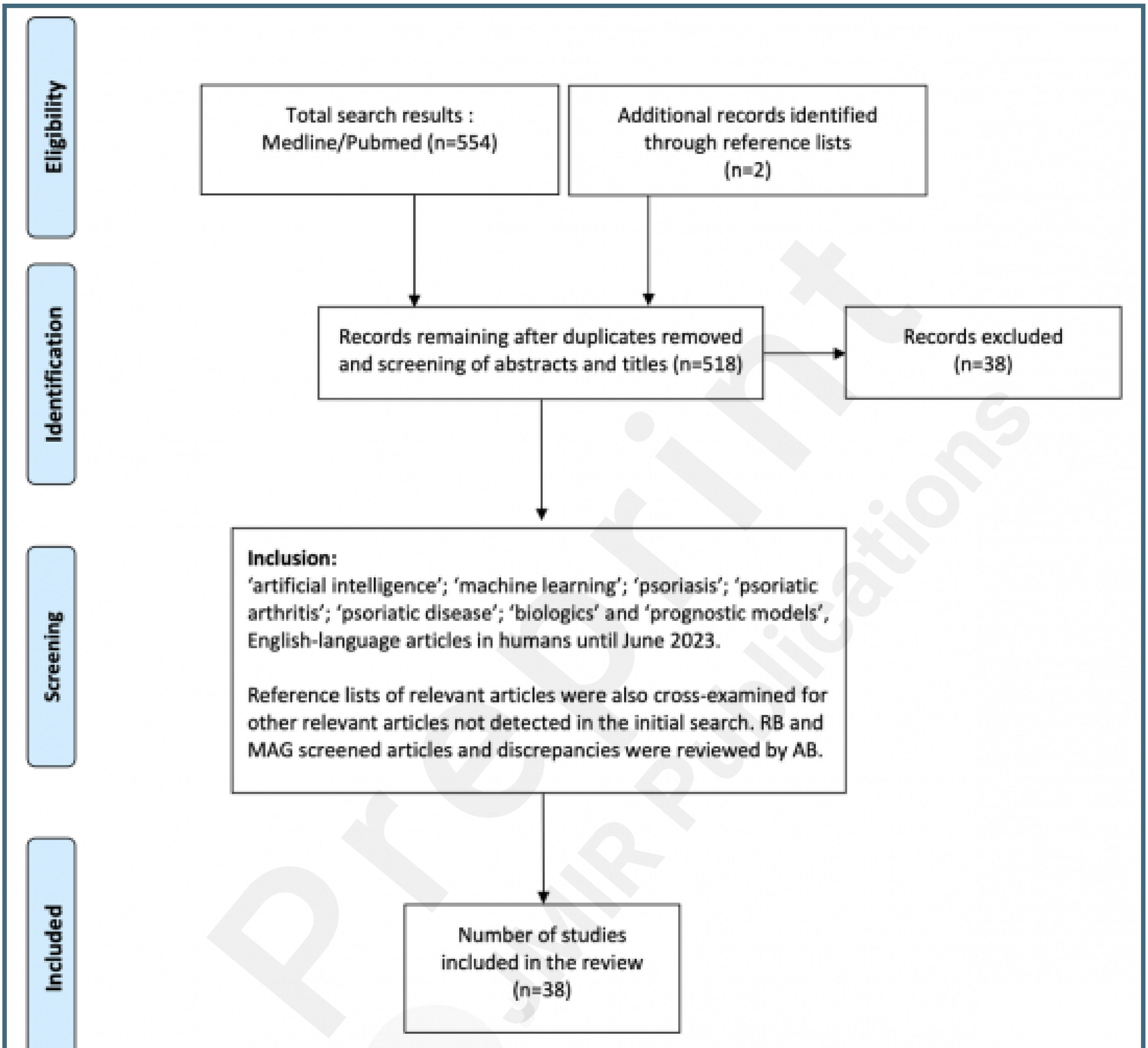

Figure 1. Flowchart of methodology to identify included studies