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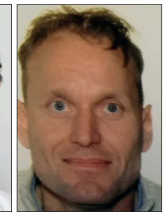
Artificial Intelligence in Dermatology – A Systematic Review



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Artificial intelligence (AI) is the science of training a machine or computer to perform human tasks. The term AI was first used in 1955, and AI has recently become increasingly popular (1). Advanced algorithms, sophisticated computers with large power and storage options, and increased data volumes, have contributed to the increase in interest in AI. AI applications can be used in many aspects of society, and are expanding into areas that were previously considered tasks for human experts.

AI applications are being developed and used within healthcare, and the question arises as to whether AI might gradually change medical practice. A key future problem within global healthcare is the immense predicted shortage of healthcare workers. The World Health Organization (WHO) has estimated a shortfall of almost 13 million healthcare worker worldwide by 2035 (2). Within the field of dermatology a lack of specialists is already evident in the UK, with only 650 dermatologists for a population of over 66 million (3, 4). Dermatologists often work under pressure, with long waiting times and insufficient time to spend with patients. New technology, and especially AI, might be useful in this field, as diagnosis in dermatology to a great extent depends on the visual recognition of pathological structures.

We performed a systematic review to identify current applications of AI within dermatology. Current and future applications, benefits and harms are reported here, together with the safety of different applications.

Methods

The Cochrane Library, Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, Embase, Science Citation Index Expanded were searched until May 2019 using the search terms "artificial intelligence" or "computer-assisted", "computer-aided" and/or "dermatology" or "dermoscopy". Relevant articles were selected, including randomized controlled trials and review articles. The reference sections of relevant articles were also searched for relevant publications.

Results

Relevant publications on applications of AI for diagnosis in dermatology were identified. The selected articles were primarily review articles, Cochrane Reviews, and larger prospective studies (5–23). Furthermore, some expert and user opinions were selected (1). The vast majority of publications deal with the diagnosis of malignant melanoma. This is understandable as malignant melanoma contributes to 80% of skin-cancer-related deaths (17). The annual incidence of malignant melanoma has increased dramatically in the last few decades, and the risk of melanoma appears to be increasing in people under the age of 40 years, especially among women (17). Furthermore, early and correct diagnosis of malignant melanoma is important, as it enables treatment by surgical resection, which is more likely to result in cure, whereas more advanced stages of the disease have a worse prognosis (17).

Artificial intelligence-based applications

The available AI-based applications identified by the search can be divided into 2 groups: (*i*) applications with the potential to alert people, through the use of a mobile phone or smart device, when they may need to see a doctor (6, 7); and (*ii*) applications that help dermatologists to increase the accuracy of diagnosing malignant melanoma (5, 9–16). Most applications in the first group and some in the second group use AI based on fractal analysis and machine learning algorithms (1). These algorithms allow comparison of a stored photograph against numerous photographs of melanoma and benign lesions, or allow comparison of the stored photograph against numerous benign and melanoma lesion characteristics learned from analysing a very high number of photographs, in order to assess the likelihood of melanoma.

Fractal analysis is based on a natural phenomenon that exhibits a repeating pattern at every scale. It can provide a quantitative measure of irregularity where regularity is expected (18). With regard to melanoma, this includes irregularities in the physical characteristics of a lesion, such as those used in established algorithms, to assist in diagnosis (e.g. the "ABCs" of melanoma, in addition to texture, patterns, and other geometrical features). Fractal analysis has been used for the diagnosis of other cancers (e.g. mammography for breast cancer) (19) which has been used by health professionals, and not by patients for assessment of their own cancer risk, as for some of the applications identified in the current study (6, 7).

Mobile phone applications

The first group, mobile phone applications, are intended to provide information about melanoma or non-melanoma skin cancer, and guidance on whether people should consult a doctor for a specific lesion that they have photographed with their smart device. Some applications are also designed to monitor skin lesions and register whether changes occur with time (6, 7). The mobile phone and smart device apps can be divided into 2 groups: those that provide analysis of the image; and those that produce a store-and-forward image to be sent to a dermatologist for evaluation (7).

Mobile phone applications using image analysis

One review identified 39 mobile phone apps for melanoma, 18 of which used some image analysis (6). A Cochrane Review of smartphone apps for triaging adults with skin lesions suspicious for melanoma included 2 studies on image analysis (7). Both studies had a high risk of bias. Sensitivities in detecting melanoma ranged from 7% (95% confidence interval (95% CI) 2–16%) to 73% (95% CI 52–88%) and specificities ranged from 37% (95% CI 29–46%) to 94% (95% CI 87–97%). For an application to be safe, it must have almost 100% sensitivity in order not to miss any diagnoses of melanoma (i.e. no false-negative cases). Ideally, the application would also have high specificity (i.e. no false-positive cases), because false-positive cases cause unnecessary worry among patients. Applications with very high sensitivity but low specificity will also cause worry, and lead to many unnecessary referrals and surgery, thereby increasing the dermatologists' workload.

Mobile phone applications using store-and-forward of images

Mobile phone apps with store-and-forward of photographic images were used in 9 out of 39 mobile phone apps on melanoma (6). These applications forward a photograph of the lesion to an experienced professional, such as a dermatologist, for review, and then communicate a recommendation regarding the nature of the lesion to the user (6). This might also be termed a teledermatology service for patients. The Cochrane Review of smartphone applications for triaging adults with skin lesions suspicious for melanoma included a study using this store-and-forward application with high risk of bias (7). This study had a sensitivity of 98% (95% CI 90–100%) and specificity of 30% (95% CI 22–40%) (7). Thus, one diagnosis of melanoma was missed (one false-negative case). This application had a specificity of only 39%, which would result in many unnecessary referrals to the dermatologist and many people worrying unnecessarily and undergoing unnecessary surgery (7).

Potential advantages in both groups of mobile phone apps are increased involvement of the public in detecting suspicious skin changes, including the chance of early detection of melanoma. Furthermore, increased patient engagement and involvement may result in better educated patients, and more effective and efficient consultations (1, 6, 7). Furthermore, both applications may allow better access to healthcare for people in remote areas.

However, routine use of these mobile phone apps is not advised based on current evidence, despite their potential advantages (7). Mobile phone apps with image analysis are not sufficiently safe, as they miss cases of melanoma, and, even worse, they may give patients false reassurance that their lesion is not cancer, thus delaying diagnosis.

Evidence regarding mobile phone apps with store-and-forward options to the dermatologist is sparse, and involves only one study (7). This method seems to be more sensitive; although, due to low specificity, it might result in many false-positives, causing unnecessary referrals, surgeries and worries.

Further development, evaluation and research into these applications is important before they can play a role in healthcare. It is important to note, however, that these apps are available to the public, and that patients will use them, even though they are not safe.

Applications to help dermatologists increase the accuracy of diagnosing malignant melanoma

The second group is applications that help dermatologists to increase the accuracy of diagnosing malignant melanoma. Diagnosis of malignant melanoma is very important, but also very difficult (8). Visual diagnosis is not easy, is highly observer-dependent, and may be associated with low accuracy when performed by young and unexperienced dermatologists. The accuracy of experts is between 75% and 84% (5, 8). Hence, other tests that may facilitate the diagnosis of melanoma in a specialist setting have been developed (5, 8–16, 19–23). These include reflectance confocal microscopy, optical coherence tomography, high frequency ultrasound, as well as computer-assisted diagnosis or AI-based applications (8–16, 19–23). Histological confirmation of malignant melanoma remains the gold standard (8). AI-based applications may provide a consistent and rather objective technique. They can assist dermatologists in different steps of analysis, such as detection of the lesion boundary, quantification of diagnostic features, classification into different lesions types (tumour staging) and visualization. Many studies have been published; a systematic review has identified 182 publications on the topic between 1985 and 2011 (5, 10, 13). Two main types of computer-assisted dermoscopy exist: computer-assisted dermoscopy based on dermoscopic images (CAD-derm) and computer-assisted dermoscopy based on spectroscopy (CAD-spect), which is predominantly multi-spectral-imaging (5, 10, 13). A Cochrane review on the use of computer-assisted dermoscopy included 42 studies with a total of 15,938 lesions (10). Twenty-four studies applied CAD-derm and 18 studies used CAD-spect. The Cochrane review found that, for a group of 1,000 skin lesions, of which 200 (20%) are given the final diagnosis of melanoma, 386 people will have a CAD-derm result suggesting that a melanoma is present and, of these, 206 (53%) will have a false-positive result (10). Twenty (3%) of 614 people with a negative CAD-derm result have a melanoma (false-negative result). Dermoscopy or CAD-derm were found to be equal in their ability to detect or rule out melanoma (10).

For a group of 1,000 people, of whom 200 (20%) are given the diagnosis of melanoma, 637 will have a positive CAD-spect result, suggesting that a melanoma is present. Of these 451 (71%) will have a false-positive result. Fourteen (4%) of 363 people with a positive CAD-spect result will have a melanoma (false-negative result) (10). CAD-spect detects more melanomas, but possibly produces more false-positive results (an increase in unnecessary surgery, referrals and worries). The review concludes that both CAD types demonstrate high sensitivity, and could be used as a back-up for specialist diagnosis to assist in the diagnosis of melanomas. The Cochrane review concludes that the available data are too limited to make a judgement on which method of CAD to use (10).

Another review also evaluated the diagnostic accuracy of dermoscopy and digital dermoscopy for the diagnosis of melanoma (13). The authors retrieved 765 articles, and 30 studies were included in their meta-analysis. The meta-analysis showed that sensitivity for CAD-based dermoscopy was slightly higher than for dermoscopy (91% vs. 88%; $p=0.076$), while specificity for dermoscopy was significantly better than CAD-based dermoscopy (86% vs. 79%; $p<0.001$). The diagnostic odds ratio for dermoscopy (51.5) and CAD-based dermoscopy (57.5) were not significantly different ($p=0.783$). The author concluded that both tests are equal for diagnosis of melanoma (13).

Based on the literature review, it appears that CAD-based dermoscopy has become a valuable diagnostic tool, although it needs further development and evaluation. It can currently be used as a supplement or back-up to regular dermoscopy. Further research is needed to establish the exact role of CAD-based dermoscopy.

Conclusion

Applications of AI in the field of dermatology are increasingly used, both by patients and health professionals. Mobile phone apps with image analysis for patients need further improvement before they can be considered safe, and not miss diagnoses of melanoma. CAD-based dermoscopy appears to have evolved into a valuable tool supplementing regular dermoscopy.

The majority of current AI applications involve melanoma, although more AI applications for the diagnosis of dermatological diseases, including other types of skin cancer and other dermatological diseases, are anticipated.

Ultimately, while reflecting on the potential of AI to improve the accuracy and efficiency of dermatological diagnosis, we must always keep in mind the holistic nature of clinical dermatology with its focus on the whole patient, and on effective, thorough and compassionate doctor–patient communication.

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