Standards in whole body photography, digital dermoscopy and artificial intelligence applied to the early diagnosis of melanoma

Introduction

Melanoma is one of the most aggressive forms of skin cancer, responsible for 60% of lethal skin neoplasms. Early detection is crucial for improving patient outcomes, particularly as the incidence of melanoma continues to rise, posing an increasing public health challenge due to the aging population and extended life expectancy.[1] Over the past few decades, dermoscopy has revolutionized the diagnosis of skin lesions by enabling in vivo observation of morphological structures not visible to the naked eye, many of which correlate with histopathological findings.[1]

As such, dermoscopy has been incorporated into the total body skin examination as the primary screening method for melanoma,[2] which involves examining each pigmented skin lesion for typical signs of melanoma. This has led to the adoption and standardization of digital follow-up techniques such as the two-step method, which combines total-body photograph (TBP) and sequential digital dermoscopy imaging (SDDI). By allowing clinicians to compare current images with previous records, these tools enable the early detection of new or evolving lesions, as well as the monitoring of macroscopic and dermoscopic changes in pre-existing ones.[3-5]

Although this method is highly effective, it can be time-consuming and is therefore selectively aimed at groups with high-risk factors, such as patients presenting a large number of nevi or atypical mole syndrome.[6]

To optimize both the efficacy and efficiency of total body examination, the integration of artificial intelligence (AI) in both TBP and dermoscopy is emerging as a promising innovation. The Intelligent Total Body Scanner for Early Detection of Melanoma (iToBoS) project aims to lead the way forward in this direction, developing an AI-based diagnostic platform that integrates various data sources including medical records, genomics data, and imaging. It does not rely solely on image analysis but also contributes to registering and eventually defining several different patient phenotypes based on various types of risk factors. Hence, this platform aims to provide a highly personalized risk assessment for each patient and for each lesion following a more global and phenotype-based approach. It will ultimately offer healthcare practitioners enhanced diagnostic tools while addressing the "black box" issue of AI models through improved transparency and interpretability.[6]

This article reviews the current standards in digital follow-up and the application of AI within the iToBoS project. It covers the indications for digital monitoring in high-risk populations, details the two-step follow-up method, provides a technical overview of imaging acquisition, and discusses the interpretation of processed images. Finally, it reviews the implications of several hardware and software technologies, including AI algorithms in the iToBoS project.

Indications for digital monitoring of patients with multiple nevi

Digital monitoring of melanoma is most effective when targeted at specific high-risk groups, as it is not feasible to implement widespread digital follow-up in the general population. Patients with multiple nevi, particularly those with genetic predispositions or a personal history of melanoma, are at significantly elevated risk, making them prime candidates for close surveillance. Various studies

highlight the increased melanoma risk associated with high total body nevus count, especially in individuals with over 50 nevi, where each additional nevus is linked to a 2-4% rise in melanoma risk.[7] Other high-risk factors include the presence of atypical or dysplastic nevi, familial melanoma syndromes, and pathogenic variations in genes, such as *CDKN2A* and *POT1*, which are frequently associated with the development of multiple primary melanomas.[8,9]

It has been shown that the two-step method, combining digital tools like TBP and SDDI, offers substantial benefits in these populations, improving diagnostic accuracy as well as reducing unnecessary biopsies, which are common in these patients.[8] Moreover, research indicates that this approach not only enhances melanoma detection rates but also reduces patient anxiety and improves long-term outcomes.[9-11]

Guidelines for digital follow-up result from the balance between scientific evidence and the practical constraints of real-world healthcare settings, including resource limitations and socioeconomic factors. Therefore, clinical guidelines such as those established by the International Dermoscopy Society prioritize those with the highest risk to ensure effective allocation of medical resources:[12]

Patients with more than 60 melanocytic nevi.

Patients with a *CDKN2A* mutation or other high-risk melanoma genetic variants.

Patients with more than 40 melanocytic nevi and a personal history of melanoma.

Patients with more than 40 melanocytic nevi and red hair and/or a Red Hair Colour (RHC) *MC1R* gene variation.

Patients with more than 40 melanocytic nevi and a history of organ transplantation.

Description of digital follow-up: the two-step method

The two-step method of digital follow-up, which integrates TBP and SDDI, is a well-established approach for the surveillance of high-risk patients for melanoma.

The first step, TBP, involves capturing high-resolution images of the entire skin surface, which serve as a baseline for future clinical comparisons. This step allows clinicians to systematically identify new lesions and monitor clinically visible changes in pre-existing ones, which may be indicative of early melanoma. TBP is especially effective for patients with numerous nevi, as it is otherwise very challenging to identify the arousal of new lesions without previous records for comparison.[13]

The second step, SDDI, focuses on dermoscopic imaging of individual lesions. Dermoscopy with polarized light provides detailed, magnified views of skin structures not visible to the naked eye, such as pigment networks, globules, streaks, and regression structures, which help differentiate benign from malignant lesions. SDDI is highly sensitive in monitoring high-risk lesions and is typically conducted at intervals of 3 to 12 months, depending on the patient's risk profile and the characteristics of their nevi.[13,14]

The efficacy of this two-step method has been demonstrated in several studies. For instance, Malvehy and Puig found that combining TBP with SDDI enabled the early detection of melanomas that would otherwise be missed using conventional visual examinations alone. Most melanomas identified through this approach were in situ or early invasive, with a median Breslow thickness of less than 1 mm, significantly improving prognosis.[5,13] Furthermore, Moscarella et al. showed that combining short-term follow-up (STFU) for single atypical lesions with long-term follow-up (LTFU) for multiple nevi allowed earlier detection of melanomas, especially in patients with a high nevus count and atypical mole syndrome.[14,15]

Technical description of image acquisition

The standardization of image acquisition for both TBP and SDDI is a critical aspect of digital follow-up for melanoma. Regular calibration of imaging equipment, as well as adherence to standardized imaging protocols, ensures consistency and reliability in documenting changes over time. The process begins with appropriate patient preparation, removing clothing, accessories, and any substances like lotions or cosmetics that might interfere with the quality of the images. The imaging room should be equipped with standardized lighting to achieve uniform conditions for every imaging session. To maintain consistency in TBP, current settings typically involve cameras mounted on fixed stands, and patients are positioned in predefined postures to ensure that the same body areas are captured the same way in each session. Camera settings, such as focal length, distance from the skin, and magnification, are kept constant to ensure uniformity in image quality across all follow-ups.[5]

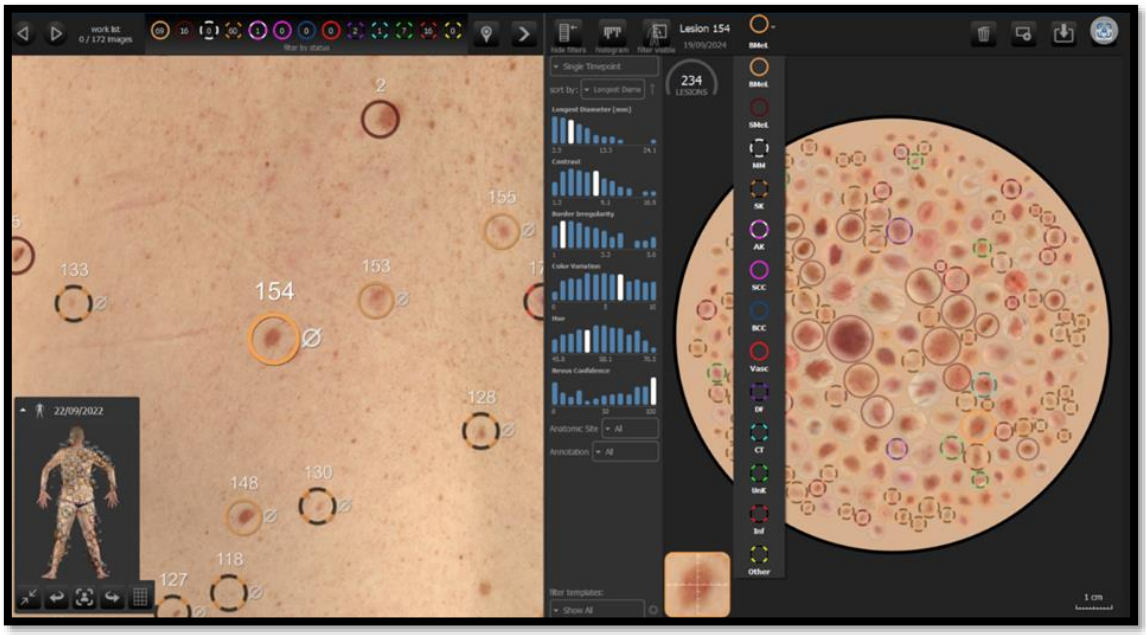
Following TBP, SDDI is performed. This second step involves capturing close-up images of individual lesions using a digital dermoscope equipped with polarized light and connected to a high-resolution color video camera. In cases where surface scales or crusts are present, an immersion fluid may be applied to improve image clarity. Magnifications typically range from 10x to 100x, with 20x being the most common for clinical use. The digital system then stores these images in a lossless format such as RAW or TIFF, which preserves maximum detail for later analysis.[5]

After receiving Human Ethics Approval in January 2023, FCRB (Fundació Clínic per a la Recerca Biomèdica) and HCB (Hospital Clínic de Barcelona) as well as the UQ (University of Queensland) initiated the clinical data collection stage of the iToBoS project using the Vectra® WB360 system by Canfield Scientific, a walk-through machine equipped with 92 cameras that capture a patient's entire skin surface in a timely manner. This advanced system generates a 3D avatar of the patient's body, mapping all moles and lesions with high-resolution fidelity. To protect participant privacy, the Vectra images are segmented into smaller 5 x 9 cm tiles, ensuring that identifying features such as faces and tattoos are excluded, a process that involves using Canfield MIRROR software. Image tiles were then generated and uploaded to the iToBoS Cloud for further annotation by the ISAHIT platform, an ethical on-demand workforce specializing in data labelling to refine lesion detection with a threshold of 3 mm diameter. Avatars are currently being reconstructed and made available progressively to the dermatologists responsible for the annotation.

Interpretation and annotations of images

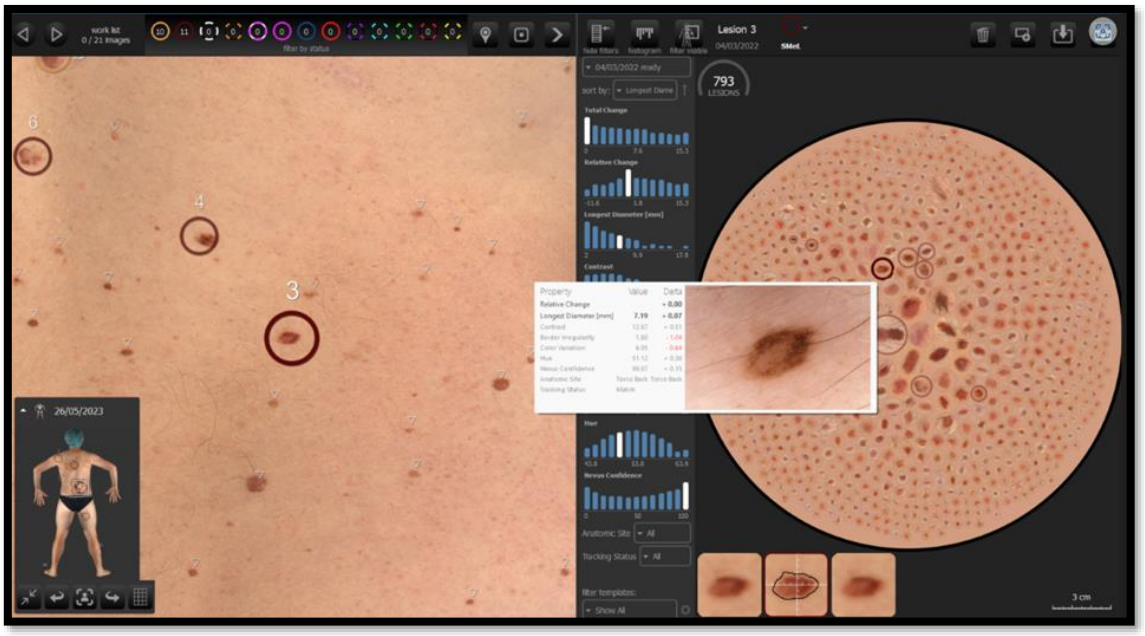
In melanoma surveillance, digital image interpretation involves analyzing clinical and dermoscopic features that differentiate benign from potentially malignant lesions. The ABCDE rule (Asymmetry, Border irregularity, Color variation, Diameter, Evolution) remains a key clinical tool for initial lesion assessment. The ABCDE criteria, besides being a useful guide for self skin examinations of patients, also form a reliable basis for patient phenotyping that allows the identification of specific lesion patterns, such as signature nevi and outliers (i.e., ugly ducklings), even when dermoscopy is not applied.[13,15] Although these clinical criteria are essential for assessing lesion and patient risk, they may not achieve the same diagnostic accuracy as dermoscopic analysis. Digital dermoscopy offers a deeper analysis, revealing structures such as atypical pigment networks, irregular dots and globules, streaks, and regression structures. Additional features, including a blue-white veil, atypical vascular patterns, or depigmentation associated with regression, heighten suspicion of melanoma. These advanced dermoscopic features are crucial for detecting malignancies that may not follow the classic ABCDE rule.

Importantly, the primary stages of the iToBoS project focuses mainly on patient phenotyping and lesion detection annotation for AI training, rather than lesion classification. This phenotyping process runs through interpretation of the reconstructed patient avatars by certified dermatologists and is based mainly on clinical criteria. Meetings were held between the FCRB, the UdG (Universitat de Girona) and UQ (University of Queensland) to develop methods for categorizing lesion images, which is as follows:

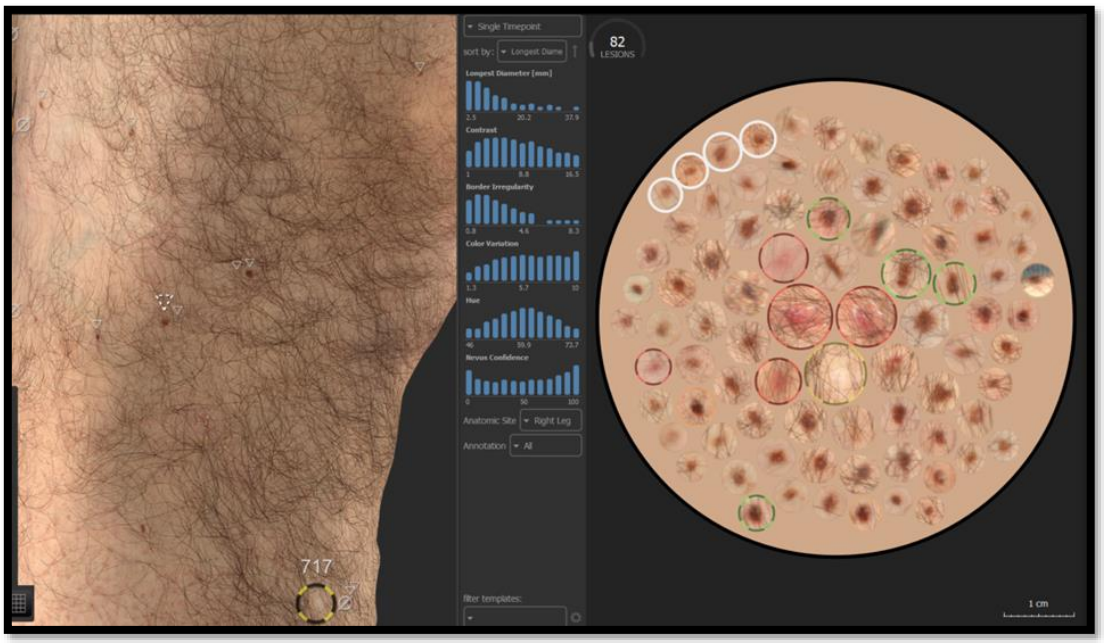


A consensus among the dermatologists responsible for lesion annotation established a structured classification of melanocytic tumors into three categories: Bmel (highly probably benign melanocytic lesions based on clinical criteria), MM (highly probably malignant melanocytic lesions based on clinical criteria), and SMel (suspicious melanocytic lesions that cannot be classified in either of the two previous categories), along with an UnK (Unknown) category for lesions that cannot be definitively classified as melanocytic without dermoscopy.

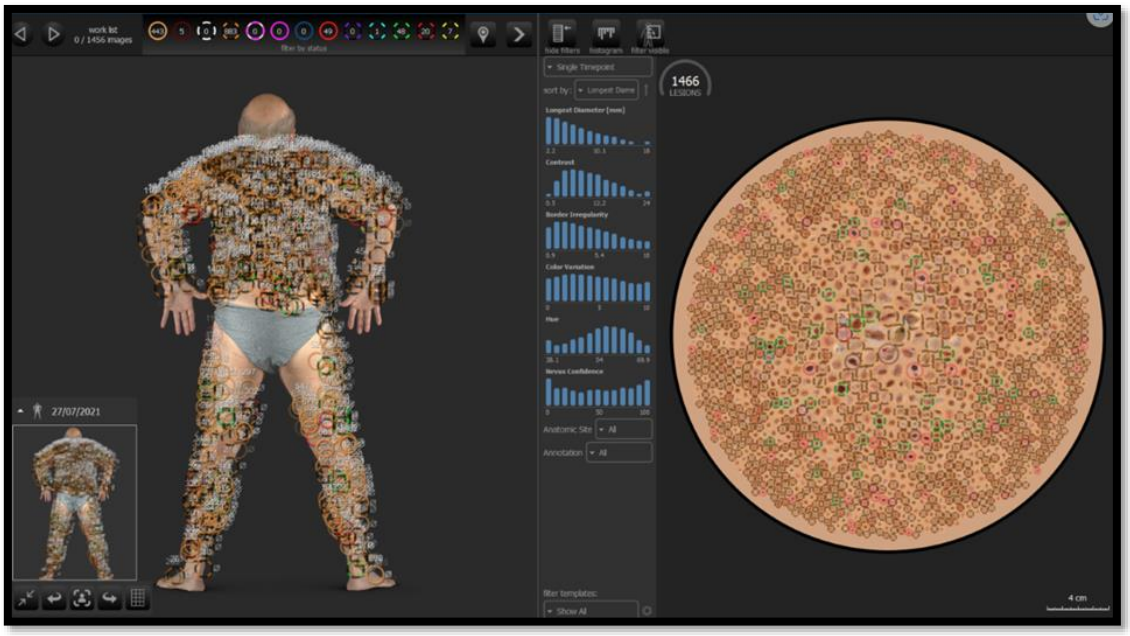
Annotation is underway with the expertise of dermatologists associated with the FCRB, HCB, UQ and UNITS (Università degli Studi di Trieste). Avatars are made available with all detected lesions requiring classification in the different clinical categories, with some suspicious ones occasionally already pre-categorized as SMel by ISAHIT:



To ease the process, each anatomical region can be assessed separately:



At the end of the process, the avatar should display as follows, with all lesions from all anatomical sites being successfully categorized before being ready for exportation:



The principal of SDDI offers the advantage of monitoring lesions over time, detecting subtle morphological changes that may indicate early malignant transformation. Comparing sequential images allows dermatologists to identify concerning developments, such as an increase in lesion size, new color variations, or irregular borders. These progressive changes, which may be early indicators of melanoma, can be detected before becoming more apparent in advanced lesions.[13,15] Techniques like 3D modeling and image-based matching enhance lesion mapping and change detection, for which a separate protocol is being developed within the iToBoS project to notify changes in lesions over time.

It should be noted that the annotation process might sometimes prove challenging in differentiating age-related skin changes, such as solar lentigines or seborrheic keratoses, from malignancies, as these benign conditions can sometimes resemble melanoma. Moreover, some benign melanocytic lesions may undergo changes due to age, pregnancy, or external factors such as sun exposure, potentially regressing or altering in appearance. The analysis implies a thorough understanding of the natural history of various skin lesions and how they evolve over time. Expert training thus represents a crucial part of the procedure in both TBP and SDDI in order to train high-quality AI.[7,15]

Description of applied technologies

The iToBoS project integrates advanced imaging and diagnostic technologies, combining 2D and 3D systems, together with digital dermoscopy. The iToBoS total body scanner (manufactured by BOSCH) employs high-resolution cameras equipped with liquid lenses that utilize two immiscible fluids with differing refractive indices, enabling high-quality images. These lenses facilitate capturing both wide-area and close-up views of skin lesions, offering dermatologists a comprehensive analysis of the skin. Additionally, the use of liquid lenses ensures consistent and sharp images regardless of the depth of field variations, essential for accurate lesion evaluation.[16]

In terms of available technologies for 2D and 3D photography, the Vectra WB360 by Canfield Scientific, FotoFinder by FotoFinder Systems GmbH, and Deviskan by DERMAVISION Solutions represent what has been most recently developed for TBP and digital monitoring.

Vectra WB360 is a 3D imaging system comprising 92 cameras that capture the entire body in high resolution, generating a 3D avatar for comprehensive lesion mapping. This system also integrates dermoscopy with high-resolution cameras, such as the Visiomed D200e, allowing close-up images of individual lesions to be accurately mapped on the 3D model.

FotoFinder's 2D system includes AI tools, such as the Moleanalyzer AI Assistant, registered as a Class II medical device in the European Union. It helps detect new or changing lesions and evaluates lesion risk based on sequential images. FotoFinder also integrates its FotoFinder Medicam 1000s dermatoscope, which offers high-resolution digital dermoscopy with polarized light technology.

Deviskan by DERMAVISION is an all-in-one device designed to streamline total body mapping and digital dermoscopy. The system provides dermoscopic images with calibrated lighting for consistent image capture, ensuring high-quality total body and dermoscopic images in one step.

The captured images, generally at 210 x 210 pixels, are optimized for detailed lesion analysis. Pixel spacing data stored in DICOM (Digital Imaging and Communications in Medicine) metadata ensure accurate physical measurements between adjacent pixels. For contact dermoscopy, a millimeter scale etched onto the glass plate is used for calibration, while non-contact methods rely on fixed lens cones for precise geometric measurements.[17]

The DICOM standard, already validated for dermoscopy, ensures a consistent format for handling medical imaging data and integrates metadata, such as the Frame of Reference UID, which accurately links multiple images of the same lesion.[18] Additionally, regional images that capture anatomical reference points are linked to dermoscopic close-ups through DICOM metadata, ensuring consistent lesion identification in one same anatomical region across different imaging sessions. This standardization allows sequential images to be aligned and compared, enhancing the longitudinal tracking of skin changes such as in lesion size, color, or shape over time, with the system flagging suspicious developments like growth or new lesions for early intervention.[19] Evaluation is still ongoing to extend DICOM standards to TBP, further standardizing full-body skin lesion monitoring.

Moreover, color correction algorithms ensure uniformity across images taken under varying lighting conditions. By analyzing color variations in key groups such as black, white, and blue-grey within the lesion masks, the system provides quantitative information on color changes that may indicate malignancy.[20]

Artificial Intelligence for Digital Follow-Up

AI is assured to play a critical role in the future of dermatology, particularly in digital follow-up. Technologies like convolutional neural networks (CNNs) have shown great promise in analyzing skin lesions and detecting changes over time, often matching or surpassing the diagnostic accuracy of expert dermatologists in controlled settings.[21,22]

While AI traditionally focuses on analyzing individual dermoscopic images for melanoma detection,[21,23] TBP offers a broader approach by capturing the entire skin surface and enabling longitudinal monitoring of lesion changes in each anatomical region. Another important opportunity in AI-driven dermatology is the integration of patient phenotyping into algorithms. Phenotyping classifies individuals based on genetic and environmental risk factors, such as skin type, sun exposure, multiple moles (nevi), and family history of skin cancer.[24,25] Additionally, AI may facilitate the identification of "ugly duckling" lesions—those that deviate from a patient's typical mole

pattern, which often signals malignancy.[11,26] The integration of these risk factors in the algorithms will rely on studies that have quantified them in terms of odds ratios (OR), allowing AI models to generate personalized risk assessments.[12,25,27]

Despite these advances, the integration of AI into routine clinical practice presents challenges, including the need for diverse datasets, standardization of image annotations, as well as data privacy, and informed consent.[28-31] Explainable AI (XAI) is also necessary for clinicians to understand AI-generated decisions, building trust in AI tools before their routine clinical use.[32,33]

International AI challenges encourage collaboration, drive innovation, and set new research standards for developing the highest-quality AI algorithms.[27] As part of the iToBoS project, two AI challenges are being organized, with the first one completed in 2024 and focusing on lesion detection and boundary segmentation in Total Body Photography (TBP) images.[34,35] The second one is underway as of January 2025. The datasets provided for these challenges include the anonymized skin images along with metadata such as age, sex, melanoma history, body site and genetic information.

Conclusion

The integration of digital follow-up techniques and AI marks a significant step forward in the early detection of melanoma, managing one of the most aggressive and fatal forms of skin cancer. The standardized two-step method, combining TBP and SDDI, has proven highly effective in monitoring high-risk patients, allowing for the early detection of new or evolving lesions. Moreover, the iToBoS project is pushing the boundaries of this field by incorporating AI-based tools that not only analyze images but also integrate clinical data and genetic risk factors, offering a personalized risk assessment for each patient.

As technology advances, the combination of AI-driven tools with expert clinical interpretation will further enhance the precision of melanoma detection, potentially reducing unnecessary biopsies and improving patient outcomes. The ongoing collaboration between healthcare professionals and AI developers in iToBoS aims to deliver AI solutions that are not only highly accurate but also transparent and easily interpretable. This comprehensive approach promises to set new standards in melanoma diagnosis and patient care.

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