Development of a Checklist Tool to Assess the Quality of Skin Lesion Images Acquired by Consumers Using Sequential Mobile Teledermoscopy

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Keywords

Melanocytic naevi · Melanoma · Skin cancer ·
Skin self-examination · Telemedicine

Abstract

Background: Mobile teledermoscopy is an emerging technology that involves imaging and digitally sending dermoscopic images of skin lesions to a clinician for assessment. High-quality, consistent images are required for accurate telediagnoses when monitoring lesions over time. To date there are no tools to assess the quality of sequential images taken by consumers using mobile teledermoscopy. The purpose of this study was to develop a tool to assess the quality of images acquired by consumers. **Methods:** Participants imaged skin lesions that they felt were concerning at baseline, 1-, and 2-months. A checklist to assess the quality of consumer sequential imaging of skin lesions was developed based on the International Skin Imaging Collaboration guidelines. A scale was implemented to grade the quality of the images: 0 (low) to 18 (very high). Intra- and inter-reliability of the checklist was assessed using Bland-Altman analysis. Using this checklist, the consistency with which 85 sets

of images were scored by 2 evaluators were compared using Kappa statistics. Items with a low Kappa value <0.4 were removed. **Results:** After reliability testing, 5 of the items were removed due to low Kappa values (<0.4) and the final checklist included 13 items surveying: lesion selection; image orientation; lighting; field of view; focus and depth of view. Participants had a mean age of 41 years (range 19–73), and 67% were female. Most participants (84%, $n = 71/85$) were able to select and image the correct lesion over time for both the dermoscopic and overview images. Younger participants (< 40 years old) scored significantly higher (8.1 ± 2.1) on the imaging checklist compared to older participants (7.1 ± 2.4 ; $p = 0.037$). Participants had most difficulty with consistent image orientation. **Conclusions:** This checklist could be used as a triage tool to filter images acquired by consumers prior to telediagnosis evaluation, which would improve the efficiency and accuracy of teledermatology and teledermoscopy processes. It may also be used to provide feedback to the consumers to improve image acquisition over time.

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Introduction

Advancements in mobile technologies have played a significant role in redefining the delivery of dermatological services to improve the diagnosis of melanoma or other skin cancers. Mobile teledermoscopy is one emerging technology that uses a dermatoscope attached to a smartphone to capture dermoscopic images of skin lesions via a mobile health application [1–6]. Mobile teledermoscopy may act as a communication tool between medical practitioners and patients for remote assessment. Patients can monitor a suspicious skin lesion identified by their medical practitioner or, alternatively, self-detect concerning lesions and forward images for remote medical assessment. A randomised, controlled trial comparing skin self-examination at home with and without mobile teledermoscopy confirmed the feasibility of mobile teledermoscopy and identified high sensitivity and specificity in detecting lesions suspicious for skin cancer in both arms [7–9]. Benefits of mobile teledermoscopy identified by consumers include the convenience of a remote service, shorter waiting times, and potential cost savings [8]. Consumers also reported a high acceptance of mobile teledermoscopy [8, 10].

One of the challenges encountered when consumers, rather than clinicians, conduct the imaging process is the quality of the images [1, 4]. When using sequential imaging to monitor a lesion over time, additional challenges may impact the ease of telediagnoses. These include changes in image orientation, lighting, and focus that may alter the appearance of the lesion. Sequential dermoscopy imaging by clinicians has been shown to increase the sensitivity for melanoma diagnosis and reduce the benign to malignant excision ratio [11]. This is because photographic evidence can demonstrate lesion stability (or lack thereof) to minimise the need for unnecessary biopsies. Standardisation is important to obtain accurate telediagnoses and guidelines have been proposed to standardise dermatological images taken by clinicians. The International Skin Imaging Collaboration (ISIC) established a set of 9 criteria to ensure images taken by clinicians are of sufficient quality for diagnoses. These include guidance on optimal lighting, background colour, field of view, and image orientation, among others [12]. Due to the recent shift of consumers conducting their own imaging and a higher dependence on telehealth services during the COVID-19 pandemic, a tool is required to assess the image quality of consumer-imaged skin lesions [13].

Fig. 1. A set of dermoscopic and overview images taken of a skin lesion at baseline, 1, and 2 months.

We developed and tested the reliability of a checklist adapted from ISIC guidelines to score the image quality of lesions longitudinally imaged by consumers. The checklist was assessed using data from study participants who conducted consumer-led mobile teledermoscopy for the early detection of skin cancer.

Materials and Methods

The images used for this study were acquired from participants in the mobile teledermoscopy arm of a randomised, controlled trial that compared mobile teledermoscopy-enhanced skin self-examinations to naked-eye skin self-examinations. The methods and

the main outcomes of the trial, including sensitivity and specificity of skin cancer detection, have been previously reported [14, 15]. Ethics approval was obtained from the Queensland University of Technology Human Research Ethics Committee (approval No. 1400000807). Briefly, the intervention group was advised to use mobile teledermoscopy to conduct 3 skin self-examinations at home, each 1 month apart. Participants were asked to image skin lesions that they felt were suspicious for skin cancer using their own smartphone, a mobile dermatoscope, and corresponding Handyscope application (app; FotoFinder System GmbH, Bad Birnbach, Germany). Participants were provided with written instructions and a video on how to use the dermatoscope and app, how to detect lesions using the asymmetry and colour rule [16], and how to conduct a whole-body skin self-examination. Participants then presented for an in-person whole-body skin examination by a dermatologist after completing their third self-examina-

Table 1. Proposed checklist to assess the quality and standardisation of consumer sequential imaging of pigmented lesions

	1	0	Description ¹
<i>Lesion selection</i>			
1. Was the same lesion dermoscopically imaged at each timepoint?	Yes	No	Ensure the patient photographed the same lesion
2. Was the same lesion imaged in the overview photographs at each timepoint?	Yes	No	
3. Can you tell which lesion was dermoscopically imaged on the overview images?	Yes	No	If there are multiple lesions in the overview image, it must be clear which is the lesion being examined
4. Can you clearly identify where the lesion of interest is located on the body?	Yes	No	The overview image should identify which area on the body the lesion is located
<i>Image orientation</i>			
5. Was the orientation of the dermoscopic images consistent over time?	Yes	No	The camera should be positioned in the same orientation (such as asking the user to hold the camera horizontally each time)
6. Was the orientation of the overview images consistent over time?	Yes	No	
<i>Lighting for overview images</i>			
7. Was the background lighting adequate to view the lesion at timepoint 1?	Yes	No	Using natural lighting is best for overview images; but broad-spectrum lighting (rather than fluorescent lighting) may be used. Even lighting will reduce shadows
8. Was the background lighting adequate to view the lesion at timepoint 2?	Yes	No	
9. Was the background lighting adequate to view the lesion at timepoint 3?	Yes	No	
10. Was the background lighting consistent over time?	Yes	No	
<i>Background colour for overview images</i>			
11. There was no reflection from objects in the background of an image	True	False	A neutral coloured, plain background should be used with no objects or distractors. Reflection of objects may change skin colour appearance
12. Absence of jewellery or other distracters in the images	True	False	
<i>Field of view for dermoscopic images</i>			
13. Is Lesion 1 in the centre of the dermoscopic image?	Yes	No	The lesion should be in the centre of the image, so the surrounding skin can be viewed with equal areas of surrounding skin at the periphery
14. Is Lesion 2 in the centre of the dermoscopic image?	Yes	No	
15. Is Lesion 3 in the centre of the dermoscopic image?	Yes	No	
<i>Focus and depth of field for dermoscopic images</i>			
16. Based on the focus, were you able to evaluate the lesion at timepoint 1?	Yes	No	The lesion, including the surrounding skin, should be in focus with no blurriness
17. Based on the focus, were you able to evaluate the lesion at timepoint 2?	Yes	No	
18. Based on the focus, were you able to evaluate the lesion at timepoint 3?	Yes	No	

¹ Adapted from the ISIC guidelines.

tion. Figure 1 shows an example of a set of dermoscopic and overview images of a skin lesion taken at the 3 timepoints.

Development of Consumer Image Quality Checklist

To assess the quality of the sequential imaging of pigmented skin lesions acquired by consumers, a checklist (Table 1) was developed based on the Standards for Dermatological Imaging established by the ISIC [12]. The guidelines were adapted to focus on the quality and standardisation of sequential images taken by consumers as opposed to health professionals.

Four domains from the ISIC recommendations were not relevant for imaging conducted by consumers using smartphones. The app used in this study automatically controls resolution (i.e., the number of pixels); therefore, resolution was not included in this checklist. The app does not have a digital measurement tool and thus the “scale and measuring using digital imaging software” domain was excluded from this checklist. The “image storage” and “colour calibration” domains were excluded from the checklist as these were not relevant to consumer imaging. Two dermatologists (H.P.S. and C.C.-L.) assessed the content of the checklist and amended the checklist accordingly until both were in agreement that the remaining items were relevant.

Checklist Scoring

The initial checklist consisted of 18 items that were scored either as of unacceptable or acceptable quality for telediagnosis receiving a value of “0” or “1,” respectively. The items were then summed for a maximum score of 18, with higher scores indicating better quality. Sub-scores were also calculated for each of the domains suggested by the ISIC, as per Table 1 (“lesion selection,” “image orientation,” “lighting for overview images,” “background colour for overview images,” “field of view for dermoscopic images,” and “focus and depth of field for dermoscopic images”).

Sample Size Calculation

To estimate the mean quality of images within ± 1.1 units with 95% confidence assuming an SD of 2.8, a total sample size of 85 evaluated sets of images were required. Bland-Altman analysis was used to calculate 95% limits of agreement for both inter and intra-rater reliability. Assuming an SD of 0.95, a total of 36 sets of images needed to be scored by 2 evaluators to calculate the 95% limits of agreement with a precision of ± 0.5 .

Assessment of Images

Participants submitted a median of 6 lesions at each skin self-examination (range 1–24). To ensure the analysis was not biased, a computer-generated list of the images from all participants was used to randomly select and assess one image set per participant.

Two researchers (U.K. and M.O.) assessed the quality of the sequential sets of dermoscopic and overview images taken by 85 participants. Each rater independently assessed a total of 71 sets of images, with 36 image sets overlapping between the 2 evaluators for the inter-rater reliability assessment. Both evaluators also assessed the 36 overlapping sets of images twice on different days at least 2 weeks apart to establish intra-rater reliability.

Statistical Analysis

The inter- and intra-rater reliability of each of the individual 18 checklist items was assessed using Cohen’s kappa, with kappa values of 0.01–0.20, 0.21–0.40, 0.41–0.60, 0.61–0.80, and 0.81–1.00

Table 2. Demographics ($n = 85$)

	<i>n</i> (%)	<i>p</i> value
Age		0.037*
40 years	45 (53)	
>40 years	40 (47)	
Sex		0.502
Female	57 (67)	
Male	28 (33)	
Relationship status		0.999
Living with partner	67 (79)	
Living without partner	18 (21)	
Highest education level		0.097
University degree/diploma	64 (75)	
Trade or technical certificate	15 (18)	
Secondary school	6 (7)	
Employment status		0.907
Full-time (including self-employed)	55 (65)	
Part-time or casual	27 (32)	
Student	0	
Retired	0	
Other	3 (3)	
Previous skin spot or mole excised or treated		0.591
Yes	53 (62)	
No or unsure	32 (38)	
Skin type		0.337
Very fair	74 (87)	
Medium	10 (12)	
Dark	1 (1)	
Self-reported naevus density		0.840
None	0	
Few (<20)	25 (29)	
Some (20–50)	34 (40)	
Many (>50)	26 (31)	

* Statistically significant.

indicating none to slight, fair, moderate, substantial, and almost perfect agreement, respectively. Items with a Cohen’s kappa of <0.4 were removed from the final checklist due to poor inter-rater reliability. Inter- and intra-rater agreement of the overall image quality score was assessed using Bland-Altman analysis. Student *t* tests and analysis of variance were used to assess whether participant characteristics were associated with overall image quality score.

Results

Eighty-five participants provided images at all 3 timepoints and remained for the analysis. The participants’ mean age was 41 years, they were mostly female (67.1%, $n = 57/85$), and had a university degree/diploma (75.3%, $n = 64/85$; Table 2).

Table 3. Individual question scores and Cohen's kappa

Question	Yes, <i>n</i> (%)	No, <i>n</i> (%)	Cohen's kappa
Lesion selection			
1. Same lesion (dermoscopic)	71 (84)	14 (16)	0.89
2. Same lesion (overview)	71 (84)	14 (16)	0.65
3. ID lesion on overview	45 (53)	40 (47)	0.49
4. Clearly ID lesion location	54 (64)	31 (36)	0.83
Image orientation			
5. Same orientation (dermoscopic)	38 (45)	47 (55)	0.55
6. Same orientation (overview)	33 (39)	52 (61)	0.66
Lighting for overview images			
7. Background lighting timepoint 1	39 (46)	46 (54)	0.30
8. Background lighting timepoint 2	31 (36)	54 (64)	0.35
9. Background lighting timepoint 3	24 (28)	61 (72)	0.15
10. Background lighting consistent over time	64 (75)	21 (25)	0.61
Background colour for overview images			
11. No reflection	38 (45)	47 (55)	0.36
12. No jewellery or distracters	74 (87)	11 (13)	0.30
Field of view for dermoscopic images			
13. Lesion 1 at centre of dermoscopic image	49 (58)	36 (42)	0.68
14. Lesion 2 at centre of dermoscopic image	40 (47)	45 (53)	0.51
15. Lesion 3 at centre of dermoscopic image	39 (46)	46 (54)	0.56
Focus and depth of field for dermoscopic images			
16. Timepoint 1 adequately focused for evaluation	60 (71)	25 (29)	0.48
17. Timepoint 2 adequately focused for evaluation	69 (81)	16 (19)	0.58
18. Timepoint 3 adequately focused for evaluation	57 (67)	28 (33)	0.50

Italicised values indicate slight or fair inter-rater reliability.

Reliability of Individual Checklist Items

Cohen's kappa scores for 13 of 18 items on the checklist showed moderate to almost perfect inter-rater agreement between the 2 evaluators (Table 3). Cohen's kappa showed fair agreement for items 7 and 8 (lighting for overview images), 11 and 12 (background colour), and slight agreement for item 9 (lighting for overview images) between the 2 evaluators.

Inter- and Intra-Rater Reliability Scores of the Overall Image Checklist

Inter-rater assessment showed that 95% of the time the 36 image quality scores of the 2 evaluators were within ± 3.61 of each other. Intra-rater reliability was assessed for both evaluators and the 95% limits of agreement showed high repeatability with image quality scores within ± 1.7 and ± 2.1 , respectively.

Final Checklist

The 5 items that had poor agreement based on Cohen's kappa calculations below 0.4 were removed. Once re-

moved, 95% of the time the scores between the 2 evaluators were within ± 2.74 of each other.

Intra-rater reliability was also reassessed after removing the 5 items that had poor agreement between the 2 raters. For Evaluator 1, 95% of the time the scores between their 2 evaluations were within ± 1.39 . For Evaluator 2, the scores were within ± 2.23 for 95% of the time between their 2 evaluations. Table 4 presents the 13-item final checklist; its score can range from 0 to 13.

Quality of Images

Based on the 13-item checklist, participants had a mean overall image quality score of 7.6 ± 2.3 (range 2–12). The domains that commonly performed well included "focus and depth of field for dermoscopic images" and "lesion selection." Domains that were poorly performed were the "lighting for the overview images" and "image orientation" (Table 5).

Most participants (84%, $n = 71/85$) were able to select and re-image the correct lesion over time for both the dermoscopic and overview images. Over half of the par-

Table 4. Final checklist after reliability testing to assess the quality and standardisation of consumer sequential imaging of pigmented lesions

	1	0
Lesion selection		
1. Was the same lesion dermoscopically imaged at each time point?	Yes	No
2. Was the same lesion imaged in the overview photographs at each time point?	Yes	No
3. Can you tell which lesion was dermoscopically imaged on the overview images?	Yes	No
4. Can you clearly identify where the lesion of interest is located on the body?	Yes	No
Image orientation		
5. Was the orientation of the dermoscopic images consistent over time?	Yes	No
6. Was the orientation of the overview images consistent over time?	Yes	No
Lighting for overview images		
7. Was the background lighting consistent over time?	Yes	No
Field of view for dermoscopic images		
8. Is Lesion 1 in the centre of the dermoscopic image?	Yes	No
9. Is Lesion 2 in the centre of the dermoscopic image?	Yes	No
10. Is Lesion 3 in the centre of the dermoscopic image?	Yes	No
Focus and depth of field for dermoscopic images		
11. Based on the focus, were you able to evaluate lesion at timepoint 1?	Yes	No
12. Based on the focus, were you able to evaluate lesion at timepoint 2?	Yes	No
13. Based on the focus, were you able to evaluate lesion at timepoint 3?	Yes	No

ticipants had dermoscopic (55%, $n = 47/85$) and overview (61%, $n = 52/85$) images that were inconsistent in their orientation over time. Most of the images were in focus for evaluation at each of the 3 timepoints (Table 3).

Demographic Associations

Younger participants (< 40 years old) submitted higher quality images and achieved significantly higher scores (8.1 ± 2.1) compared to older participants (7.1 ± 2.4 ; $p = 0.037$; Table 2). No other demographic variables were significantly associated with the image quality scores.

Discussion

During COVID-19 an increase in the use of asynchronous teledermatology services has been observed globally [17]. Teledermatology has become a crucial method of continuing to deliver care during the peak of the pandemic, with all non-urgent in-person dermatology visits postponed. The quality of consumer-taken images is thus critical for the safe delivery of teledermatology services and sequential imaging should employ consistent imaging techniques to aid comparison of images over time [18]. There has been a steady increase in the number of mobile apps, even prior to COVID-19, that facilitate image capture and lesion tracking available for the general public to support the early detection of skin cancers, and

Table 5. Overall and domain scores (13-item checklist)

	Mean	Range	95% CI
Overall score	7.6	2–12	7.1–8.1
Domain			
Lesion selection	2.8	0–4	2.6–3.1
Image orientation	0.8	0–2	0.7–1.0
Lighting for overview images	0.2	0–1	0.2–0.3
Field of view for dermoscopic images	1.5	0–3	1.3–1.7
Focus and depth of field for dermoscopic images	2.2	0–3	2.0–2.3

dermatoscopes targeted at consumers have also become available [19]. However, despite an increased reliance on teledermatology, there are no imaging quality checklists for images taken outside of clinical practices particularly by non-experts [13, 20, 21]. The lack of development, validation, and adoption of universal imaging practices may result in lack of consumer training, and high variation in image quality [21, 22]. For example, if 2 images are taken of a lesion months apart with different orientation and lighting, this can jeopardise the ability of the clinician to detect relevant changes over time. Therefore, education and guidance for consumers to conduct reimaging in a standardised way based on the quality checklist developed here has strong potential to improve the accuracy of telediagnoses.

In clinical practice we envisage that this checklist will also improve the workflow for clinicians. This checklist could be implemented as a pre-screening tool for medical assistants, whereby they screen the images for quality prior to forwarding the images to a clinician for interpretation. If the images fail to properly score in a quality checklist domain, the patient would be asked to repeat the imaging process and re-send the image. Such a system has the potential to save time and increase the efficiency of time-poor clinicians. Participants in this study were provided with imaging instructions; however, despite this attempt, some still struggled to capture images of the lesions correctly. Over half of participants did not have the same image orientation in at least one of their follow-up images. Further written and visual instructions on holding the camera horizontal to the skin surface in each image may be helpful. Consumers could also complete the quality checklist themselves before submitting their images. From the image sets evaluated in this study, a small proportion of images (5%) were unsuitable for clinical assessment [15], indicating that consumers are usually capable of taking images that are acceptable; however, better quality could further improve the benefit of consumer-acquired teledermoscopy.

Three items on overview image lighting and 2 items on background colour were removed from the checklist due to poor inter-rater reliability. Rather than capturing lighting acceptability at each of the 3 timepoints, the final checklist contains a single item that asks for lighting consistency across the timepoints. Overview images are important as they provide an indication of lesion shape, size, and anatomic location, and aid lesion re-identification over time [23, 24]. Consumers should capture overview images in the same light source to ensure consistency [25]. Inconsistent lighting can significantly challenge teledermatologists to provide a diagnosis, and we found the main inconsistency was images taken in natural and artificial light [26]. While using natural light is best for overview images, this is not always practical due to variability in daylight hours, seasonal changes, and weather conditions which cannot be controlled [12, 25]. Overall, our results indicate participants may have had more difficulty standardising the overview images, rather than the dermoscopic images. In this study, the participants were provided with a dermatoscope with in-built lighting which reduces the variability of dermoscopic lighting. However, not all dermatoscopes will have this feature. While reflection from objects in the background of an image may change the appearance of skin tone [12], this item was removed due to the poor inter-rater agreement,

but perhaps should be reintroduced with a more stringent definition, including specifically indicating the absence of jewellery covering the lesion, absence of a shadow over the lesion, and so on, which may improve the inter-rater reliability of this domain.

The next step in the development of this checklist is to derive a cut-off score to determine if images are acceptable for a telediagnosis. This cut-off score will help medical assistants determine whether to forward the images to the dermatologist for assessment or back to the consumer to re-image the lesions.

Limitations

The volunteer sample may limit the generalisability of the results as participants were potentially more receptive to using mobile technologies [9]. Over half of the participants were female, well educated, and this study excluded participants without an iPhone. This study was also limited by a small sample size, and further testing is required in larger cohorts. This checklist was tested on skin lesions for the early detection of skin cancer only, but further testing could assess its reliability for imaging of other inflammatory skin diseases. This checklist was developed and tested for individuals who conducted imaging at 3 separate timepoints. The checklist may be adapted to assess images captured once only or at a different number of timepoints.

Conclusions

This image quality checklist includes the key aspects of dermatological imaging that in our view are paramount for standardisation of sequential imaging by consumers. With further validation on a larger sample and a defined cut-off score, this image quality checklist may be used in clinical practice to improve the workflow and determine if the image quality is sufficient to enable accurate telediagnoses.

Key Message

We developed a checklist to assist with standardisation of image quality in consumers.

Statement of Ethics

This study was approved by the Queensland University of Technology Human Ethics Committee (QUT approval No. 1400000807).

Conflict of Interest

H.P.S. is a shareholder of MoleMap NZ Limited and e-derm consult GmbH, and undertakes regular teledermatological reporting for both companies. H.P.S. is a Medical Consultant for Canfield Scientific Inc., Revenio Research Oy, and also a Medical Advisor for First Derm. C.C.-L. is an advisory board member for BMS and Helsinn Pharm.

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Author Contributions

U.K., H.P.S., and C.C.-L. created and assessed the checklist. U.K. and M.O. assessed the quality of the sequential sets of dermoscopic and overview images. C.H. and M.J. conducted the randomised, controlled trial data collection. U.K. and B.B.-S. conducted the statistical analysis. U.K., C.H., and M.O. participated in the drafting and writing of the manuscript. All authors contributed to the interpretation and critical revision of the manuscript. All authors provided final approval of this paper.

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