The Comparative Use of Multiple Electronic Devices in the Teledermoscopic Diagnosis of Early Melanoma

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Abstract

Background: The use of mobile electronic devices as support to medical activity was largely implemented in the past decade.

Introduction: Our first aim was to evaluate the frequency of use of different electronic devices, that is, personal computer (PC), notebook, tablet, smartphone, in a pool of dermatologists recruited to perform multiple online testing session on difficult melanocytic skin lesions (MSLs) cases. The second aim was to evaluate the feasibility of each device in terms of teledermatologic diagnostic performance; the use of four different diagnostic methods, that is, intuitive diagnosis and three dermoscopic algorithms, was also investigated.

Materials and Methods: A total of 111 dermatologists with 4 different levels of experience in dermoscopy, performed 4 tests (intuitive diagnosis and iDScore, ABCD rule, 7-point-checklist-

based diagnosis) on 979 MSLs blinded cases. Each testing session was performed with a preferred device.

Results: The overall highest areas under the receiver operating characteristic (AUROC) (82%) was obtained by young generation dermoscopists 1–4 years experience) when using an integrated clinical dermoscopic algorithm (iDScore) on a notebook. The average dermatologist using the iDScore obtained AUROC 77.40% with large screen devices (PC and notebook) 77.6% with small screen (tablet, smartphone) and 78.2% by combining the two.

Discussion: Young generation of dermoscopists alternately use different devices, whereas elderly generation still prefer to use the PC. The diagnostic performances obtained with small/large screen were not statistically different from those obtained with fixed/mobile devices.

Conclusions: Mobile devices were feasible tools to achieve adequate diagnostic accuracy in difficult MSLs, on a teledermatology setting, independently from participant skill level/age.

Keywords: teledermatology, dermoscopy, early melanoma, atypical nevi, telemedicine

Introduction

The use of telemedicine has been developed in the past decades among several branches of medicine and subspecialties to improve both diagnosis and treatment monitoring for those patients who have limited access to a face-to-face consultation with either the general practitioner or the specialist (e.g., elderly patients unable to be moved and patients living in rural areas).¹ Moreover, as far as information technology has become day-by-day less expensive, and the quality of imaging has increased, telemedicine has acquired growing consent among health care practitioners and patients. The recognition and management of dermatologic conditions basically relies on the interpretation of clinical or instrumental images, thus the growing interest for teledermatology as a consequence of dermatology itself. Teledermatology was progressively implemented to enable general physicians (or dermatologists) to request the second opinion of a dermatologist/expert dermoscopist for a suspicious

skin lesion bypassing the conventional pathway of patients' referring. This can be realized in a *live interactive* or in a *store and forward* modality.¹⁻⁴

To date, store-and-forward teledermatology proved to be effective in the triage of patients with skin neoforation, both in terms of improved access to dermatologic consultation and reduced costs.¹⁻³ More recently, the field of teledermoscopy (TDS), that is, the sharing of standardized dermoscopic images of pigmented skin lesions, has been implemented and extended to educational purposes to novices. Indeed, adding standardized dermoscopic images to clinical pictures demonstrated to significantly improve the diagnostic accuracy of telediagnosis (by ~15%) particularly for melanocytic skin lesions (MSL).¹⁻⁸ Although several TDS studies have underlined the importance of training the person taking the dermoscopic photograph in several, no globally accepted standards for taking dermoscopic photographs of MSL exist to date.⁹⁻¹² In contrast, there are recent evidences that using dermoscopic images acquired with small screen mobile devices do not negatively affect the accuracy of teledermatologic consultations between primary care setting and dermatology department.¹³

We first aimed to evaluate, the frequency of use of four devices—(1) personal computer (PC), (2) notebook, (3) tablet, and (4) smartphone—in a pool of dermatologists recruited to perform multiple online testing session on difficult atypical MSLs (aMSLs). The second aim was to investigate if the use of a portable versus fixed or small versus large-screen device characteristics could affect the accuracy of the teledermoscopic diagnosis of aMSLs (i.e., atypical nevi with worrisome dermoscopic features, AN, and early melanomas, EM). A further aim was to compare the performances according to the dermatologists' skill level in dermoscopy and to the diagnostic method applied, among intuitive diagnosis and versus algorithm-based diagnosis (i.e., *iDScore*, ABCD rule, and 7-point-checklist-based diagnosis).^{10,11}

Materials and Methods

TELEDERMATOLOGY TESTS

This study was carried on from January 2018 to March 2019 and was part of the project "European web platform for the development of a scoring classifier for early melanoma detection" (EADV PPRC project no. 2016-021).¹¹ In brief, we developed a web platform for TDS, i.e., teledermatology web platform (TWP) that served for the collection of a large data set of 979 lesions (662 AN, 317 EM) provided by eight European dermatology centers, including standardized dermoscopic images and relevant clinical data. Participants were invited dermatologists of different level of experience in dermoscopy, including novices (i.e., <1 year experience—level I) and more experienced (2–4 years experience—level II; 5–8 years experience—level III; >8 years experience—level IV). Each participant was required to test their ability in teledermoscopic diagnosis of 30 randomly assigned consecutive cases, blinded to histological diagnosis. Each case was composed by a clinical image, a standardized dermoscopic image (polarized light dermoscopy, magnification $17\times-20\times$, ≥ 1 Mpx, 300–600 dpi, JPEG/PNG) and four relevant clinical data (i.e., maximum diameter, body localization, and patient age). For each case, participants were at first required to give a diagnosis of nevus/melanoma by only looking at the dermoscopic + clinical picture and anamnestic data (*intuitive diagnosis*) (panel 1) (Fig. 1c). Then they had to fill three consecutive panels dedicated to the *iDScore* (Fig. 1d), to the ABCD rule (Fig. 1e) and to the 7-point checklist (Fig. 1f). Informative panels for educational purposes (i.e., definition of dermoscopic terminology, link to the scientific papers, and description of the three algorithms) were included within each testing webpage.¹¹ Finally, they were able to visualize the testing session results after completing the whole analysis.

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ELECTRONIC DEVICE USE

The TWP was accessible by any electronic device with internet connection, but we restricted the data analysis to four devices of common use and available for dermatologists of different experience in dermoscopy, including PC, notebook, tablet, and smartphone. We registered the type of electronic device used during the connection and their peculiar display setting features. By using a simple token-based login, participants were enabled to access the website by using the four different devices. In addition, they had the possibility to choose the sequence of cases evaluation and were free to stop and resume their testing session any time they wanted. In each testing panel, each image could be enlarged by 50% with a specific tool: this allowed a visualization on every display similar to that of the native camera setting. It was, otherwise, possible to enlarge each image to have a wide screen visualization on every device to visualize details within the lesion, without losing definition, according to the video card of the device.

STATISTICAL ANALYSIS

Descriptive statistics and graphic methods were used to describe the distribution of all data required from evaluations. The frequency of use of the four different devices, either alone or in combination, in different skill level groups was recorded. The peculiar use of devices with small screen was compared with those with large screen, and that of portable versus fixed devices, grouped in transversal categories. The average diagnostic performances obtained with these categories were calculated and expressed as areas under the receiver operating characteristic (AUROC). The statistical difference between AUROCs was tested

Fig. 1. Examples of testing session home pages displayed on a PC (resolution $1,920 \times 1,080$ px) **(a)** and of the final page displayed on a notebook (resolution $1,280 \times 800$ px) **(b)**. Example of early melanoma: the intuitive diagnosis panel displayed on a tablet (resolution $1,112 \times 834$ px) **(c)**; the *iDScore* panel displayed on a smartphone (resolution 812×375 px) **(d)**; ABCD rule panel displayed on a tablet (resolution $1,024 \times 768$ px) **(e)**; 7-point checklist panel displayed on a smartphone (resolution $1,920 \times 1,080$ px) **(f)**.

using bootstrap method. The average diagnostic performances obtained with the four tests were examined according to the device type (i.e., screen width/portability) and the participant skill level e grouped as I–II and III–IV, to obtain adequate sample size. The application of the *iDScore* method was further investigated by comparing the results of the single device use and the two categories of skill level. A significance level of 95% was set. Statistical analysis was performed with SPSS software, version 10, Chicago, SPSS, Inc., and R version 3.6.2.

Results

A total of 111 dermatologists/dermatology residents completed their testing session; globally, each image was evaluated three times on average by different participants, obtaining a total of 3,300 different evaluations.

CHARACTERISTICS OF ELECTRONIC DEVICES

PCs used by participants had a display resolution ranging from 1,366 × 768 px to 2,560 × 1,440 px (1–4 Mpx), with 16:9 display ratio. Notebook had a display resolution from 1,280 × 800 px to 1,920 × 1,080 px (1–2 Mpx) with 16:9 display ratio. Tablets had a display resolution from 1,024 × 768 px to 1,112 × 834 px (1–2 Mpx) with 4:3/3:2 display ratio. Smartphones had a display resolution from 414 × 736 px to 1,920 × 1,080 px (0.5–2 Mpx) with 16:9 display ratio.

FREQUENCY OF USE OF ELECTRONIC DEVICES

The rates use of the four different devices, either alone or in combination, according to skill level and to the device portability, are reported in *Table 1*. Experienced dermatologists (level IV) chose their PC in 51% of evaluations, with only a

Table 1. Characteristics of Devices Used for 3,300 Teledermoscopic Evaluations Performed by 111 Participants, Grouped According to Their Skill Level

DEVICE	SKILL LEVEL I	SKILL LEVEL II	SKILL LEVEL III	SKILL LEVEL IV
	N= 270 (%)	N= 1,110 (%)	N= 600 (%)	N= 1,350 (%)
PC	132 (48.9)	452 (40.7)	285 (47.5)	691 (51.2)
Notebook	11 (4.1)	122 (11.0)	69 (11.5)	98 (7.3)
Tablet	27 (10.0)	58 (5.2)	15 (2.5)	80 (5.9)
Smartphone	32 (11.9)	207 (18.6)	139 (23.2)	102 (7.6)
Notebook, PC	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Tablet, PC	16 (5.9)	7 (0.6)	1 (0.2)	6 (0.4)
Smartphone, notebook	7 (2.6)	44 (4.0)	23 (3.8)	76 (5.6)
Smartphone, PC	25 (9.3)	159 (14.3)	49 (8.2)	217 (16.1)
Smartphone, tablet	16 (5.9)	5 (0.5)	4 (0.7)	5 (0.4)
Smartphone, notebook, PC	2 (0.7)	5 (0.5)	2 (0.3)	21 (1.6)
Smartphone, tablet, notebook	1 (0.4)	26 (2.3)	7 (1.2)	26 (1.9)
Smartphone, tablet, PC	1 (0.4)	4 (0.4)	2 (0.3)	23 (1.7)
Smartphone, tablet, notebook, PC	0 (0.0)	21 (1.9)	4 (0.7)	5 (0.4)
Screen dimensions				
Large screen (notebook/PC/notebook+PC)	143 (53.0)	574 (51.7)	354 (59.0)	789 (58.4)
Small screen (smartphone/tablet/smartphone+tablet)	75 (27.8)	270 (24.3)	158 (26.3)	187 (13.9)
Mixed	52 (19.3)	266 (24.0)	88 (14.7)	374 (27.7)
Portability				
Fixed device (PC)	132 (48.9)	452 (40.7)	285 (47.5)	691 (51.2)
Portable ^a	94 (34.8)	462 (41.6)	257 (42.8)	387 (28.7)
Mixed (PC+ smartphone/PC+tablet/PC+notebook)	44 (16.3)	196 (17.7)	58 (9.7)	272 (20.1)

^aPortable devices categories: smartphone/tablet/notebook/smartphone+tablet/smartphone+motebook/tablet+PC.

minority choosing the smartphone (7.6%). In contrast, 23% of level III dermatoscopists chose their smartphone, compared with 47.5% choosing their PC. Tablet instead was the preferred device for the youngest participants, level I, with 10% of evaluations. The notebook was used by 11% of participants belonging to level II and III. The combinatory use of two devices was more frequent in group level IV, 16% choosing smartphone + PC. The combined use of three devices was more frequent in skill level II, 2.3% choosing smartphone + PC + tablet. Finally, the contemporary use of all four devices was chosen by group level II (1.9%). About half of the evaluations (51% to 58.4%) were performed by using large screen devices, either notebook, PC or notebook + PC. Portable devices were used for 42.8% of evaluations by skill level III.

DIAGNOSTIC PERFORMANCES

Table 2 illustrates the AUROCs that were obtained by all 111 dermatologists according to the dimension of the screen and portability of the electronic devices used to connect to the TWP. The performances obtained with each one of the four diagnostic tests are also given. Of note, when applying the *iDScore* method, the percentage variation from intuitive diagnosis method was +16% for large screen and +10% for small screen. Indeed, the diagnostic performance reached with the intuitive diagnosis was 70.5% with small screen

devices and 66.1% with large screen devices (68% AUROC when using small and large screen in combination). Of converse, when using the *iDScore*, the reached performance was 77.6% on small screen and 77.4% on large screen, and even higher when using a combination of the two (78.2%) to connect to the TWP.

As per the portability, the highest diagnostic performances were reached when applying the *iDScore* on lesions visualized on portable (AUROC 78.5%) and or fixed + portables (AUROC 78.7%) devices combined (Table 2).

When considering the unique use of a device for test performance (Fig. 2), the highest diagnostic performance measured as AUROC was reached when the *iDScore* method was applied. The overall highest AUROC value was reached when using the notebook (82%), followed by the tablet (79%); interestingly, the smartphone and PC obtained the same accuracy (77%).

Finally, Figure 3 compares the average diagnostic performances obtained by the young dermatologists of level I and II (i.e., 1–4 years experience) with those of the more experienced participants of level III and IV (i.e., >5 years experiences) when applying the *iDScore* method. Of note, the overall highest area under the ROC curve was obtained by young (level I + II) when using a tablet (AUROC82%): when using a notebook, young were as performant as groups III+IV (same AUROC81%).

Table 2. Diagnostic Accuracy Obtained by 111 Dermatologists in the Four Different Tests, According to the Type of Electronic Device Used to Connect to the Teledermatology Web Platform

DEVICE	AVERAGE AUC (95 % CI)/TEST			
	INTUITIVE DIAGNOSIS	<i>iDScore</i>	ABCD RULE	7-POINT CHECKLIST
Screen dimension				
Large screen ^{a,b,c,d,e}	0.661 (0.636–0.687)	0.774 (0.752–0.796)	0.691 (0.666–0.716)	0.683 (0.658–0.708)
Small screen ^{a,d,e}	0.705 (0.664–0.745)	0.776 (0.741–0.811)	0.691 (0.651–0.731)	0.694 (0.654–0.735)
Mixed ^{a,b,d,e}	0.680 (0.641–0.719)	0.782 (0.748–0.815)	0.720 (0.683–0.758)	0.699 (0.661–0.736)
Portability				
Fixed device ^{a,b,d,e}	0.660 (0.631–0.688)	0.766 (0.742–0.790)	0.686 (0.659–0.714)	0.670 (0.643–0.698)
Portable ^{a,d,e}	0.688 (0.657–0.719)	0.785 (0.758–0.812)	0.693 (0.662–0.724)	0.702 (0.672–0.733)
Mixed ^{a,b,d,e}	0.685 (0.639–0.731)	0.787 (0.749–0.825)	0.740 (0.696–0.783)	0.713 (0.670–0.756)

^aIntuitive diagnosis was statistically different from *iDScore*.

^bIntuitive diagnosis was statistically different from ABCD rule.

^cIntuitive diagnosis was statistically different from 7-point checklist.

^d*iDScore* was statistically different from ABCD rule.

^e*iDScore* was statistically different from 7-point checklist.

AUC, area under the ROC curve; CI, confidence interval.

Fig. 2. Diagnostic performances obtained by 111 participants when using a unique preferred device to connect to the TWP: comparison of all four diagnostic methods. TWP, teledermatology web platform.

Discussion

The use of mobile electronic devices, especially smartphones, has exponentially increased in the past decades for medical clinical imaging communication, especially for dermatologic cases.^{13–15} Worldwide, smartphone users are sup-

posed to be 4–6 billion. As a consequence, several teledermatology applications have been developed for smartphones and used both in a *live interactive* and in a *store-and-forward* mode.^{16–19} Despite promising results reported in study setting, a large number of dermatologists in daily practice do not feel completely confident of managing atypical MSLs in teledermatology setting with a *store-and-forward* modality. Especially oldest generation dermatologists, still often distrust small screen portable devices for diagnosis, choosing classic *face-to-face* examination. This can determine a considerable delay in skin tumor detection in elderly poorly movable people living in large territories.^{20–22}

This study refers to the first experience of a teledermoscopic experimental setting, where a representative sample of participants of different skill ranger was recruited to perform multiple teledermoscopic testing sessions on difficult aMSLs, by spontaneously choosing among four type of electronic device for each connection to

our TWP (Table 1). To date, no significant difference in image quality of clinical pictures or impact on reported outcome measures was noted between the tested smartphone models, whereas no study has compared the impact of the use of different device on the same data set of dermoscopic pictures of

Fig. 3. Diagnostic performances obtained when using the *iDScore*, according to the level of experience of 111 participants: average AUC values (square) with lower and upper bounds of 95% CI (line). AUC, area under the ROC curve; CI, confidence interval.

aMSL.¹⁴ Furthermore, almost all teledermatology studies including mobile electronic devices have been referred to a web-based platform whose data are displayed on an liquid crystal display monitor of a PC.¹⁴

Taken together, the findings from descriptive analysis showed that novices of skill level I (<1 year experience in dermoscopy) did not exhibit any preference concerning the width of the screen and/or the portability of the device; elderly participants (i.e., skill level IV, >8 years experience in dermoscopy) appeared to prefer to the exclusive use of their PC. In particular, all participants from level I to level III (i.e., range 1–8 years experience in dermoscopy) selected their smartphone, either used alone or in combination with other devices, as second choice after the PC chose their (Table 1). This trend is in line with literature studies focused on the use of smartphone for teledermatology consultation, not only for skin cancer, but also for other skin conditions.^{16–20}

The second goal was to ensure an optimal visualization of both dermoscopic and clinical images on all electronic devices, independently from the size of the screen the use of small screen portable devices had been discouraged since the beginning for teledermatology application. More recently, technical advances allow the realization of portable small screen devices with adequate and/or comparable display resolution; however, the visualization of dermoscopic images on mobile phones for analysis was still not considered.^{14,23–25} We here showed that the connection on a dedicated TWP allowed both a standard, enlarged, and >50% visualization of dermoscopic aMSL images on the display, with unaltered image quality (Fig. 1). This was verified by the high AUROC values obtained in the testing sessions performed with either small/large screen devices, unique/combined devices, fixed/mobile devices ranging from medium (0.5–1MP) to high resolution (2–4MP) (Table 2, Fig. 2a). Indeed, we reported similar diagnostic performances when using small screen devices or large screen devices (AUROC ≥ 0.77). Interestingly, the rate of right diagnosis given by all participants as *intuitive diagnosis* without the help of algorithms was higher with small screen devices (AUROC 70%) compared with large screen devices (AUROC 66%) (Fig. 2a). In addition, performances obtained when using mobile devices were not inferior to that reached with fixed device (PC) (AUROC ≥ 0.78). The AUROC value achieved in this experimental teledermoscopic setting on difficult aMSLs diagnosis can be explained by the efficient combination of a properly realized TWP¹² and the application of the *iDScore* algorithm specifically designed for this kind of lesions.¹¹ Indeed, the whole TWP was of rapid, intuitive, and effective use for both young and elderly users and educational pages of easy consultation and visualization were available.

Limitation of this study include the selection of aMSL images to be evaluated was performed by expert dermoscopy in secondary referring Dermatologic centers, generating a possible selection bias; participants declared the preferred unique device or a combination of device to use to connect to the TWP: eventual different/combined use occurring during the testing sessions were impossible to monitor due to privacy rules; the expertise level in dermoscopy was self-declared.

Taken together, these findings suggest some considerations. First, when adequate technical requirements of pictures are guaranteed, the diagnostic accuracy of dermatologists on difficult MSLs seems not to be negatively affected by the use of electronic devices with small screen. Second, the development of new integrated applications for teledermoscopic purposes can open new possibilities in terms of tele-education, research and training, compared with currently available webiste.^{14–26} Third, the *iDScore* resulted to be a feasible and effective integrated scoring-based method that can support dermatologists in daily clinical practice to perform a correct triage of patients presenting with clinically and dermoscopically suspicious MSLs.^{9–11} In particular, it can be applied to smartphone and tablet to orientate the differential diagnosis between EM from AN in a *live interactive* manner, or to notebook and tablet in a *store and forward* setting. Further studies will explore the potentiality of *iDScore*-based application for differential diagnosis of other pigmented skin lesions.^{10,11}

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