Semi-automated total body photography supports robust delivery of skin cancer monitoring services during the SARS-CoV-2/COVID-19 pandemic

Elizabeth D Drugge[1] PhD MPH, Rebecca M Sarac[2] MD, Patricia Fay[3] DPT MPH, and Rhett J Drugge[4] MD

Affiliations: [1]New York Medical College, School of Health Sciences and Practice, Valhalla, New York, USA, [2]Cleveland Medical Center, Case Western Reserve University, Cleveland, Ohio, USA, [3]Rutgers, The State University of New Jersey, Newark, New Jersey, USA, [4]Sheard & Drugge PC, Stamford, Connecticut, USA

Corresponding Author: Elizabeth D Drugge PhD MPH, Department of Public Health-Epidemiology, School of Health Sciences and Practice, Institute of Public Health, 19 Skyline Drive, 2nd Floor, North Wing, Hawthorne, NY 10532, Tel: 914-594-2728, Email: Elizabeth_Drugge@nymc.edu

Abstract

Background: The SARS-CoV-2/COVID-19 pandemic dramatically impacted the delivery of healthcare, including dermatological services. In the initial stages of the pandemic, reduced patient flow produced a dramatic drop in the volume of skin cancer screening. Consistent with COVID-19 precautions, our practice conducted visual skin examinations (VSE) utilizing semi-automated total body photography (TBP).

Methods: A cross-sectional study of patient characteristics and self-reported melanoma risk factors associated with TBP usage was conducted on all patients from May to November 2020 in a single practitioner private dermatology setting. The process and histopathology-confirmed outcomes were compared to those in the same 6-month period in 2019.

Results: For the May-November 2020 timeframe, those who opted for the home TBP (35%) compared to clinic TBP were younger, had higher self-reported skin cancer risk, and were more likely to have had previous TBP sessions. Overall, the number of TBP sessions increased, while dermoscopy usage and biopsy number decreased. There was no change in the number and distribution of skin cancer diagnoses compared to the same period in 2019. The Melanoma-In-Situ:Invasive Melanoma (MIS:INV) ratio was above the U.S. ratio reported for 2020 of 0.95:1 (95,710 MIS:100,350 INV).

Conclusion: Semi-automated TBP was successfully implemented during the pandemic without affecting skin cancer detection.

Keywords: COVID-19, melanoma screening, SARS-CoV-2, self-assessment of skin cancer risk, skin cancer screening, store-and-forward, teledermatology, telemedicine, total body photography

Introduction

The devastating impact of the SARS-CoV-2/COVID 19 pandemic on healthcare delivery [1] requires rewiring of traditional social patterns of behavior. In healthcare, the pandemic is amplifying pre-existing infection control processes and incorporating additional COVID-19 safety procedures. Chinese dermatologists from Sichuan province recently noted a near-complete collapse of the services that require dermatologists to be in close physical proximity to their patients during the pandemic [2]. Similarly, there has been a reported decrease in dermatology services and consequent decrease in skin cancer detection in the United States [3]. The close contact required for traditional physical examinations places healthcare professionals and patients in dangerous proximity and requires the development of innovative alternative approaches to help deliver essential dermatology care during this crisis.

Since the 1990s, dermatologists have pioneered the use of telehealth services (store-and-forward as well as live-video models) to effectively treat patients in rural and underserved communities [4]. Dermatologists were shown to be just as accurate in diagnosing skin cancer via imaging as in person

examinations [5,6]. Paradoxically, the mainstay of dermatology practice, VSE, has recently been considered to be of dubious merit in screening for melanoma; the US Preventive Task Force's position is that the VSE is not an effective strategy for skin cancer screening [7,8].

High-quality image capture and processing expertise are increasing the integration of high-quality images of the skin as an essential component of the electronic medical record. Noninvasive imaging technologies are important tools for screening individuals at risk for skin cancer. Serial TBP with semi-automated TBP have been shown to be an effective alternative for melanoma detection at an early curable phase [9,10].

Use of semi-automated TBP enables delivery of dermatology services without risk of exposure to the highly infectious airborne agent, SARS-CoV-2, in the clinic setting where the staff remains at a distance of at least 6 feet from the patient. Further, to accommodate "stay in place" recommendations, a transportable version of the semi-automated TBP camera array was brought by van to patients' homes. We report the effect using this photography system to provide intermediate examinations during a six-month period in 2020 and compare outcomes to those during the same six-month period in 2019.

Methods

This cross-sectional study describes data extracted from a proprietary electronic health record and image capture database of all patients over the age of 18 who were seen either in- person or at their homes in a single-practitioner general dermatology practice between May 11 and November 11, 2020. We also compared services utilized and skin cancer outcomes during the 2020 period with those from the same period 6-month period in 2019. All patients had up-to-date skin cancer risk assessments and scoring as described previously [11], and based on numerical weighting of responses to questions were centered on a review of the melanoma risk factor literature (**Table 1**), [11].

Data extracted on the patient population located within an urban and surrounding suburban environments outside of New York City included the following sociodemographic characteristics (gender, age, marital status and education level); skin cancer risk factors (genetic, behavioral and environmental);

Table 1. *Risk factor score distribution (RJD & Mark Naylor, poster presentation).*

Variable	Categories	Score
Education	None	0
	Elementary	1
	High School	2
	College	3
	Grad School	4
Hair color	Black	0
	Brown	1
	Blonde	2
	Red	3
Eye Color	Brown	0
	Green/Hazel	1
	Blue/Grey	2
Fitzpatrick Skintype	VI	0
	V	1
	IV	2
	III	3
	II	4
	I	5
Self History Skin Cancer	No	0
	Yes	1
Self History Melanoma	No	0
	Yes	1
Family History Skin Cancer	No	0
	Yes	1
Family History Melanoma	No	0
	Yes	1
Moles (>3 mm)	None	0
	Less than 20	1
	20 to 29	2
	30 to 39	3
	40 to 49	4
	50 or more	5
Moles (>6 mm)	None	0
	1 to 5	1
	6 to 9	2
	10 or more	3
Sunburns (>5 years)	No	0
	Yes	1
Sunburns (<5 years)	No	0
	Yes	1

skin cancer outcomes through diagnostic codes using the International Classification of Diseases [ICD-10] codes (C43.0–C43.9 for Malignant Melanoma (MM), D03.0–D03.9 for Melanoma in Situ (MIS), C44.01–C44.91 for Basal Cell Carcinoma (BCC), C44.02–C44.92 for Squamous Cell Carcinoma (SCC), and D04.0–D04.9 for Squamous Cell Carcinoma in Situ (SCCIS); CPT code 96904 was used to identify TBP sessions with each session referred to as a "scan" and coded as either "on site" or "mobile services;" telemedicine visits were identified by CPT modifier 95.

As has been previously described [12-14], automation of TBP is achieved by remotely activated simultaneous image capture using an array of 25 cameras housed in a phototherapy booth with choreographed patient poses to achieve standard lighting and positioning. Each session produces a full mosaic of 65 high quality images which are transferred to a secure office server at the end of each day.

Following a two-month pandemic adjustment period (March and April), patients were contacted as usual and offered semi-automated TBP either in the clinic with COVID-19 restrictive accommodations or via mobile delivery to their homes. Patients who opted to visit the clinic during this time were screened for COVID-19 symptoms before entering the office and guided by a technician who remained at least 6 feet from the patient at all times to a room designated for TBP. All office door and equipment handles were covered with copper and enhanced COVID measures were taken to minimize infection between patients.

For the mobile option, a portable version of the TBP system was placed in the back of a 2019 Ford Transit 250 extended high-roof cargo van that was physically isolated from the cab of the van where the technician operated the image-capture system. Transitioning to the mobile format was based on previous events where portable semi-automated TBP had been used for cancer screenings at health centers and corporate healthcare events. All systems were checked for protocol and process before the first mobile appointment on May 11. The driver, upon arriving at the patients' homes, contacted the patient via text message to screen for symptoms and if negative, opened the van doors. Patients were instructed to enter the TBP booth via the back of a van and to follow the visual and auditory prompts. The TBP booth doors were closed by the technician prior to starting the automated image capture software. Following each TBP session, the booth and handles were cleaned according to protocol. Patients were then offered either an in-office visit or a teledermatology follow-up visit after review of TBP images. In contrast to the usual practice of TBP followed by dermoscopic imaging of all new and changed lesions and VSE, detection of a lesion of concern in either baseline or serial TBP image review resulted in an in-office visit and dermoscopic imaging prior to biopsy without VSE.

Data was imported into STATA, StataCorp (2015) statistical software, release 14, college Station, TX, for analysis, and Pearson's chi-squared test, Fisher's exact test, and ANOVA were used to evaluate differences between patients imaged in the clinic or at home (mobile) as well as differences between services utilized and skin cancer outcomes for patients in 2019 compared to 2020. Bivariate logistic regression was used to assess stratified associations with 95% confidence intervals between predictors and TBP method usage as the outcome variable at a significance level of 0.05.

Results

May–November 2020

From May 11 to November 11, 2020, 5,319 patient appointments were conducted for 2,555 patients. Total body photography was used for 1,675 patients, of which 591 (35.3%) were accommodated via the mobile service and 1,083 of 1,675 (64.7%) were performed in the clinic. The number of TBP sessions as well as proportion of clinic to mobile events was consistent throughout the six-month period, χ^2=4.8101, P=0.439 (**Figure 1**). Four of the 1,675 patients (0.24%) had two TBP sessions during the six-month period, one clinic and one mobile, and the method used for the first TBP session was used for the analysis. For TBP in the clinic, 581 of 1,083 (53.65%) were baseline and 502 of 1,083 (46.35%)

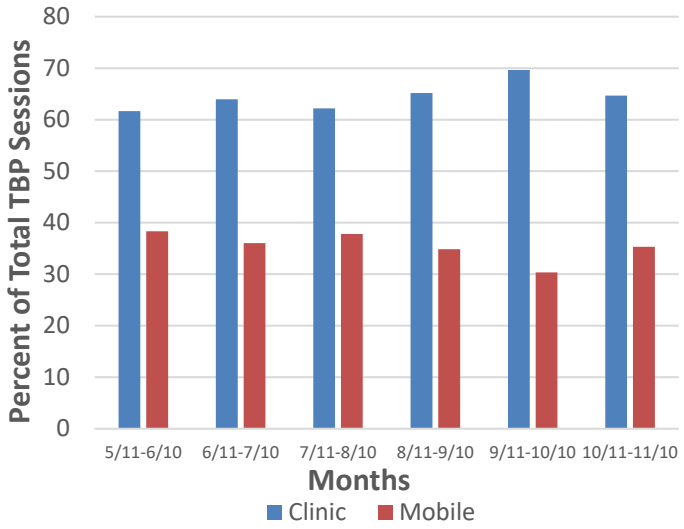

Figure 1. *Percent of total body photography (TBP) sessions in the clinic or mobile from May 11 to November 10, 2020.*

were follow-up scans. In contrast, mobile TBP patients were more likely to have follow-up scans, 361 of 591 (61.08%) compared to 230 of 591 (38.92%) of baselines, P<0.001.

The distribution of gender and education by mobile TBP patients was similar to that reported by clinic TBP patients. However, they tended to be younger and more likely to report marital status other than "married" (**Table 2**). Phenotypically, those who opted for mobile TBP were more likely to have lighter hair and eye color, a family history of skin cancer and melanoma, and more likely to report "fewer than 20 moles over three mm." Mobile TBP patients also were 1.3 (1.04, 1.61) times more likely to report sunburn "sometimes" within the last 5 years compared to clinic TBP patients. Furthermore, the overall score, calculated as described in **Table 1**, was significantly higher in the mobile TBP population (Table 3).

Eight hundred and eighty-seven of 5,319 (16.5%) of the appointments during the six-month period in 2020 were via telemedicine. A larger proportion of mobile TBP, 357 of 587 (60.8%), were followed by a telemedicine appointment compared to 230 of 587 (39.2%) which were followed by in-office appointments.

May–November 2019 versus May–November 2020

The total number of patients who received services between May 11 and November 11, 2020 was 92.4% of that seen during the same period in 2019. Specifically, 2,555 patients with 5,319 patient visits (2.08 visits per patient) in 2020 compared to 2,711 patients with 6,140 patient visits (2.26 visits per patient) in 2019 (Table 3).

The number of TBP sessions was greater in 2020 (including both in-office and mobile TBP) compared to 2019 (1,594 versus 1,255) a result that was consistent during the time period except for the first month (May) χ^2=27.4447, P=0.001 (**Figure 2**). Compared to 46.3% of patients who had TBP in 2019,

Table 2. *Sociodemographic variables stratified by total body photography delivery method.*

Variable	Categories	Total N=1,674 N (%)	Clinic N=1,083 (64.7) N (%)	Mobile N=591 (35.3) N (%)	P[a] -value	OR (95% CI)	P[b]-value
Gender	Female Male	815 (48.7) 859 (51.3)	518 (47.8) 565 (52.2)	297 (50.3) 294 (49.7)	 0.343	Ref 0.91 (074, 1.11)	 0.343
Age	Mean (SD)	54.5 (17.3)	55.5 (17.4)	52.6 (17.1)	**0.001**	0.99 (0.98, 0.99)	**0.001**
Marital status	No Yes *Missing*	1,083 (64.7) 496 (29.6) *95 (5.7)*	655 (60.5) 360 (33.2) *63 (6.3)*	428 (72.4) 136 (23.0) *27 (4.6)*	**0.001**	Ref 0.58 (0.46, 0.73)	**0.001**
Education	None Elementary Highschool College Graduate *Missing*	13 (0.8) 58 (3.5) 213 (12.7) 725 (43.3) 614 (35.7) *52 (3.1)*	10 (0.96) 33 (3.2) 148 (14.2) 466 (44.6) 387 (37.1) *40 (3.7)*	3 (0.5) 25 (4.3) 65 (11.2) 259 (44.7) 227 (39.2) *12 (2.0)*	 0.226	Ref 2.53 (0.63, 10.15) 1.46 (0.39, 5.50) 1.86 (0.51, 6.81) 1.96 (0.53, 7.20)	 0.19 0.57 0.35 0.31

Significant P values appear in bold (P<0.05, Students t-test (continuous); Chi-square statistic (categorical).
[a]P value: 0.05 ANOVA (continuous); Chi-square statistic (categorical); significant P values appear in bold text.
[b]P value: 0.05; Odds Ratios; significant P values appear in bold text.

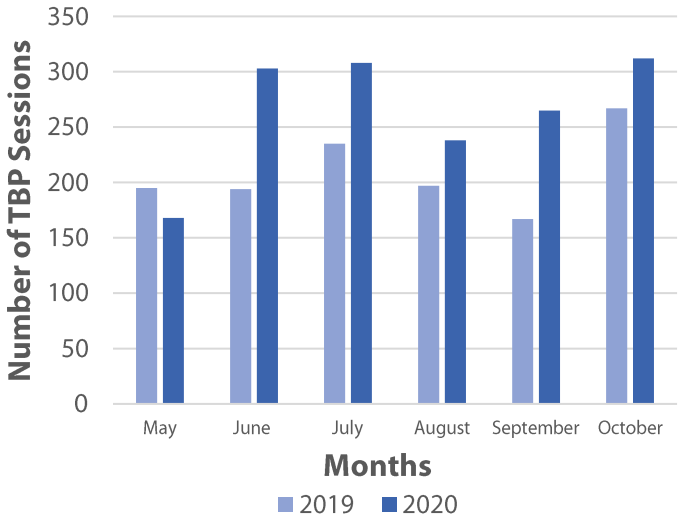

Figure 2. *Total number of total body photography (TBP) sessions in 2019 and 2020 from May to November.*

62.4% had TBP, either in office or mobile, in 2020. Further, the number of dermoscopic images taken of patients with new or evolving lesions following TBP was markedly reduced, from 7,426 in 2019 and 2,479 in 2020, as was the number of biopsies, 369 in 2019 and 280 in 2020 (**Table 4**).

Despite changes in patient processing, including increased number of TBP sessions (office and mobile), introduction of teledermatology services and decrease in dermoscopic images, we found a similar distribution of skin cancer, P>0.05, and similar percent of skin cancer detected per patient, 7.3% and 7.2% in 2019 and 2020 respectively. (**Table 4**). The MIS:INV ratio, 2.3:1 for 2019 and 1.7:1 for 2020, were both above the US MIS:INV ratio reported for 2020 of 0.95:1 (95,710 MIS:100,350 INV), [18]. Finally, the number of biopsies per skin cancer was reduced from 1.86 to 1.52.

Discussion

The COVID pandemic has presented daunting challenges for both providers and patients, necessitating the search for innovative and alternative approaches to maintain healthcare despite the presence of a highly contagious airborne pathogen. Semi-automated TBP with time-lapse comparison was developed to provide a sensitive and standardized platform for skin cancer detection [15]. The ability to rapidly pivot the semi-automated

Table 4. *Patient services and skin cancer outcomes between May 11 and November 10, 2019, and 2020.*

Year	2019	2020	
	N (%)	N (%)	P value
Patient Visits	6,140	5,320	
Patient	2,711	2,555	
Visits per Patient	2.26	2.08	
Telemedicine Appointments % Patient Visits		887 16.7	
TBP Sessions	1,255	1,594	
% Patients with TBP	46.3	62.4	
Biopsies	369	280	
Dermoscopic Images	7,426	2,479	
Images per TBP Session	5.92	1.56	
Skin Cancers			
MM	3 (1.5)	3 (1.6)	
MIS	7 (3.5)	5 (2.7)	
BCC	86 (43.4)	92 (50.0)	
SCC	86 (43.4)	73 (39.7)	
SCCIS	16 (8.1)	11 (6.0)	0.733
Total	**198**	**184**	
Skin Cancers per Patient (%) **Biopsies/Skin Cancer**	7.3 1.86	7.2 1.52	

TBP system to a mobile platform has provided a framework to assess dermatology service delivery during these challenging times and to prepare for changes in healthcare delivery systems for the future.

During the last six months, semi-automated TBP was successfully delivered to patients' homes as well as in a restricted capacity in the clinic using a system which can be operated remotely and satisfies the requirements of social distancing for both the clinical staff as well as the patient. Analysis of patient records suggests that there were several interesting differences between patients who preferred to have TBP in the clinic compared to those who opted for the mobile platform. In general, we found that the patients who opted for mobile TBP were younger and had a higher self-reported risk for skin cancer. Specific risk factors were lighter hair and eyes as well as a family history of skin cancer and melanoma. They were also more likely to report that they had some moles less than three mm than none and that they have had sunburns within the last five years.

Further, mobile TBP patients were more likely to have had TBP previously and were more likely to use

telemedicine for follow-up care. The technology was securely delivered to a patient population already familiar with the process and eager to maintain skin cancer monitoring without risking infection. One explanation for the differences in mobile TBP patients compared to those seen in the clinic could be the inclusion of other home-bound family members who appreciated the convenience of mobile TBP. Interestingly, the proportion of mobile and clinic TBP seemed to be maintained at a ratio of approximately 1:2 during the 2020 6-month period, despite ebbs and flows in COVID cases and changes in restrictions.

Comparing outcomes from the same period (May–November) in 2019 with that in 2020, COVID restrictions resulted in several changes in patient processing without much change in patient volume. First, the number of visits per patient decreased from 2.26 in 2019 to 2.09 in 2020 with a relatively small reduction, approximately 8%, in the number of patients. Second, the number of TBP sessions for the 6-month period in 2020 (clinic and mobile) increased approximately 30% from 2019 and 62.4% of patients seen in 2020 had TBP compared to only 42.3% in 2019. Third, the number of dermoscopic images was dramatically reduced from 2019 to 2020 (7,426 to 2,479 respectively). Finally, the number of biopsies was reduced from 369 to 280 and number of biopsies per skin cancer detected from 1.86 to 1.52 from 2019 to 2020, respectively. Acknowledging cyclical fluctuations in patient volume and service usage from year to year, changes in scan numbers, dermoscopic images and biopsies reported for 2020 appear to be markedly changed from the previous year. Despite these changes, the number of skin cancers, percent of patients with skin cancer, and distribution of skin cancer type did not change significantly.

These results suggest that there may be opportunities to increase the efficiency of skin cancer detection. Current best practice for the identification and evaluation of new or changing lesions involves a two-step process of TBP followed by dermoscopy [16]. Clinical images are used to identify new and changed lesions whereas dermoscopic images reveal discrete microscopic details consistent with malignancy [16,17]. COVID restrictions forced highly selective use of close-contact dermoscopic imaging and greater reliance on high resolution clinical images to identify suspicious lesions. As a result, the specificity of the process appeared to increase significantly. Patients may benefit by reducing the number of potentially unnecessary procedures, thereby reducing the number of people anxiously awaiting results.

Strengths of this study include expedited delivery of TBP during COVID-related social distance regulations and standardized documentation for data analysis. We saw a high rate of compliance from a defined patient population in acceptance of semi-automated TBP and self-reported skin cancer risk in a practice with a high yield of early melanoma detection while minimizing unnecessary biopsies: MIS:INV ratio (2.3:1) for 2019 and (1.7:1) for 2020 compared to the US ratio reported for 2020 of 0.95:1 (95,710 MIS:100,350 INV), [18].

Limitations include the use of a risk factor questionnaire that was neither derived from a statistical model nor validated, inability to generalize the findings from this study to other populations, and limited distribution of the TBP system to general dermatologists. In addition, the cross-sectional design and the limited time frame of the study compromise the strength of the results.

In the future, the demand for mobile TBP may continue in a post-pandemic environment given its high acceptance rate and convenience for patients. In addition, mobile TBP has the capacity to reach a greater proportion of the population as well as provide targeted screening services at large healthcare centers, nursing homes, community centers and residential settings.

Conclusion

The results of this study suggest that semi-automated TBP can effectively provide a socially distanced adjunct to dermatology services. Compared to clinic patients, those who opted for the home scanning service (35%) were younger, had higher self-reported skin cancer risk, and were more likely to have had previous scans. Compared to the

same 6-month period in 2019, the number of TBP scans increased, whereas the number of dermoscopic images and biopsies decreased. Despite adjustments to the process, the number of skin cancers per patient remained relatively unchanged.

As we begin to think about the present as well as future contagion outbreaks and potential modifications to the healthcare system to ensure safe delivery of services, we are forced to redefine distribution of resources to increase effectiveness and efficiency. Mobile delivery of semi-automated TBP has the potential to decrease access barriers for a greater number of people and to become an integral part of dermatology care in the future.

Potential conflicts of interest

Rhett Drugge MD is the inventor and holder of the intellectual property rights of the Melanoscan system (US patent 7,359,748). The remaining authors have no interests to declare.

References

1. Emanuel EJ, Persad G, Upshur R, et al. Fair allocation of scarce medical resources in the time of covid-19. *N Engl J Med*. 2020;382:2049-2055. [PMID: 32202722].
2. Chen Y, Pradhan S, Xue S. What are we doing in the dermatology outpatient department amidst the raging of the 2019 novel coronavirus? *J Am Acad Dermatol*. 2020;82:1034. [PMID: 32081700].
3. Litchman GH, Rigel DS. The immediate impact of COVID-19 on US dermatology practices. *J Am Acad Dermatol*. 2020;83:685-686. [PMID: 32422226].
4. Pak HS. Teledermatology and teledermatopathology. *Semin Cut Med Surg*. 2002;21:179-189. [PMID: 12322991].
5. Whited JD, Hall RP, Simel DL, et al. Reliability and accuracy of dermatologists' clinic-based and digital image consultations. *J Am Acad Dermatol*. 1999;41:693-702. [PMID: 10534630].
6. Whited JD, Mills BJ, Hall RP, et al. A pilot trial of digital imaging in skin cancer. *J Telemed Telecare*. 1998;4:108-112. [PMID: 9744167].
7. Adamson AS, Pignone MP. Eliminating copayments for skin cancer screening—a public health policy with insufficient evidence. *JAMA Dermatol*. 2019;155:1339. [PMID: 31418768].
8. Tripp MK, Watson M, Balk SJ, Swetter SM, Gershenwald JE. State of the science on prevention and screening to reduce melanoma incidence and mortality: The time is now. *CA Cancer J Clin*. 2016;66:460-480. [PMID: 27232110].
9. Drugge ED, Sarac RM, Elston DM, Drugge RJ. Correlation of total body photography frequency and invasive melanoma depth. *J Am Acad Dermatol*. 2020;82:768-769. [PMID: 31706932].
10. Drugge ED, Volpicelli ER, Sarac RM, et al. Micromelanomas identified with time-lapse total body photography and dermoscopy. *J Am Acad Dermatol*. 2018;78:182-183. [PMID: 29241777].
11. Drugge ED, Okundaye OI, Sarac RM, Drugge RJ. Melanoma screening using patient self-assessed risk and total body photography. *Dermatol Online J*. 2019; 25(7). [PMID: 31450271].
12. Drugge RJ, Nguyen C, Drugge ED, et al. Melanoma Screening with serial whole body photographic change detection using melanoscan technology. *Dermatol Online J*. 2009;15:1. [PMID: 19723475].
13. Drugge RJ, Nguyen C, Gliga L, Drugge ED. Clinical pathway for melanoma detection using comprehensive cutaneous analysis with melanoscan. *Dermatol Online J*. 2010;16:1. [PMID: 20804678].
14. Drugge RJ, Drugge ED. Temporal image comparison (serial imaging) in assessing pigmented lesions. *Dermatol Clin*. 2017;35:447-451. [PMID: 28886800].
15. Marino ML, Carrera C, Marchetti MA, Marghoob AA. Practice gaps in dermatology: Melanocytic lesions and melanoma. *Dermatol Clin*. 2016;34:353-362 [PMID: 27363893].
16. Salerni G MD, Carrera C MD, Lovatto L MD, et al. Characterization of 1152 lesions excised over 10 years using total-body photography and digital dermatoscopy in the surveillance of patients at high risk for melanoma. *J Am Acad Dermatol*. 2012;67:836-845. [PMID: 22521205].
17. Salerni G MD, Carrera C MD, Lovatto L MD, et al. Benefits of total body photography and digital dermatoscopy ("two-step method of digital follow-up") in the early diagnosis of melanoma in patients at high risk for melanoma. *J Am Acad Dermatol*. 2011;67:e17-e27. [PMID: 21683472].
18. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2020. *CA Cancer J Clin*. 2020;70:7-30. [PMID: 31912902].
19. Fitzpatrick TB. The validity and practicality of sun-reactive skin types I through VI. *Arch Dermatol*. 1988;124:869–71. [PMID: 3377516].

Table 3. *Self-reported melanoma risk factors stratified by total body photography delivery method.*

Variable	Categories	Total N=1,674	Clinic N=1,083 (64.7)	Mobile N=591 (35.3)	P[a] value	OR (95% CI)	P[b] value
Hair color	Black Brown Blonde Red *Missing*	132 (7.9) 1,094 (65.4) 338 (20.2) 59 (3.5) *51 (3.1)*	98 (9.1) 709 (65.5) 205 (18.8) 37 (3.4) *35 (3.2)*	34 (5.8) 385 (65.1) 134 (22.7) 22 (3.7) *16 (2.7)*	**0.043**	Ref 1.57 (1.4, 2.36) 1.89 (1.21, 2.96) 1.71 (0.89, 3.30)	 **0.032** **0.005** 0.108
Eye color	Brown Green/Hazel Blue/Grey *Missing*	592 (35.4) 478 (28.6) 568 (33.9) *36 (2.2)*	394 (36.4) 321 (29.6) 344 (31.8) *24 (2.2)*	198 (33.5) 157 (26.6) 224 (37.9) *12 (2.0)*	**0.041**	Ref 0.73 (0.75, 1.26) 1.30 (1.02, 1.65)	 0.836 **0.034**
Fitzpatrick skin-type [19]	VI V IV III II I *Missing*	27 (1.6) 393 (23.5) 184 (11.0) 564 (33.7) 363 (21.7) 97 (5.8) *46 (2.8)*	21 (1.9) 260 (24.0) 132 (12.2) 346 (31.9) 225 (20.8) 63 (5.8) *37 (3.4)*	6 (1.0) 133 (22.5) 52 (8.8) 218 (36.9) 139 (23.5) 34 (5.8) *9 (1.5)*	0.065	Ref 1.79 (0.71, 4.54) 1.38 (0.53, 3.61) 2.21 (0.88, 5.56) 2.17 (0.86, 5.51) 1.89 (0.70, 5.13)	 0.220 0.513 0.093 0.103 0.212
Self-history skin cancer	No Yes *Missing*	1,322 (79.0) 311 (18.6) *41 (2.5)*	853 (79.0) 197 (18.2) *33 (3.1)*	469 (79.4) 114 (19.3) *8 (1.4)*	0.093	Ref 1.05 (0.81, 1.36)	 0.696
Self-History Melanoma	No Yes *Missing*	1,471 (87.9) 159 (9.5) *44 (2.6)*	954 (88.1) 93 (8.6) *36 (3.3)*	517 (87.5) 66 (11.2) *8 (1.4)*	0.112	Ref 1.31 (0.94, 1.83)	 0.113
Family-history skin cancer	No Yes *Missing*	960 (57.4) 671 (40.1) *43 (2.6)*	649 (60.0) 399 (36.8) *35 (3.2)*	311 (52.6) 272 (46.2) *8 (1.4)*	**0.001**	Ref 1.42 (1.16, 1.75)	 **0.001**
Family-history of melanoma	No Yes *Missing*	1,221 (72.4) 387 (23.1) *66 (3.9)*	812 (75.0) 221 (20.4) *50 (4.6)*	409 (69.2) 166 (28.1) *16 (2.7)*	**0.001**	Ref 1.50 (1.18, 1.88)	 **0.001**
Moles (>3 mm)	None Less than 20 20 to 29 30 to 39 40 or 49 50 or more *Missing*	578 (34.5) 816 (48.8) 117 (7.0) 49 (2.9) 15 (0.9) 49 (2.9) *50 (3.0)*	401 (37.0) 502 (46.4) 74 (6.8) 29 (2.7) 9 (0.8) 30 (2.8) *38 (3.5)*	177 (30.0) 314 (53.1) 43 (7.3) 20 (3.4) 6 (1.0) 19 (3.2) *12 (2.0)*	0.070	Ref 1.42 (1.13, 1.78) 1.32 (0.87, 2.00) 1.56 (0.86, 2.84) 1.51 (0.53, 4.31) 1.43 (0.79, 2.62)	 **0.003** 0.195 0.143 0.441 0.239
Moles (>6 mm)	None 1 to 5 6 to 9 10 or more *Missing*	*1,022 (61.1)* *492 (29.4)* *65 (3.9)* *41 (2.5)* *54 (3.23)*	674 (62.2) 307 (28.4) 36 (3.3) 25 (2.3) *41 (3.8)*	348 (58.9) 185 (31.3) 29 (4.9) 16 (2.7) *13 (2.2)*	0.110	Ref 1.17 (0.93, 1.46) 1.56 (0.94, 2.59) 1.24 (0.65, 2.35)	 0.176 0.085 0.511
Sunburns (>5 years)	No Yes *Missing*	1,117 (66.7) 513 (30.7) *44 (2.6)*	713 (65.8) 335 (30.9) *35 (3.2)*	404 (68.4) 178 (30.1) *9 (1.5)*	0.565	Ref 0.94 (0.75, 1.17)	 0.565
Sunburns (<5 years)	Never Sometimes Frequently *Missing*	583 (34.8) 991 (59.2) 56 (3.4) *44 (2.6)*	395 (36.5) 613 (56.6) 39 (3.6) *36 (3.3)*	188 (31.8) 378 (64.0) 17 (2.9) *8 (1.4)*	**0.043**	Ref 1.30 (1.04,1.61) 0.92 (0.50, 1.66)	 **0.019** 0.772
Total score	Mean (SD)	12.77 (5.18)	12.46 (5.17)	13.33 (5.17)	**0.002**	1.03 (1.01, 1.05)	**0.002**

[a]P value: 0.05 ANOVA (continuous); Chi-square statistic (categorical); significant P values appear in bold text.
[b]P value: 0.05 Odds Ratios; significant P values appear in bold text.