Comparative effectiveness study of face-to-face and teledermatology workflows for diagnosing skin cancer

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Background: The effectiveness and value of teledermatology and face-to-face workflows for diagnosing lesions are not adequately understood.

Objective: We compared the risks of biopsy and cancer diagnosis among 2 face-to-face workflows (direct referral and roving dermatologist) and 4 teledermatology workflows.

Methods: Retrospective study of 59,279 primary care patients presenting with a lesion from January through June 2017.

Results: One teledermatology workflow achieved high-resolution images with use of a dermatoscope-fitted digital camera, a picture archiving and communication system, and image retrieval to a large computer monitor (in contrast to a smartphone screen). Compared with direct referral, this workflow was associated with a 9% greater probability of cancer detection (95% confidence interval [CI], 2%-16%), a 4% lower probability of biopsy (relative risk, 0.96; 95% CI, 0.93-0.99), and 39% fewer face-to-face visits (relative risk, 0.61; 95% CI, 0.57-0.65). Other workflows were less effective.

Limitations: Differing proficiencies across teledermatology workflows and selection of patients for direct referral could have caused bias.

Conclusion: Implementation is critical to the effectiveness of teledermatology. (J Am Acad Dermatol 2019;81:1099-106.)

Key words: comparative effectiveness research; dermatology/diagnosis; dermatology/epidemiology; dermatology/organization and administration; skin cancer; telemedicine.

Teledermatology has become a reality, particularly for underserved populations. New technologies have been introduced, and workflows have changed in recent years, necessitating contemporary evaluations.[1-4] Over the past decade, Kaiser Permanente Northern California has used 4 teledermatology modalities to triage cases presenting to primary care. We used this experience to conduct a retrospective comparative effectiveness study of primary care patients receiving care through 2 face-to-face and 4 teledermatology workflows. Outcomes included the probabilities of biopsy, cancer diagnosis, and a dermatology visit that did not result in a diagnosis of skin cancer. Our null hypothesis was that the risks of outcomes were the same for each of the 4 teledermatology and 2 face-to-face

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Funding sources: Supported solely by The Permanente Medical Group, Rapid Analytics Unit.
Conflicts of interest: None disclosed.
Accepted for publication January 19, 2019.
Reprints are not available from the authors.

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Published online February 7, 2019.
0190-9622/$36.00

https://doi.org/10.1016/j.jaad.2019.01.067

diagnostic modalities. This knowledge is important for optimizing implementation of teledermatology.

METHODS

Setting

Kaiser Permanente Northern California is a prepaid, integrated, closed system that provides health care using the Epic electronic medical record (EMR) to 4.1 million diverse members.[5] Access to dermatology is managed by primary care. Because of historic, geographic, and population differences, the mix of primary care workflows used to triage skin lesions are heterogeneous across the system's medical centers (Fig 1). Face-to-face workflows include direct referral to the dermatology clinic and staffing with a roving dermatologist who comes to the primary care provider's examination room to see the patient within minutes of receiving a referral request. Of the health plan's 23 medical centers, only 7 (30%) use roving as an option for dermatology referral. Roving is not always used, when available, because some patients cannot wait for the roving dermatologist and the roving dermatologist is not always available. Among patients who receive teledermatology, only less than 0.7% request a face-to-face appointment, with most patients who insist on an appointment being directly referred.

The teledermatology workflows are identified in Table I by the names of their store-and-forward technologies. Each medical center implements teledermatology based on the local context. All clinicans and support staff receive training in the technologies available at their medical center and on photograph taking. Retraining occurs when dermatologists identify consistently inadequate photographs. Primary care physicians choose a workflow based on patient needs, local resources, local practices, and convenience. Stentor (now iSite, Philips, Eindhoven, The Netherlands and Andover, MA) is a high-resolution picture archiving and communications system originally purchased to store and transmit radiology images.[6] As part of the Stentor workflow, medical assistants are trained to take photographs using a digital camera (Nikon, Canon, Tokyo, Japan) and a separate digital dermatoscopic camera (3Gen DermLite Cam, 3Gen, San Juan Capistrano, CA), although the dermatoscopic camera was not used with some photographs. Cortext (Imprivata, Lexington, MA) and Haiku (Epic Systems, Verona, WI) are text messaging products that enable primary care physicians to send photographs from their smartphones.[7,8] Magnifying lenses (×10 or ×15) were occasionally used with smartphones. Finally, patients can use the patient portal, which is a secure, online website and messaging system, to send their own photographs directly to their primary care physician or dermatologist, which offers convenience and eliminates copayment.

CAPSULE SUMMARY

- The benefit of teledermatology for triaging potential skin cancers is not adequately understood.
- The quality of the viewed image and the addition of dermoscopy drive outcomes.
- With the right equipment, teledermatology can offer excellent cancer detection with reduced wait times, fewer biopsies, and fewer nonessential dermatology clinic visits.

Study design and population

The retrospective cohort study included health plan members, aged 18 to 89 years, who had a primary care encounter for a skin lesion (alone or with a rash) during January through June 2017. Primary care encounters included both face-to-face visits and patient portal messages. Each patient was counted only once, and the date of visit to the primary care provider or the date of upload to the patient portal was defined as the date of entry into the study. We excluded patients who had contact with dermatology during the 6 months preceding study entry.

Lesions were documented differently for teledermatology and face-to-face modalities because of differences in clinical workflows. For teledermatology, the primary care provider used a dropdown menu to record the skin condition as a lesion or rash into the EMR as a smart phrase. Face-to-face encounters were recorded into the electronic consultation system (eConsult, Epic Systems, Verona, WI) by the primary care provider as problem descriptions. We used natural language processing of the problem description to identify lesions, using terms related to cancer, such as *skin check*, *growth*, *wart*, *mole*, *keratosis*, *keloid*, *cyst*, *skin tag*, *ulcer*, *bump*, *scar*, *granuloma*, *blister*, *nevus*, and *lesion not further specified*.

Data collection

The exposure variable was diagnostic workflow, classified as direct referral, roving, or teledermatology with or without image enhancement. Teledermatology workflows used 1 of 4 store-and-forward technologies: Stentor, Haiku, Cortext, or patient portal. Image enhancement with Stentor

Abbreviations used:

CI: confidence interval
EMR: electronic medical record
RR: relative risk

included dermoscopy and with Haiku and Cortext included magnification. Outcomes included the dermatologist's disposition (advice given or appointment recommended), wait time (days), biopsy (yes/no), and skin cancer detection (yes/no).

Dispositions for direct referral to the dermatology clinic were coded as appointment completed within 30 days, appointment not completed within 30 days, advice provided, and other. Dispositions for roving were classified as visit with roving dermatologist and e-Consult closed, visit in the dermatology clinic in the following 30 days and eConsult closed, and other. For teledermatology, the dermatologist's disposition was classified as advice given, clinic appointment recommended and completed within 30 days, clinic appointment recommended but not completed within 30 days, and other. Wait time was calculated as days from the initial encounter with the primary care provider to the date of the dermatologist's disposition.

Biopsies performed 0 to 30 days after the primary care encounter were captured from surgical pathology codes. Cancer cases were identified from pathology reports containing diagnoses for basal or squamous cell carcinoma (Systematized Nomenclature of Medicine codes D5402, M8070-M8074, M8076, M8090-M8094, M8720, M8721, M8730, M8742, M8743, M8745, and M8772-M8774) or malignant melanoma (validated natural language processing algorithm used for clinical care).[9-12]

Statistical analysis

Relative risks (RRs) and 95% confidence intervals (CIs) of biopsy and skin cancer diagnosis were assessed by using generalized estimating equations with binomial response variables and log functions.[13] We examined patient age, sex, race/ethnicity, recent skin cancer history, and medical center as potential confounders, retaining those that had clinical significance or had sufficiently improved the goodness of fit as measured by the Akaike information criterion.

Primary analyses used an intention-to-treat approach, which included all patients whose initial encounter was teledermatology even if they received advice only and never had a face-to-face visit with a dermatologist or failed to complete their recommended dermatology appointment. This approach mimics the methods used for a randomized controlled trial. By including all patients, the analysis assessed whether dermatologists correctly classified patients who did and did not need a dermatology appointment based on their risk of skin cancer, patient no-show rate, and risk of biopsy or skin cancer among those who had an appointment. To assess the number of face-to-face dermatologist visits needed to detect 1 skin cancer, we restricted the patients assessed to patients with a face-to-face visit[14] and compared each of the teledermatology

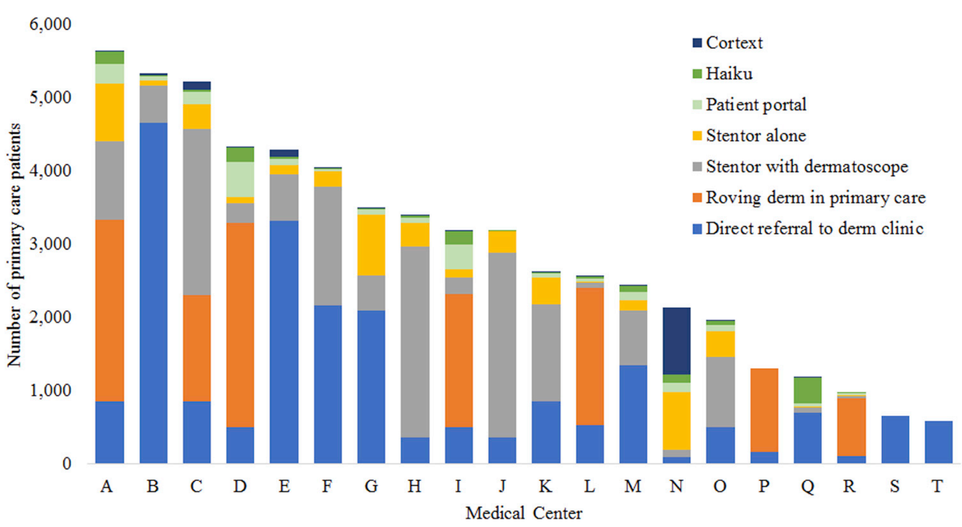

Fig 1. Heterogeneity in diagnostic workflows used in primary care (59,279 Kaiser Permanente Northern California members, aged 18-89 years, presenting with lesion in the period from January through June 2017).

Table I. Teledermatology workflows used most commonly at Kaiser Permanente Northern California

Characteristic	Teledermatology workflow			
	Stentor	**Cortext**	**Haiku**	**Patient portal**
Developer	Stentor	Imprivata	Epic	Epic
Integration into the EMR	Fully integrated	Stand-alone smartphone application	Fully integrated	Fully integrated
Photographer	Medical assistant	Primary care provider	Primary care provider	Patient
Camera	Nikon, Canon, 3Gen	Smartphone	Smartphone	Smartphone or camera
Image enhancement	Dermoscopy	Magnification lens	Magnification lens	None
Image forwarding and storage	PACS* server	Text message (saved to smartphone only)	EMR server	EMR server
Image retrieval and viewing	Desktop or laptop computer	Smartphone†	Desktop or laptop computer	Desktop or laptop computer
Synchronicity‡ by reading dermatologist	Asynchronous	Synchronous	Asynchronous	Asynchronous
Integration into the EMR and long-term image storage	Yes	No	Yes	Yes
Convenience	Less convenient, requires access to a computer	Mobile, greater convenience to physicians	Mobile, greater convenience to physicians	Convenient to patient, increases access, eliminates copayment
Image quality	Image quality with dermoscopy is outstanding	Image quality not as good as with dermoscopy, but a reshoot can be requested immediately	Image quality not as good as with dermoscopy, but a reshoot can be requested immediately	Image quality is often poor

EMR, Electronic medical record; *PACS*, picture archiving and communication system.

*The PACS is fully integrated with the EMR, with essentially no lag time.

†Could be retrieved on a personal computer or web application, but during the period of study most views were on a smartphone.

‡With asynchronous modalities, the image is uploaded and stored in the EMR with a lag time of 5 to 15 minutes. Typically, the dermatologist schedules time to retrieve and interpret a batch of images on a personal computer. In contrast, with synchronous modalities, the image is transmitted as a text message from the primary care provider's smartphone to the dermatologist's smartphone. The lag time is seconds, and the dermatologist strives to interpret the image immediately during the patient's visit with the primary care provider so that a reshoot is possible.

Table II. Characteristics of 59,279 Kaiser Permanente patients with a primary care encounter for a skin lesion, aged 18-89 years seen from January to June 2017

Patient characteristic	Face to face: Direct referral* (n = 21,911)	Face to face: Roving dermatology* (n = 12,327)	Teledermatology* (n = 25,041)
Age at primary care visit, %			
18-24 y	3.4	4.2	3.9
25-34 y	10.0	14.4	10.7
35-44 y	12.1	14.7	12.5
45-55 y	16.9	17.3	16.3
55-64 y	23.3	20.2	22.7
≥65 y	34.2	29.1	34.0
Sex, %			
Male	43.4	44.2	42.1
Female	56.6	55.8	57.9
Race, %			
White	77.4	67.0	73.6
African American	2.2	4.2	2.7
Asian	6.1	13.2	8.1
Hispanic	7.6	8.3	8.6
Other	4.3	4.4	4.4
Missing	2.1	2.6	2.3
History of skin cancer, %	9.4	8.1	8.8

*All *P* values are less than .001 in this large data set.

workflows with direct referral. All analyses were performed with SAS software (version 9.4, SAS Inc, Cary, North Carolina).

This project was exempt from institutional review board review.

RESULTS

We identified 111,117 potentially eligible primary care patients. We excluded 978 patients (0.8%) who had a dermatology visit during the 6 months before their primary care visit and then restricted the sample to 59,279 patients (54%) who had a lesion. Of these, 25,041 (42%) had teledermatology, 21,911 (37%) had direct referral to dermatology, and 12,327 (21%) had referral to a roving dermatologist. Of the 59,279 patients, one-third were aged 65 years or older, 57% were women, 26% were nonwhite, and 9% had a history of skin cancer (Table II).

Of the patients with direct referral, 88% completed their dermatology appointment with an average wait time of 7.3 days, 8% did not complete their appointment, 1% received advice without an appointment, and 3% had other dispositions. With regard to patients seen by a roving dermatologist, 71% of consults were completed after the roving encounter, 27% of patients had a follow-up visit in the dermatology clinic with an average wait time of 5.8 days, and 2% of patients had other dispositions. Of the teledermatology patients, 49% received advice without an appointment (average wait time, 5 hours), 39% received a dermatology appointment that was completed after an average wait time of 8.3 days, 6% were booked for a dermatology appointment that was not completed, and 6% had other dispositions. As regards the entire teledermatology population, 88% of dispositions were completed, and the average wait time to diagnosis was 3.3 days.

The intention-to-treat analysis included every patient who presented to primary care with a lesion. The frequency of biopsy was 35% among patients directly referred to dermatology (Table III). In multivariable analysis, the likelihood of a biopsy was highest for patients with direct referral (RR for all, <1.0). The frequency of cancer detection was 12% for direct referral (Table IV). In multivariable analysis, the RR for the association of diagnostic workflow with skin cancer detection was 1.02 (95% CI, 0.93-1.12) for roving, 1.09 (95% CI, 1.02-1.16) for Stentor with dermoscopy, and less than 1.0 for other teledermatology workflows. We also made comparisons after restriction to patients seen via teledermatology, in which Stentor with dermoscopy was associated with the highest likelihood of biopsy and cancer detection.

To assess the number of dermatology visits needed to detect 1 skin cancer, we restricted the analysis to those with a face-to-face visit to dermatology. All teledermatology workflows were associated with fewer dermatology visits to detect 1 skin cancer (Table V). For example, Stentor with dermoscopy required 39% fewer visits than direct referral did (RR, 0.61; 95% CI, 0.57-0.65).

DISCUSSION

We conducted a retrospective study to investigate the effectiveness and efficiency of 4 teledermatology and 2 face-to-face workflows in relation to risk of skin cancer detection, biopsy, and a visit to the dermatology clinic that did not result in a skin cancer diagnosis. Among the direct referrals, 35% received a biopsy and 12% had a skin cancer diagnosed. We found that Stentor with dermoscopy was associated with a 9% greater probability of cancer detection compared with direct referral (95% CI, 2%-16%), was associated with 4% lower probability of biopsy (RR, 0.96; CI, 0.93-0.99), and required 39% fewer face-to-face visits. These findings are consistent with anecdotal reports by dermatologists in our setting

Table III. Intention to treat: Association of diagnostic workflow with risk of biopsy within 30 days (59,279 Kaiser Permanente Northern California members aged 18-89 years seen from January to June 2017)

			Compared with direct referral		Compared with Stentor with dermoscopy	
Procedure	Patients presenting to primary care with a lesion, n	Patients in whom a biopsy was performed, %	Adjusted relative risk*	95% CI	Adjusted relative risk*	95% CI
Direct referral	21,911	35	1.00	Reference	—	—
Roving	12,327	26	0.89	0.84-0.93	—	—
Stentor with dermoscopy	15,544	32	0.96	0.93-0.99	1.00	Reference
Stentor without dermoscopy	4886	27	0.90	0.85-0.95	0.93	0.88-0.98
Cortex with magnification	113	26	0.71	0.52-0.97	0.72	0.53-0.99
Cortex without magnification	1100	29	0.79	0.71-0.88	0.80	0.72-0.90
Haiku with magnification	99	20	0.75	0.51-1.11	0.74	0.50-1.09
Haiku without magnification	1328	23	0.88	0.80-0.98	0.86	0.77-0.96
Patient portal	2070	19	0.69	0.63-0.76	0.69	0.63-0.76

*The intention-to-treat analysis included all patients who presented to primary care, even if they did not complete their recommended visit to dermatology. Adjusted for age, sex, race/ethnicity, and medical center. History of skin cancer did not confound the associations. Roving dermatologists were located at medical centers that served disproportionate numbers of non-White populations at lower risk of skin cancer.

Table IV. Intention to treat: Association of diagnostic workflow with risk of cancer within 30 days (59,279 Kaiser Permanente Northern California members aged 18-89 years, January to June 2017)

			Compared with direct referral		Compared with Stentor with dermoscopy	
Procedure	Patients presenting to primary care with a lesion, n	Patients in whom cancer developed, %	Adjusted relative risk*	95% CI	Adjusted relative risk*	95% CI
Direct referral	21,911	12	1.00	Reference	—	—
Roving	12,327	9	1.02	0.93-1.12	—	—
Stentor with dermoscopy	15,544	13	1.09	1.02-1.16	1.00	Reference
Stentor without dermoscopy	4886	9	0.94	0.85-1.03	0.84	0.76-0.93
Cortex with magnification	113	10	0.83	0.48-1.42	0.70	0.41-1.21
Cortex without magnification	1100	9	0.75	0.60-0.93	0.64	0.51-0.79
Haiku with magnification	99	5	0.76	0.33-1.75	0.62	0.27-1.44
Haiku without magnification	1229	7	0.92	0.75-1.13	0.77	0.61-0.97
Patient portal	2070	6	0.70	0.58-0.83	0.61	0.51-0.74

*The intention-to-treat analysis included all patients who presented to primary care, even if they did not complete their recommended visit to dermatology. Adjusted for age, sex, race/ethnicity, and medical center. History of skin cancer did not confound the associations. Roving dermatologists were located at medical centers that served disproportionate numbers of non-White populations at lower risk of skin cancer.

indicating that they have a better view of the lesion with dermoscopy than with plain eyesight because of good image resolution with use of a large viewing screen. Alternatively, the consistent use of Stentor with dermoscopy was the most common workflow used in our setting, and its consistent use may have led to a training effect for both the medical assistant who took the picture and the dermatologist who viewed it in that training improved their performance.[15] If so, the Stentor workflow could have benefited from experience, although only patients whose image involved use of a dermatoscope realized this benefit. We did not observe a relationship of Cortext, Haiku, or the patient portal to improved cancer detection. Dermoscopy was not widely available for smartphones during the study period. The second face-to-face workflow, roving dermatology, was not associated with improved cancer detection.

Other advantages of Stentor with dermoscopy include integration with the EMR and long-term storage of photographs (Table I). On the other hand, the smartphone applications, Cortext and Haiku, are more convenient for physicians because they are mobile. Many patients use the patient portal to eliminate the primary care visit and its copayment and would not otherwise come to medical attention. These patients had lower cancer detection, suggesting lower risk, missed cases, or barriers that reduced follow-up. Patients can be trained to take better photographs,[16] and recently our health system has improved its instructions to patients. Other options

Table V. Number needed to treat: Association of diagnostic workflow with cancer diagnosis (59,279 Kaiser Permanente Northern California members aged 18-89 years seen from January to June 2017)

Procedure	Face-to-face visits with a dermatologist, n	Patients in whom cancer developed, %	Compared with direct referral		Compared with Stentor with dermoscopy	
			Adjusted relative risk*	95% CI	Adjusted relative risk*	95% CI
Direct referral	18,735*	14	1.00	Ref	—	—
Stentor with dermoscopy	7424	27	0.61	0.57-0.65	1.00	Reference
Stentor without dermoscopy	2557	18	0.75	0.68-0.83	1.23	1.14-1.37
Cortex with magnification	50	22	0.52	0.33-0.83	0.89	0.56-1.45
Cortex without magnification	475	21	0.67	0.54-0.81	1.14	0.93-1.41
Haiku with magnification	39	10	0.83	0.35-2.00	1.59	0.66-3.85
Haiku without magnification	573	14	0.74	0.60-0.89	1.28	1.04-1.59
Patient portal	780	15	0.85	0.71-1.00	1.37	1.15-1.64

*The model was adjusted age, sex, race/ethnicity, and medical center. History of skin cancer did not confound the associations.

to lower the barrier for patients to obtaining high-quality diagnoses are being discussed and include drop-in visits with a medical assistant who could take high-quality photographs.

More than 20 recent studies have compared the sensitivity, specificity, and agreement of diagnosis made through teledermatology versus through direct referral. Teledermatology has a sensitivity greater than 90% and a specificity greater than 80% compared with direct referral, whereas agreement with pathologic diagnosis was greater than 80%.[3] These studies were consistent enough that a systematic review judged the evidence to be sufficient to conclude that teledermatology provides good diagnostic and treatment concordance while increasing access and reducing cost. Use of advanced dermoscopy and confocal microscopy has been found to improve diagnostic accuracy.[3,17] Fewer studies have reported on the effectiveness of teledermatology for improving the diagnosis and management of skin cancer and other skin conditions. A randomized controlled trial found that the proportions of patients whose skin disease improved, remained the same, or got worse were similar in the teledermatology and usual care groups.[18] Another randomized trial reported no difference in outcome for patients with acne.[19] An observational study assessed whether clinic visits plus teledermatology led to better outcomes than did clinic visits alone; it revealed a benefit with the addition of teledermatology. An observational study of patients triaged and then confirmed to have melanoma found that the teledermatology group had a more favorable initial prognosis.[20] Implementation factors are critical to teledermatology effectiveness.[21,22] Past implementation studies differed from ours in their scope, focusing more closely on clinical workflows used for follow-up and provider proficiency and less on teledermatology technologies. Published studies are consistent in reporting lower costs, shorter wait times, and increased patient satisfaction with teledermatology than with direct referral.[3,4,23-27]

Selection bias was possible if primary care physicians selected patients with the most suspicious lesions for Stentor with dermoscopy, selected patients with moderate-risk lesions for direct referral to dermatology, and selected patients with low-risk lesions for other teledermatology workflows. We find it difficult to believe that the highest-risk patients would be selected for Stentor with dermoscopy in place of a clinic visit, particularly because the frequency of biopsy was relatively low for Stentor with dermoscopy. Patients referred directly to the dermatology clinic may have additional lesions assessed and subjected to biopsy, and this would increase the likelihood of cancer detection and lead to underestimation of the magnitude of the true benefit of Stentor with dermoscopy.

We did not assess costs. Medicare physician reimbursement for relevant dermatology office visits ranges from $50 to $100. Teledermatology requires clinician training to properly use a dermatoscope. Each patient then requires about 5 minutes by the primary care provider and about 10 minutes by the dermatologist. Retail equipment costs are about $500 for a camera and $2000 for a dermatoscopic camera. Nor did we assess the patient's satisfaction with care, although this has been reported on extensively in past studies.[25] A 2011 report of interviews with 17 dermatologists identified several barriers to implementation, including inadequate teledermatology training,[28] reimbursement delays and nonreimbursement, costly and inefficient software, poor communication with referring providers, poor image quality, and inadequate patient histories. Because Kaiser Permanente is integrated, the results that we observed may be better than would be achieved in other settings. Notwithstanding, we believe that our main finding, namely, that the quality of the viewed image drives outcomes, is generalizable to other settings and is useful for making investment decisions.

In conclusion, use of a dermatoscopic camera, a picture archiving and communication system, and a large high-resolution monitor was associated with excellent cancer detection, fewer visits to the dermatology clinic, and reduced wait times. We plan to support further adoption of dermoscopy, increased training to improve image quality, and further consideration of the value of viewing images on a larger computer monitor.

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