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Estimating the cost of skin cancer detection by dermatology providers in a large healthcare system

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Abstract

Background—Data on the cost and efficiency of skin cancer detection through total body skin examination (TBSE) are scarce.

Objective—To determine the number needed to screen (NNS) and biopsy (NNB) and cost per skin cancer diagnosed in a large dermatology practice in patients undergoing TBSE.

Methods—Retrospective observational study.

Results—From 2011 – 2015, 20,270 patients underwent 33,647 visits for TBSE; 9956 lesion biopsies were performed yielding 2,763 skin cancers, including 155 melanomas. The NNS to detect one skin cancer was 12.2 (95% CI 11.7–12.6) and one melanoma was 215 (95% CI 185–252). The NNB to detect one skin cancer was 3.0 (95% CI 2.9–3.1) and one melanoma was 27.8 (95% CI 23.3–33.3). In a multivariable model for NNS, age and personal history of melanoma

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This study was approved by the University of Pittsburgh Institutional Review Board

Conflicts of interest: Dr. Kirkwood has served as a consultant for Bristol Myers Squibb, Merck, Novartis, Roche, Genentech, EMD Serano, and Array Biopharma and has received grants from Prometheus and Merck. Dr. Ferris has served as a consultant for DermTech International. The remaining authors have no relevant financial interests to report.

Author Contributions:

Dr. Laura Ferris and Martha Matsumoto had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Ferris, Matsumoto. *Acquisition, analysis, and interpretation of data:* Ferris, Ho, Matsumoto, Saul, Secrest, Anderson. *Drafting of manuscript:* Ferris, Matsumoto, Secrest Anderson. *Critical revision of the manuscript for important intellectual content:* Kirkwood, Ho, Saul. *Statistical analysis:* Matsumoto, Secrest, Anderson. *Obtained funding:* Ferris, Kirkwood. *Study supervision:* Ferris.

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were significant factors. Age switches from a protective to a risk factor at 51 years. The estimated cost per melanoma detected was \$32,594 (95% CI \$27,326–\$37,475).

Limitations—Data are from a single healthcare system and based on physician coding.

Conclusions—Melanoma detection through TBSE is most efficient in patients over age 50 and those with a personal history of melanoma. Our findings will be helpful in modeling the cost effectiveness of melanoma screening by dermatologists.

Keywords

melanoma; skin cancer; screening; cost; detection; biopsy

INTRODUCTION

Although studies indicate that total body skin examination (TBSE) is an effective means to detect melanoma at an early, treatable stage,^{1,2} the United States Preventive Services Task Force (USPSTF) concluded that current evidence was inadequate to evaluate the balance of benefits and harms of melanoma screening by TBSE.³ Quantifying the cost of screening to the healthcare system is important for drawing conclusions about the benefits and harms of screening. Cost effectiveness studies have been used to estimate and model societal costs and benefits of population melanoma screening projects, however these are predominantly in the primary care setting, or under the setting of a clinical trial.^{4–7} Nevertheless, the practical costs of melanoma screening in the setting of dermatology practices has not been well-studied in the United States.

Using visits coded as skin cancer screening visits performed by dermatology practitioners at a large healthcare system with both academic and community-based providers, we aimed to determine the number needed to screen (NNS) and number needed to biopsy (NNB) to diagnose one skin cancer, two standard metrics of screening efficacy,⁸ as well as the cost per skin cancer diagnosed during TBSE.

METHODS

We identified all visits occurring at University of Pittsburgh Medical Center (UPMC)-affiliated dermatology offices from January 1, 2011 to December 31, 2015 in which skin cancer screening was performed using International Classification of Diseases (ICD) diagnoses V76.43 (ICD-9) or Z12.83 (ICD-10), which code for “Encounter for screening for malignant neoplasm of the skin.” To assess the accuracy of using ICD diagnoses in identifying TBSE visits, we employed published methodology as follows⁹: 100 eligible visits with and 100 eligible visits without these ICD-9/10 diagnoses were randomly selected and charts were manually reviewed to calculate positive and negative predictive values.

Data extraction

For each identified visit, visit and patient level data were extracted from the electronic medical record (EMR). Patient level data included sex, date of birth, race and ethnicity (self-reported), personal history of melanoma, personal history of any skin cancer. Age was

determined as of first dermatology visit. Age was subsequently dichotomized at age 50 based upon preliminary statistical analyses showing melanoma risk increased over this age, and for consistency with melanoma screening cost-effectiveness studies.⁶ Personal history of melanoma and of any skin cancer were determined using ICD-9/10 codes (V10.82 or Z85.820 for melanoma, V10.83 or Z85.828 for non-melanoma skin cancer, respectively) associated with current or prior visits, pathology reports containing melanoma diagnoses in our system, and EMR health history data. Visit level data included current procedural terminology (CPT) codes. CPT codes were used to determine level of service for each visit and procedures associated with visits, including any codes used to denote lesion removal for pathologic examination (including biopsy, shave, and excision), and preparation of slides and examination by a dermatopathologist. The Medicare physician fee schedule non-facility cost was used to determine cost associated with each CPT code (Supplemental Table 1).¹⁰

Pathology reports from all visits in which a skin lesion was removed for pathologic examination (on day of or up to one month after the office visit) were reviewed to categorize lesions as pigmented or non-pigmented and to obtain the diagnosis of the lesion removed.

Statistical analysis

Poisson regression was used to model counts of any skin cancer, melanoma, and non-melanoma skin cancer (NMSC). NNS was calculated as the inverse of the absolute risk of skin cancer per patient-visit in univariate regression models. NNB was calculated as the inverse of the absolute risk of skin cancer per patient-biopsy in univariate regression models. Only pigmented lesion biopsies were used to calculate NNB for melanoma. Only non-pigmented lesion biopsies were used to calculate NNB for NMSC. All biopsies were used to calculate NNB for any skin cancer. Poisson regression was used with one observation per patient for both univariate and multivariable models. To adjust for patients with multiple visits and biopsies, an exposure variable corresponding to number of visits for NNS estimates and number of biopsies for NNB estimates were included. Mixed models were initially attempted; however, due to high proportion of patients with a single visit and low number of melanomas diagnosed, these models did not converge. Stepwise regression was used to select factors from those significant in univariate models for multivariate models. Stepwise regression models included age, sex, and personal history of skin cancer and melanoma as potential covariates for selection in multivariable models, and used a selection p-value of <0.05.

Biopsied patient rate (BPR) was calculated as the number of visits in which a biopsy was performed divided by the total number of screening visits. Biopsy rate (BR) was calculated as the BPR times the mean number of biopsies per biopsied patient (MBP). Chi-square tests were used to compare BR by age, sex, and personal history of skin cancer. Average visit cost was broken down into the cost of the office visit and biopsy costs, including dermatopathology costs. Student's t-test was used to compare visit costs by age, sex, and personal history of skin cancer. Normal bootstrap confidence intervals were calculated for cost per cancer detected and p-values for comparisons were calculated by permutation method. Cost per melanoma detection was calculated as NNS x mean cost per visit. All statistical analyses were performed in R 3.3.1 (R Core Team, Vienna, Austria).¹¹

Ethical considerations

This study was approved by the University of Pittsburgh Institutional Review Board (PRO16080018).

RESULTS

Population presenting for skin cancer screening

During the 5-year study period, 33,647 TBSEs were performed in 20,270 adult patients (age 18 years), with a mean of 1.66 TBSEs per patient. Patients with personal history of skin cancer were more likely to have multiple TBSEs during the study period ($p < 0.001$) (Table 1).

Validation of identifying TBSEs by ICD diagnoses

Of the 100 randomly sampled records with ICD diagnoses V76.43 or Z10.43, a TBSE was performed in 97% of the visits on manual review of the electronic chart (PPV 97%). Of the 100 randomly sampled records without these ICD diagnoses, a TBSE was performed in 17% of the visits on manual review of the electronic chart (NPV 83%).

All skin cancers

In total, 2763 skin cancers were diagnosed from 9956 biopsies. For all skin cancers, NNS was 12.2 (95% CI 11.7–12.6) and NNB was 3.0 (95% CI 2.9–3.1) (Figures 1 and 2). In univariate analysis, NNS and NNB were lower with increasing age, in males, and in patients with a personal history of any skin cancer ($p < 0.001$ for all, Figures 1 and 2). Personal history of melanoma was also associated with lower NNB ($p = 0.035$). In multivariable models for NNS and NNB, age, sex and skin cancer history remained significant factors after stepwise regression ($p < 0.001$ for all, Table 2).

Melanoma skin cancers

In total, 155 melanomas were diagnosed from 4930 biopsies of pigmented lesions. Review of all melanoma cases showed that 81/156 (51.9%) were not identified as suspicious by the patient per chart history, and thus were truly detected through TBSE. Overall, the NNS was 215 (95% CI 185–252) and NNB was 27.8 (95% CI 23.3–33.3) to detect one melanoma (Figures 1 and 2). In univariate models, NNS was lower with increasing age ($p < 0.001$), in males ($p < 0.01$) and in patients with a personal history of melanoma ($p < 0.001$), but not in patients with a personal history of any skin cancer (Figure 1). In univariate modeling, age switches from a protective to a risk factor at 51 years old. Increasing age ($p < 0.001$) and male sex ($p < 0.01$) were associated with lower NNB (Figure 2). However, after controlling for age, male sex lost significance, and age was the only factor included in the regression model for NNB by stepwise selection. In a multivariable model for NNS, age ($p < 0.001$) and personal history of melanoma ($p < 0.001$) were significant factors (Table 2).

Non-melanoma skin cancers

In total, 2607 NMSC were diagnosed in 5026 biopsies for non-pigmented lesions. For NMSC, NNS was 12.9 (95% CI 12.4–13.4) and NNB was 1.6 (95% CI 1.5–1.7) (Figures 1

and 2). In the univariate model, both NNS and NNB were lower with increasing age, in males, and in patients with a personal history of any skin cancer ($p < 0.001$ for all, Figures 1 and 2). Personal history of melanoma was also associated with lower NNB ($p < 0.01$). In the multivariable model, sex, age, and any skin cancer history remained significant factors ($p < 0.001$ for all, Table 2).

Costs of screening

The overall mean visit cost for a skin cancer screening visit was \$150, consisting of \$105 (70%) for office visit costs and \$45 (30%) for biopsy and dermatopathology costs (a value that accounts for the fact that a biopsy was not performed at every visit) (Table 3). Biopsy rate (BR) per visit for all lesions was higher in males, patients over age 50, and patients with a personal history of skin cancer (Table 3). Pigmented lesion BR was highest in patients with a personal history of melanoma and patients under age 50.

The cost per melanoma detected was estimated to be \$32,594 and \$2,496 per NMSC diagnosis (Table 3). For melanoma, the point estimates of the cost of detection was higher for females than males ($p=0.043$) and higher in patients under age 50 ($p=0.002$). The lowest cost per melanoma detected was observed in patients with a personal history of melanoma at \$15,714 which was significantly less than the cost of detection for patients without a history of melanoma ($p<0.05$) (Table 3). Given these findings, we looked specifically at cost of melanoma detection in men over age 50 and found costs were significantly lower than in younger males and females ($p<0.001$ and $p=0.018$, respectively). Cost per melanoma detection did not differ significantly in women under 50 versus 50 and older ($p=0.258$), in males versus females under age 50 years ($p=0.113$), or in patients with versus without a personal history of any skin ($p=0.495$).

DISCUSSION

Our data from over 33,000 TBSEs performed in dermatology offices in a large healthcare system show that screening is most efficient and least costly in patients at higher risk of melanoma due to age and history of a previous melanoma. In our study population, the overall NNS was 215 and NNB was 27.8 to detect one melanoma, while the NNS was 12.9 and NNB was 1.6 for NMSC. The NNS and NNB to detect one melanoma dropped above the age of 50 in our population, suggesting that screening is likely to be highest yield starting at this age. TBSE in patients with a personal history of melanoma is high-yield with a cost per melanoma detected of less than half of that seen in the overall study population.

Our findings likely reflect the higher risk population evaluated in a dermatology versus primary care office. Data from 15 years of American Academy of Dermatology screenings by dermatologists found an NNS of 668 for each melanoma detected.¹² About 14% of those screened reported a history of skin cancer versus 25% in our population.¹² The German SCREEN (Skin Cancer Research to Provide Evidence for Effectiveness of Screening in Northern Germany) program, in which 360,288 people were screened, primarily by primary care physicians, reported the NNS to find one melanoma was 620; fewer than 3% of participants reported a skin cancer history, and the NNB was 28.¹³

Few studies have evaluated cost at the patient-level. Gordon et al. performed a patient-level cost analysis using data from an Australian clinical trial of skin screening.¹⁴ Patients attended free screening clinics and only those with suspicious lesions were referred for biopsy. A cost of \$12,152 per melanoma detected can be derived from their data, but this does not include the costs of all screening visits. Extrapolation from the data of Hoorens *et al*/from 1668 screened patients show that the NNS and NNB to find one melanoma were 208.5 and 3.25, respectively, yielding a cost per melanoma diagnosed of \$5,346.¹⁵ However, as these data were collected in the setting of a study on screening efficiency and not routine practice, biopsies performed at patient request were likely reduced.

Other studies using Markov models to attempt to quantify the cost-effectiveness of screening have found that screening strategies such as a single screening of the general population or surveillance of high-risk patients in a specialized clinic are cost effective.^{6,7,16} Data such as ours can be useful for future modeling by providing valuable data from a real-world clinical setting in the United States. For example, in one Belgian model of the cost effectiveness of screening, a cost of \$5.30 per screening was used.⁷ Using the cost of office visits observed in our cohort would result in significantly different findings.

While our approach allowed us to collect encounter-level data for a large number of visits, the use of this type of data has several limitations. Our analysis is limited to visits coded as visits for skin cancer screening and approximately 17% of TBSEs performed during the study period were not identified by this strategy, although the NPV of 83% is within the range reported by other EMR studies (67.7–100%).⁹ We also do not know the degree of clinical suspicion for each biopsy performed, and if some were performed due to patient request rather than strong suspicion for skin cancer. Our analysis did not account for additional downstream screening costs such as treatment costs for skin cancers or other lesions, such as actinic keratoses, diagnosed during screening. Also, our data are reflective of TBSE for early detection and cannot necessarily be translated to population-based screening, as our dermatology-based population would be considered higher risk due to the large percentage of patients with a personal history of skin cancer. Screening of the asymptomatic general population would likely be more expensive due to lower disease prevalence.

In our study, office visits contributed to the majority of screening costs, and only 0.46% of these visits result in a melanoma diagnosis. One way to reduce the cost per melanoma detected is to increase melanoma prevalence in the screened population. This can be accomplished by selective screening by specific criteria: 1) age and sex; 2) personal history of melanoma; or 3) pre-screening by strategies such as self-examination, trained partner examination, or community-based screening.^{1,6,8,15,17,18} Increasing biopsy sensitivity will also reduce the cost per melanoma diagnosed. Strategies shown to achieve this include provider training programs and routine use of dermoscopy.^{18,19}

Few studies have attempted to measure the cost per cancer detected. In one study of mammography in Medicare beneficiaries, the cost per breast cancer diagnosed was \$16,524 among women ages 66–74, a number similar to our cost per melanoma diagnosis in our

highest risk patient groups (age 50 and older and patients with a personal history of melanoma).²⁰

Our data support targeting high-risk populations for screening by dermatologists. Population-based screening in a primary care setting with subsequent referral to dermatology for suspicious lesions, may offer a more cost-effective alternative for screening of lower risk patients^{21,22} by improving the pre-test probability of melanoma in the population examined by dermatologists while leveraging the higher diagnostic accuracy among dermatologists, reducing both missed melanomas and unnecessary biopsies of benign lesions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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ABBREVIATIONS

BPR	Biopsied patient rate
BR	Biopsy rate
CI	Confidence interval
CPT	Current procedural terminology
EMR	Electronic medical record
ICD	International Classification of Diseases
MBP	Mean number of biopsies per biopsied patient
MelHx	Personal history of melanoma
NMSC	Non-melanoma skin cancer
NNB	Number needed to biopsy
NNS	Number needed to screen
NPV	Negative predictive value
PPV	Positive predictive value
SCHx	Personal history of skin cancer

SD	Standard deviation
TBSE	Total body skin examination(s)
USPSTF	United States Preventive Services Task Force
USD	United States Dollar

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Figure 1. Number needed to screen for melanoma, all skin cancers, and non-melanoma skin cancers (NMSC)

The number needed to screen (NNS) is displayed as a mean value (bar) and 95% confidence interval (lines indicate lower and upper bound of the interval). NNS values are plotted for melanoma (top panel), all skin cancers (middle panel), and non-melanoma skin cancers (NMSC, bottom panel). NNS indicates the number of screening visits required to diagnose one cancer of the given type and is displayed for subgroups within our patient population. MelHx = personal history of melanoma. SCHx = personal history of skin cancer.

Figure 2. Number needed to biopsy for melanoma, all skin cancers, and non-melanoma skin cancers (NMSC)

The number needed to excise or biopsy (NNB) is displayed as a mean value (bar) and 95% confidence interval (lines indicate lower and upper bound of the interval). NNB values are plotted for melanoma (top panel), all skin cancers (middle panel), and non-melanoma skin cancers (NMSC, bottom panel). NNB indicates the number of biopsies or excisions required to diagnose one cancer of the given type and is displayed for subgroups within our patient population. MelHx = personal history of melanoma. SCHx = personal history of skin cancer

Table 1

Patient Demographics in Screening Skin Examination cohort, 2011–2015.

Variable	Unique Patients*	Total Screening Visits
N	20,270	33,647
Female sex	12722 (62.8)	19990 (59.4)
Male sex	7548 (37.2)	13657 (40.6)
Age (years)	52.7 ($\pm$ 17.4)	55.5 ($\pm$ 17.1)
Race		
Missing	493	680
American Indian/Alaskan Native	13 (0.1)	18 (0.1)
Asian/Pacific Islander	56 (0.3)	65 (0.2)
Black	193 (1)	231 (0.7)
White	19515 (98.7)	32653 (99.0)
Hispanic/Latino ethnicity	86 (0.4)	120 (0.4)
Personal history of melanoma	1164 (5.7)	3572 (10.6)
Personal history of any skin cancer	4983 (24.6)	13120 (39)
Diagnosed with melanoma during study period	149 (0.74)	155 (0.46)
Diagnosed with non-melanoma skin cancer during study period	1600 (7.9)	2024 (6.0)

Data presented as either *n* (%) or mean ($\pm$ SD)

* Variables as of the patient's first visit between 2011–2015

Table 2

Multivariable analysis for positive screen or biopsy of melanoma, non-melanoma skin cancer, and any skin cancer

	Positive screen		Positive biopsy	
	Relative Risk (95% CI)	p-value	Relative Risk (95% CI)	p-value
Melanoma *				
Male Sex	1.35 (0.98–1.86)	0.06	Not selected	
Age (years)	1.02 (1.01–1.03)	< 0.001	1.04 (1.03–1.05)	< 0.001
Personal history of melanoma	1.93 (1.27–2.92)	< 0.01	Not selected	
Non-melanoma skin cancer *				
Male sex	1.91 (1.77–2.08)	< 0.001	1.47 (1.33–1.62)	< 0.001
Age (years)	1.04 (1.04–1.05)	< 0.001	1.01 (1.01–1.02)	< 0.001
Personal history of any skin cancer	1.30 (1.20–1.41)	< 0.001	1.36 (1.23–1.50)	< 0.001
Any skin cancer *				
Male Sex	1.88 (1.74–2.03)	< 0.001	1.60 (1.45–1.75)	< 0.001
Age (years)	1.04 (1.04–1.04)	< 0.001	1.04 (1.03–1.04)	< 0.001
Personal history of any skin cancer	1.26(1.17–1.37)	< 0.001	1.43 (1.30–1.58)	< 0.001

* Significant covariates remaining after multivariable stepwise regression. Stepwise models originally included hypothesis driven covariates of age, sex, and personal history of skin cancer and melanoma, with stepwise p-value cut off <0.05

Table 3
Biopsy rates, costs per visit, and cost per any skin cancer diagnosis and melanoma diagnosis

	Number of TBSEs	Biopsy Rate	Pigmented lesion Biopsy Rate	Average visit Cost [†]	Percent of costs from biopsy	Cost (95% CI) per melanoma (in USD) [‡]	Cost (95% CI) per NMSC (in USD) [‡]
All Patients	33647	0.22	0.12	150	30%	32555 (27032,37548)	2493 (2397,2590)
Age < 50	11401	0.20	0.16	146	28%	51990 (30483,70030)	9141 (7784,10406)
Age 50+	22246	0.23	0.098	152	32%	27498 (22399,32003) *	1836 (1763,1910) *
Male	13657	0.25	0.12	156	34%	27013 (20718,32878)	1718 (1638,1800)
Age < 50	3360	0.20	0.15	146	28%	81668 (0,200592)	6282 (4728,7593)
Age 50+	10297	0.27	0.11	160	35%	22521 (16960,27519)	1412 (1338,1482) *
Female	19990	0.20	0.12	146	28%	38315 (28176,47261) #	3724 (3484,3965) #
Age < 50	8041	0.20	0.17	146	28%	45142 (23462,63482)	11285 (8911,13444)
Age 50+	11949	0.20	0.092	146	28%	34766 (23821,44405)	2564 (2393,2731) *
Personal history of melanoma							
Yes	3572	0.25	0.16	158	34%	15697 (9310,20871)	2307 (2028,2560)
No	30075	0.21	0.12	149	30%	37701 (30340,44323) *	2522 (2415,2623)
Personal history of any skin cancer							
Yes	13120	0.25	0.11	149	34%	30545 (23083,37793)	1595 (1524,1669)
No	20527	0.20	0.13	149	28%	34085 (26496,40862)	4048 (3761,4323) *

[†] Based on Medicare data for office-visit CPT codes.

^{*} Significantly (p<0.05) different than other age subgroup or yes/no subgroup within the table specified category (all patients, male, female, personal history of melanoma, personal history of skin cancer).

[#] Significantly (p<0.05) different than males.

Abbreviations: NMSC (Non-melanoma skin cancer); TBSE (Total Body Skin Examination); USD (United States Dollar)