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ORIGINAL ARTICLE

Cost-Effectiveness of Melanoma Screening in Inflammatory Bowel Disease

Alyce J. M. Anderson[1] · **Laura K. Ferris**[3] · **David G. Binion**[4] · **Kenneth J. Smith**[5]

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Abstract

Background and Aims Inflammatory bowel disease (IBD) patients are at increased risk of melanoma and non-melanoma skin cancers, and preventive care guidelines in IBD favor annual skin examinations. Here we estimate the cost-effectiveness of annual melanoma screening in IBD.

Methods Melanoma screening was defined as receiving annual total body skin examinations starting at age 40 from a dermatologist. Screening was compared to US background total body skin examination rates performed by primary care practitioners. A Markov model was used to estimate intervention costs and effectiveness. Future costs and effectiveness were discounted at 3% per year over a lifetime horizon. Strategies were compared using a willingness-to-pay threshold of $100,000/quality-adjusted life year (QALY) gained.

Results Annual melanoma screening cost an average of $1961 per patient, while no screening cost $81 per patient. Melanoma screening was more effective, gaining 9.2 QALYs per 1000 persons, at a cost of $203,400/QALY gained. Screening every other year was the preferred strategy, gaining 6.2 QALYs per 1000 persons and costing $143,959/QALY. One-way sensitivity analyses suggested the relative risk of melanoma in IBD, melanoma progression, and screening costs were most influential with clinically plausible variation, leading to scenarios costing < $100,000/QALY gained. Probabilistic sensitivity analyses suggested screening every other year was cost-effective in 17.4% of iterations.

Conclusions Screening for melanoma in IBD patients was effective but expensive. Screening every other year was the most cost-effective strategy. Studies to identify IBD patients at the highest risk of developing melanoma may assist in targeting a prevention program in the most cost-effective manner.

Keywords Cost-effectiveness · Melanoma · Skin cancer screening · Inflammatory bowel disease

Introduction

Inflammatory bowel disease (IBD) is a collection of immune-mediated disorders of the gastrointestinal tract including Crohn's disease and ulcerative colitis. It is estimated that 40% of patients will experience extraintestinal manifestations of IBD, with skin complications being one of the most common [1]. IBD skin complications include an increased risk of melanoma and non-melanoma skin cancers [2–4]. Overall, IBD is associated with a 33% increase in melanoma risk [2]. While the etiology of the increased susceptibility is not fully known, evidence suggests medication exposures and disease-related inflammation may contribute to the elevated risk of skin malignancy [5].

Currently, there are no clear recommendations for melanoma screening in the general US population. In 2009 and again in 2016, the US Preventive Services Task Force report

The work was performed at the University of Pittsburgh Medical Center.

✉ Alyce J. M. Anderson
ajm197@pitt.edu

[1] University of Pittsburgh School of Medicine, 3550 Terrace Street, Pittsburgh, PA 15261, USA

[2] Present Address: 200 Lothrop Street, BST WR 1112, Pittsburgh, PA 15213, USA

[3] Department of Dermatology, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

[4] Division of Gastroenterology, Hepatology and Nutrition, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

[5] Department of Medicine, University of Pittsburgh, Pittsburgh, PA, USA

did not recommend routine skin cancer screening, citing a lack of evidence of anticipated harms and benefits with screening [6, 7]. Since the initial 2009 recommendations, some evidence in favor of skin cancer screening and associated reduced mortality has evolved. Research studies suggest that melanoma awareness and screening are associated with increased melanoma diagnoses, thinner melanomas, and a reduction in melanoma-related mortality [8–10]. However, these studies were primarily performed in large population-based cohorts and do not provide specific information about high-risk populations, such as IBD. IBD-specific guidelines encourage patient awareness, self-skin examinations, and referral of patients for a skin examination by a physician [11]. The American College of Gastroenterology (ACG) preventive medicine guidelines for IBD patients suggest an annual melanoma screening skin examination, independent of biologic therapy [11]. It is also recommended that patients on immunomodulators (6-mercaptopurine or azathioprine) also obtain a skin cancer screening examination due to an increased risk of non-melanoma skin cancers [11].

A handful of studies over the last two decades have evaluated the cost-effectiveness of national melanoma screening programs [12]. Overall, these studies suggest that annual population-wide screening is cost-prohibitive and may result in unnecessary morbidity from screening in low-risk persons. However, the studies generally agree that screening patients at a higher risk of melanoma (i.e., siblings of persons with melanoma) are cost-effective strategies [12]. Despite the published studies evaluating population-based screening, it is uncertain how this translates to IBD patients with an increased risk of skin cancers.

Our primary aims were to determine the costs and effectiveness of the guideline-recommended annual melanoma screening in the IBD population, and two alternative strategies of screening every other year and once at age 50. We also sought to determine the variables that most influence the cost-effectiveness of screening in order to optimize a pragmatic approach to melanoma screening for IBD patients.

Materials and Methods and Design

Model Structure and Perspective

Using TreeAge Healthcare Pro 2015 software (TreeAge Software Inc., Williamstown, MA), we created a Markov state-transition model to evaluate the cost-effectiveness of skin cancer screening by a dermatologist compared to routine background screening. Screening for melanoma occurs from 40 to 80 years of age and was chosen to start at age 40 to designate midlife. We used a 6-month cycle length over a lifetime horizon. All costs were measured in US dollars and adjusted to the equivalent 2016 dollar using the consumer price index inflation calculator [13]. Effectiveness was measured in quality-adjusted life years (QALYs). Future costs and QALYs were discounted at 3% per year. Our primary measured outcomes of the model were costs and effectiveness. Our predetermined willingness-to-pay (WTP) threshold was set at $100,000/QALY, based on contemporary US benchmarks [14].

Model Cohort

Our hypothetical cohort included adult IBD patients of average disease severity. IBD patients remained melanoma free and acquired melanoma based on published incidence rates that reflected their increased melanoma risk due to IBD [2]. Once patients developed melanoma, they transitioned to an undiagnosed melanoma state (Fig. 1). Patients with undiagnosed melanoma subsequently either had it detected by a

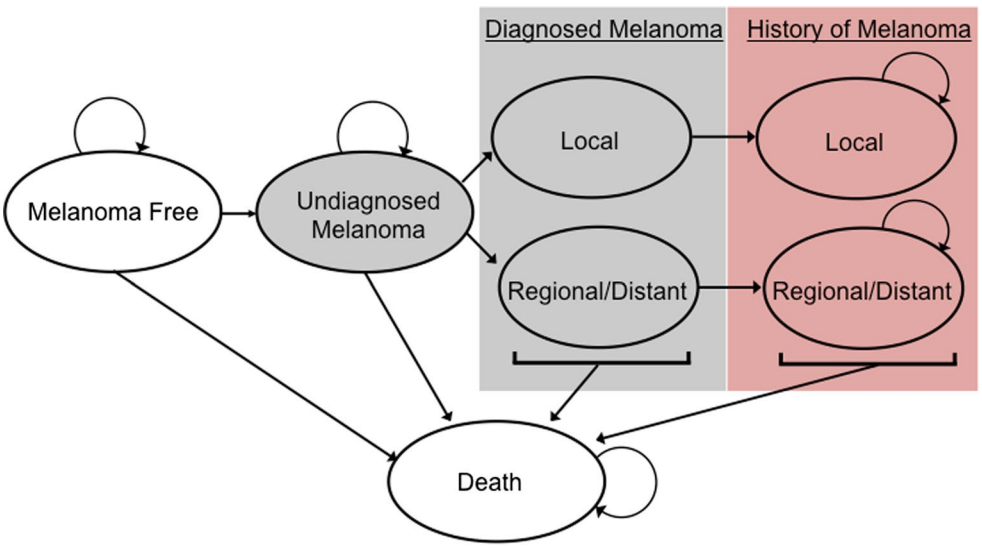

Fig. 1 Markov state transition model. Health states included in model, with shaded health states indicating the presence of melanoma or history of melanoma. Looped arrows indicate that individuals are allowed to remain in this transition state across multiple cycles

physician or remained in the undiagnosed melanoma state (Fig. 1). Melanoma detection rates for dermatologists and PCPs were obtained from the published literature (Table 1). Once diagnosed, patients were classified as having local (stage 1 or 2) or regional/distant (stage 3 or 4) melanoma [15]. After the melanoma diagnosis, patients became melanoma survivors or died. Melanoma survivors entered a melanoma surveillance program of total body skin examinations every 6 months and had an increased likelihood of developing a second primary melanoma, which was influenced by age [16].

Melanoma incidence and survival statistics were obtained from the Surveillance, Epidemiology, and End Results (SEER) database [17]. Patients with melanoma, regardless of diagnostic status, had higher mortality according to disease stage than did patients who were melanoma free. Age- and gender-specific US life tables determined survival estimates in the melanoma-free population and background mortality [18].

Model Assumptions

In order to model melanoma screening in IBD patients, we made a number of assumptions. We assumed all IBD patients had the same average relative risk of melanoma. We did not model differences in IBD disease severity or exposure to IBD therapies. There is primary literature suggesting anti-tumor necrosis factor (anti-TNF) exposure increases

Table 1 Model probabilities, costs, and utilities

	Base case	Monte Carlo distribution		Distribution	References
		Low value	High value		
Probabilities (%)					
Background skin cancer screening	10	1.0	31.2	Beta	[24–26]
Annual screening adherence	82.6	59.6	96.2	Beta	[33, 34]
Screening adherence with history of melanoma	96.0	88.3	99.4	Beta	[35]
Dermatologist sensitivity	89.0	65.4	99.1	Beta	[36]
PCP sensitivity	80.0	62.5	93.5	Beta	[36]
Melanoma: stage I or II (local)	84.0	63.3	96.2	Beta	[17]
Local melanoma, dermatologist screened	91.7	75.5	98.6	Beta	[37]
Local melanoma, PCP screened	83.4	71.6	93.1	Beta	[37]
Melanoma: stage III	8.9	7.1	10.9	Beta	[17]
Melanoma: stage IV	3.8	2.1	5.8	Beta	[17]
Progression: local to distant melanoma	10.0	3.5	20.5	Beta	Expert opinion [20]
Costs ($)					
Skin cancer screening examination	108.85	31.85	281.78	Gamma	[22]
Melanoma diagnosis/biopsy	104.55	28.96	232.69	Gamma	[22]
Melanoma: stage I or II (local)	4,027.20	919.61	10,350.70	Gamma	[38]
Melanoma: stage III	13,646.81	7098.16	21,570.37	Gamma	[38]
Melanoma: stage IV	27,237.19	6389.26	70,037.62	Gamma	[38]
Utilities					
Inflammatory bowel disease	0.800	0.647	0.925	Beta	[39]
Active melanoma diagnosis					
Melanoma: stage I	0.93	0.781	0.991	Beta	[40]
Melanoma: stage II	0.92	0.711	0.999	Beta	[40]
Melanoma: stage III	0.72	0.508	0.896	Beta	[40]
Melanoma: stage IV	0.58	0.396	0.750	Beta	[40]
History of melanoma					
Melanoma: stage III	0.94	0.763	0.998	Beta	[40]
Melanoma: stage IV	0.50	0.276	0.720	Beta	[40]
Other parameters					
Relative risk of melanoma in IBD	1.33	1.0	3.30	Log normal	[2]
NNB—dermatologist	17.4	7.89	30.55	Gamma	[41]
NNB—PCP	32.8	22.58	46.54	Gamma	[41]

PCP primary care physician, *IBD* inflammatory bowel disease, *NNB* number needed to biopsy to diagnose one melanoma

melanoma risk in IBD and in other populations routinely exposed to biologics [4, 19]. However, our base-case relative risk of melanoma in the IBD population did not incorporate any additional risk of exposure to biologic therapy, as the recent meta-analysis from which it was derived did not provide definitive evidence regarding therapeutic influences on melanoma risk in IBD [2]. Given the ongoing uncertainty of this parameter, relative risk of melanoma was varied over plausible ranges in sensitivity analyses. We assumed adherence to annual skin cancer screening would be similar to overall adherence to IBD-related appointments and medical therapy, which was derived from the literature (Table 1).

Localized melanomas are defined as one category within the SEER database. We assumed that approximately 75% of diagnosed melanomas confined locally would be stage 1 melanomas (tumor thickness < 1.0 mm and/or between 1.01 and 2.0 mm without ulceration), and the other 25% stage 2 melanomas (tumor thickness between 1.01 and 2.00 mm with ulceration, or any tumor > 2.01 mm without nodal involvement regardless of thickness) [15]. We assumed that 10% of all undetected local melanomas would transition to regional/distant melanoma in the following year based on expert opinion and consistency with previous melanoma screening cost-effectiveness analyses [20]. Additionally, while melanoma screening programs are likely to detect NMSCs, including basal cell carcinoma and squamous cell carcinoma, we did not include this detection in our model as this analysis has been shown to be cost-effective in Crohn's disease patients previously [21].

Costs and Effectiveness

Cost estimates associated with melanoma screening and treatment were obtained from the published literature and US databases, as were utilities for IBD and stages of melanoma (Table 1). Medicare physician fee schedules were used to estimate the costs associated with a screening visit and skin biopsy [22]. Effectiveness was measured in QALYs. QALYs of average IBD and melanoma health states were derived from the published literature (Table 1) and were adjusted by age [23]. Age-based utility from 40 to 54 years old was 0.92, from 55 to 64 years was 0.88, and for 65+ years was 0.84 [23].

Screening Strategies

The base-case skin cancer screening strategy included an annual total body skin examination by a dermatologist. This screening program began at 40 years of age and continued until death or 80 years of age. This was compared to background rates of skin cancer screening by primary care practitioners which were estimated through the published literature [24–26]. Background screening was not dependent on age and continued until death in both strategies. We also evaluated alternative screening strategies to reduce the overall screening intensity on IBD patients including screening every other year and screening once at age 50. Screening once at age 50 was chosen to mirror previous melanoma screening cost-effectiveness models [20]. All other model parameters remained the same during the evaluation of the alternative frequency screening strategies.

Cost-Effectiveness Analysis

A series of one-way sensitivity analyses were performed to determine the variables that most influence the incremental cost-effectiveness ratio (ICER), defined as the change in cost over the change in effectiveness. Variables were evaluated over plausible ranges and guided by the available published literature. We used deterministic sensitivity analyses to define parameter thresholds at WTP levels of $100,000/QALY and $150,000/QALY. We employed probabilistic sensitivity analysis simultaneously sampling parameter distributions over 10,000 trials, to determine the percent of model iterations favoring screening at predetermined WTP levels. We used beta distributions for probabilities and utility values, and gamma distributions for cost parameters and number needed to biopsy variables (Table 1) [27]. Relative risk of melanoma was modeled using a log-normal distribution [27].

Results

Base-Case Analysis and Screening Strategies

In the IBD population, annual melanoma screening by a dermatologist cost $1961 per person compared to background screening which was $81 per person (Table 2). Annual screening was more effective, gaining an additional 9.2 QALYs per 1000 persons. The resulting ICER for the base-case analysis was $203,400/QALY (Table 2). We also evaluated screening every other year from 40 to 80 years of age. In this scenario, screening cost an average of $999 per person, while background screening costs remained the same at $81 per person. Incremental effectiveness decreased to 6.4 QALYs per 1000 persons, resulting in an ICER of $143,959/QALY. Finally, screening for melanoma once at age 50 resulted in lower screening costs, lower incremental effectiveness of screening of only 0.4 QALYs per 1000 persons, and a lower ICER as compared to the base case (Table 2). However, the screen once at age 50 strategy cost $153,518/QALY and was dominated by the lower ICER of the more effective screening every other year strategy (Table 2).

All three evaluated scenarios did not meet the WTP threshold of $100,000/QALY gained. Therefore, melanoma

Table 2 Cost-effectiveness analysis results

	Cost	Incremental cost	Effectiveness (QALY)	Incremental effectiveness (QALY)	Incremental cost-effectiveness ratio
No screening/background	$81	–	16.5924	–	–
Base case: annual screening	$1961	$1880	16.6017	0.0092	$203,400/QALY
Screening every other year	$999	$918	16.5988	0.0064	$143,959/QALY
Screening once at age 50	$148	$66	16.5928	0.0004	$153,518/QALY

QALY quality-adjusted life year

screening is not strictly cost-effective or the preferred strategy as compared to background levels of skin cancer screening. However, given the three tested strategies, the most cost-effective approach is screening every other year with an ICER of $143,959/QALY, which is lower than screening annually and screening once at age 50.

One-Way Sensitivity Analyses

Percent Progression from Local to Regional Melanoma

The percent of patients progressing from local to regional disease over time is unknown, and our value was based on previously published models for consistency. Given this uncertainty, we performed one-way sensitivity analysis on this parameter from 2% progression to 15% progression in the base-case annual melanoma screening scenario. Despite varying the parameter from 2 to 15%, there was no value that satisfied WTP cutoffs of $100,000 or $150,000/QALY. As the progression percentage increased, the ICER decreased from $382,815/QALY at 2% progression to $181,799/QALY at the highest estimate of 15% progression (Table 3).

When we repeated this one-way sensitivity analysis in the favored strategy of screening every other year, we obtained similar results. As the progression percentage increased, the ICER decreased from $231,734/QALY at 2% progression to $142,307/QALY at the highest estimate of 15% progression (Table 3).

At low progression percentages, screening every other year is the clearly preferred strategy (>$150,00/QALY difference) as compared to screening annually. However, at higher progression percentages, the differential in the ICERs of the two strategies of screening annually or every other year is smaller (approximately $40,000) (Table 3).

Relative Risk of Melanoma in IBD

There is relative uncertainty in the increased melanoma risk in IBD patients. We used a conservative estimate of a relative risk (1.33) derived from a meta-analysis [2]. In our one-way sensitivity analyses, we evaluated relative risks between 1.0 and 4.0. In the base-case strategy of screening every year, the ICER is less than $100,000/QALY if the relative risk of melanoma in IBD patients is greater than 2.81 (Table 3). The ICER is less than $150,000/QALY if the relative risk of melanoma in IBD is less than 1.83 (Table 3).

We performed the same sensitivity analysis of the relative risk of melanoma in the favored strategy of screening every other year. Results of one-way threshold analysis for this strategy were similar. When screening every other year, the ICER remains less than $100,000/QALY as long as the relative risk of melanoma in IBD patients is greater than

Table 3 One-way sensitivity analyses

	Base case	Range	Resulting ICER		Willingness-to-pay threshold	
			Low value	High value	$100,000/QALY	$150,000/QALY
Base case: annual screening						
Progression percentage	10%	2–15%	$382,815	$181,799	n/a[a]	n/a[a]
Relative risk of melanoma in IBD	1.33	1.0–4.0	$268,394	$72,356	2.81	1.83
Cost of melanoma screening	$108.85	$25–$200	$46.383	$374,088	$53.63	$80.33
Alternative strategy: screening every other year						
Progression percentage	10%	2–15%	$231,734	$142,307	n/a	8.15%
Relative risk of melanoma in IBD	1.33	1.0–4.0	$189,560	$52,255	1.95	1.27
Cost of melanoma screening	$108.85	$25–$200	$33,023	$264,554	$75.62	$113.42

ICER incremental cost-effectiveness ratio, *IBD* inflammatory bowel disease, *QALY* quality-adjusted life year

[a]Value outside of plausible range given specified willingness-to-pay threshold

1.95 (Table 3). The ICER remains less than $150,000/QALY as long as the relative risk of melanoma in IBD is less than 1.27, which is slightly less than the base-case parameter (Table 3).

Cost of Melanoma Screening by a Dermatologist

Melanoma screening cost significantly influenced the results. The base-case cost of screening was $108.85 [22]. We varied this cost in one-way sensitivity analysis from $25 to $200 in the annual screening strategy. To maintain an ICER under a WTP threshold of $100,000/QALY, screening cost must remain less than $53.63 per examination (Table 3). When we repeated the one-way sensitivity analysis in the more favored strategy of screening every other year, screening costs needed to remain less than under $75.62 per screen to result in an ICER less than $100,000/QALY gained (Table 3).

Two-Way Sensitivity Analysis

While not strictly cost-effective compared to our WTP threshold, screening every other year was the preferred strategy as compared to the base case and guideline recommendations of screening annually. One-way sensitivity analyses demonstrated that the relative risk of melanoma and the percent progression from local to regional disease have an important influence on the ICER (Table 3). We performed two-way sensitivity analyses on these parameters, varying them simultaneously, as they are both uncertain characteristics of melanoma, which may be different in the setting of IBD. Two-way sensitivity analysis was performed for the screening strategy of every other year (Fig. 2). Screening every other year is favored at higher relative risks and increased probabilities of melanoma progression, as indicated in Fig. 2.

Probabilistic Sensitivity Analyses

We evaluated the screening every other year strategy using probabilistic sensitivity analysis over 10,000 trials. Screening every other year was cost-effective in 17.4% of model iterations at a WTP threshold of $100,000/QALY. At a WTP threshold of $150,000/QALY, screening every other year was cost-effective in 44.8% of iterations (Fig. 3).

Discussion

Screening for melanoma in IBD patients was effective but expensive. With a WTP threshold of $100,000/QALY in place, screening for melanoma in the IBD population was not cost-effective. Compared to background rates of skin examinations by PCPs, dermatology-based screening for melanoma in IBD patients was more effective, but substantially more expensive. Of the three screening strategies examined, screening for melanoma every other year was the preferred strategy, compared to screening once at age 50 or screening annually.

Our one-way sensitivity analyses suggest that the cost-effectiveness of melanoma screening depends on the percent of melanomas that progress from local to regional disease. This finding is consistent with previous models of melanoma screening in the general population [20]. Interestingly, this variable is difficult to define and currently unknown. Our chosen estimate was based on previous models and was not IBD specific. IBD-specific estimates of this parameter may

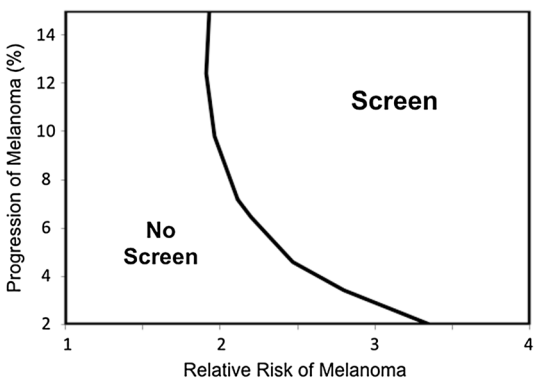

Fig. 2 Two-way sensitivity analysis. Two-way sensitivity analysis of the progression percentage of melanoma (*y*-axis), and the relative risk of melanoma in inflammatory bowel disease patients (*x*-axis). Separation plane is a willingness-to-pay threshold of $100,000/QALY. Preferred strategy (screening every other year or no screening) is labeled in each respective area

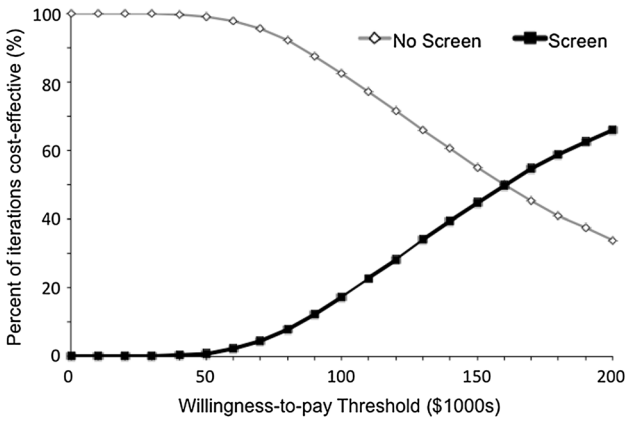

Fig. 3 Probabilistic sensitivity analysis. Cost-effectiveness acceptability curves show the likelihood that melanoma screening (black square) and no screening (open circle) are considered cost-effective over a range of willingness-to-pay thresholds when parameters are simultaneously varied over their distributions

influence the overall cost-effectiveness of melanoma screening programs.

The relative risk of melanoma was also varied in sensitivity analyses. Of the papers included in the systematic review from which the base-case relative risk of 1.33 was derived, the relative risk of melanoma ranged from 0.70 to 5.41 [2]. However, the majority of relative risk estimates of melanoma in IBD were between 1.00 and 2.00 [2]. Additionally, while not statistically different between groups, Crohn's disease patients had an increased incidence of melanoma compared to ulcerative colitis, with a relative risk of 1.51 and 1.23, respectively [2]. This suggests initially targeting screening to Crohn's disease patients could be one way to stratify patients who are at a higher risk. In addition, typical risk factors for skin cancer including family history could also be utilized. Family history of melanoma increases a patient's individual risk. It is estimated that the melanoma relative risk in those with a family history is 1.74 (1.4–2.1), which fits within the range by which this parameter was varied in one-way sensitivity analyses [28].

There are also studies suggesting medication exposures can increase the risk of melanoma in immunosuppressed populations including IBD [4, 19, 29]. Long et al. [4] reported an increase in melanoma in IBD over time, which paralleled the increase in biologic use in years 1997–2009. Additionally, subgroup analyses suggested patients with long-term duration of anti-TNF biologics demonstrated increased odds of melanoma compared to those with short-term use [4]. While the findings revolving around increased melanoma risk with anti-TNF exposure require additional validation, duration of immunosuppression and exposure to biologics could be used to target dermatologic screening to IBD patients at the highest risk of melanoma, making screening more cost-effective. In this model, we varied melanoma risk to include the added risk of anti-TNF exposure. We estimate that additional risk to be 1.88 (95% CI 1.08–3.29), which results in an overall relative risk of approximately 2.5 and is within our sensitivity analysis range [4].

In this study, our WTP threshold was set at $100,000/QALY gained. However, the selection of WTP thresholds remains somewhat arbitrary for programs evaluated in the USA. Therefore, our results should be taken in context given WTP thresholds are often predetermined cutoffs and do not accurately translate to programmatic decisions or justify implementation. It is often recommended to evaluate programs upon a continuum of WTP thresholds from $50,000 to $200,000/QALY [14]. The preferred strategy of screening every other year has an ICER of $143,959/QALY, which fits comfortably in the suggested range of evaluation. However, screening every year for melanoma is at the high end of the range of WTP thresholds, slightly above $200,000/QALY. The modeled program was also exclusively within dermatology. While our current preventive care guidelines in IBD recommend annual screening regardless of age, screening every other year by dermatologists may be a suitable alternative to annual screening. Additionally, targeting older populations may be beneficial, as screening of those younger than 40 will result in even more unfavorable cost-effectiveness estimates due to lower risk of melanoma. Other potential modifications may include, but are not limited to, attempting to lower the cost of screening, partnering with dermatology in new holistic care models including IBD medical homes, incorporating teledermatology to increase patient access to dermatologic care, as well as increasing the focus on primary prevention and education about skin cancer to improve early self-detection in IBD patients [30, 31].

Our analysis is limited as data are derived from multiple sources, each associated with their own inherent biases. Our analysis did not include more expensive newer treatments for advanced melanomas, a potential limitation, as costs were derived from a publication that precedes immunotherapy. However, the range of treatment costs evaluated in our study is inclusive of a majority of reported estimates [32]. Despite this, we could have overestimated the ICER of screening due to this limitation. Additionally, there are unknown parameters and remaining uncertainty in parameters relating specifically to the risk and behavior of melanoma in IBD patients. We also did not include NMSC in our model. IBD patients are at an increased risk of NMSC, and it is more prevalent than melanoma; however, it is rarely fatal [3, 4]. NMSC is similarly discovered through total body skin examinations, and the detection of NMSC would add costs as well as benefits. A recent paper by Okafor et al. [21] suggests screening for NMSC in patients with Crohn's disease is cost effective. They found screening all Crohn's disease patients annually was the most cost-effective strategy, with every other year screening as the second best strategy. The addition of NMSC screening may improve the ICER of this study, however we sought to specifically model melanoma, and the additional costs and benefits of NMSC detection is outside the scope of this analysis. The addition of NMSC skin cancer to this model would add an additional level of uncertainty and complexity, because the true incidence and detection rates of NMSC are difficult to define given they are not reported to SEER in the same fashion as melanoma. Introducing NMSC detection would make the conclusions about melanoma screening difficult to interpret.

While current preventive care guidelines exist to promote annual skin examinations in IBD, it is uncertain how frequently IBD patients currently obtain skin cancer screening. Our estimates of background screening were derived from the general population, which is likely an underestimation as IBD patients generally have increased healthcare contact. However, these data on physician and patient adherence to skin cancer screening guidelines in the IBD population

are unknown. Proper estimates of background screening in IBD will further clarify the potential benefits of a melanoma screening program and strengthen our analysis.

In summary, compared to background primary care detection, screening annually for melanoma in IBD patients was more effective, but more expensive. Screening for melanoma every other year by a dermatologist was the preferred strategy. Future research evaluating the risk and behavior of melanoma in IBD, including determining therapies most associated with increased risk of melanoma, is needed to clearly define the costs and benefits of melanoma screening. However, based on what is known to date about melanoma in IBD, it does not appear that screening is very cost-effective under common WTP thresholds. While research is ongoing, primary prevention of skin cancers through counseling on sun protection remains of utmost importance among IBD patients. Presently, targeting high-risk subgroups, such as those with certain medication exposures, older age, or a family history of skin cancer, for dermatologic examinations will assist in designing the most cost-effective approach to melanoma screening in IBD.

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Author's contribution Alyce Anderson, PhD, contributed to drafting of manuscript, figure design, table creation, data collection, model creation, and critical review of the manuscript. Laura K. Ferris, MD, PhD, contributed to collection of data, model review, and critical review of the manuscript. David G. Binion, MD, contributed to collection of data, model review, and critical review of the manuscript. Kenneth J. Smith, MD, MS, contributed to project supervision, assistance with model creation, model review, and critical review of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest Laura Ferris serves as a consultant for DermTech, International. David Binion has served as a consultant for Janssen Biotech and Abbvie, and reports grant support from Takeda, Shire, Abbvie and Merck. Alyce Anderson and Kenneth Smith declare that they have no conflicts of interest to disclose.

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