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Cost-effectiveness analysis of using dermatologists versus pediatricians to treat mild to moderate acne

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Abstract

Objective: To assess the cost-effectiveness from the payer perspective of using dermatologists versus pediatricians to treat acne in adolescents ages 10-18. Methods: A Markov model was constructed to explore outcomes over a 2-year period from the US private payer perspective. Patients ages 10-18 with acne entered the model under the "dermatologist" and "pediatrician" conditions. In each 3-month cycle, each modeled patient received topical retinoids, benzoyl peroxide (BP), antibiotics, or no treatment, and could progress to an acne-free state or remain in an acne state. Results: The average patient spent 42.3% of the time in acne-free states under the dermatologist condition and 28.0% of the time in acne-free states under the pediatrician condition. The cohort of 1000 patients experienced 1900 total quality-adjusted life years (QALYs) at a cost of $2.33 million in the dermatologist condition and 1883 total QALYs at a cost of $1.62 million in the pediatrician condition, yielding an ICER of $40,000/QALY. Most sensitivity analyses confirmed the base case results. Conclusion: Dermatologist treatment appears cost-effective related to producing additional QALYs at a cost of less than $100,000 per QALY gained. Health plans should consider creating incentives to direct enrollees to dermatologists for acne treatment.

Keywords: economic analysis, Markov model, quality-adjusted life years, adolescents, topical retinoids, benzoyl peroxide, antibiotics, primary care, specialty care

Introduction

Acne vulgaris is nearly ubiquitous among adolescents in the United States, often beginning at age 10 or younger and extending through early adulthood [1]. Past studies have demonstrated major differences between dermatologists and pediatricians in prescribing patterns [2, 3]. Some health insurers favor incentivizing patients to see pediatricians for acne. Although outright "gatekeeping" by allowing patients to see a specialist only by referral is no longer common, many health plans contain disincentives to see a specialist, such as higher co-pays [4]. Advocates of favoring pediatricians for acne treatment suggest that the non-specialist approach should be lower in cost, either from non-specialist visits themselves being less costly or from the lower cost of the medications prescribed [5]. Health plan administrators who believe that acne is merely cosmetic and not a significant cause of morbidity are likely to adopt a strictly cost-minimizing approach, in which prescribing the least costly treatment is of primary importance. If the goal is to weigh costs against benefits gained, such as QALY, then focusing strictly on the lowest cost may be short-sighted and may even lead to greater costs at a later point, such as those associated with the treatment of psychiatric sequelae such as depression [6, 7]. Acne can have as much quality-of-life (QOL) impact as other major medical conditions, such as asthma, arthritis, and diabetes [7]. Economic analysis can allow comparison across various diseases by comparing the QALYs gained by different possible healthcare interventions.

In treating acne, dermatologists may bring benefit from their extensive knowledge of the acne disease process and latest treatment options, as well as acne-specific strategies to induce better patient adherence. Although topical retinoids, the preferred option of dermatologists and endorsed by practice guidelines[8, 9], are more expensive than over-the-counter (OTC) treatments like benzoyl peroxide (BP), topical retinoids are more successful in disease clearance and maintenance of clear skin [9]. Most medical dermatologists also treat acne frequently and are aware of the specific challenges involved in getting adolescents to use their medication correctly, a topic frequently emphasized at national dermatology conferences [10].

Although the specific reasons for differences in prescribing patterns between dermatologists and pediatricians are not completely understood, it appears there are significant misconceptions that limit the use of topical retinoids among pediatricians [2, 3]. Concerns about tolerability may persist, based on experience with older topical retinoid preparations that were more irritating, but have been superseded by newer products [2, 11]. Some physicians may believe that topical retinoids, especially branded topical retinoids, are unnecessarily costly [12]. However, OTC preparations are not easy to use, especially in the sense that patients will tend to discontinue them as soon as their acne is clear, often leading to relapse. Although fairly effective in clinical trials, OTC preparations like BP have much lower effectiveness in everyday practice, especially over the long term. Patients have often tried OTC preparations before seeking medical care from either their primary care physician or a specialist. Patients who are adherent enough to experience success with an OTC preparation are often weeded out of the population before they first seek medical care for their acne [13]. Thus, typical acne patients need a substantial amount of close guidance and preferably, a treatment with considerable "forgiveness" with regard to adherence [14].

The main objective of this study is to determine whether dermatologist treatment is cost-effective and whether health insurance plans should direct enrollees to dermatologists for acne treatment.

Methods

The population of interest for this examination is a cohort of identical adolescent acne patients ages 10-18 under the two alternative scenarios of being treated by a dermatologist, and being treated by a pediatrician. In keeping with the data previously collected using the NAMCS, we excluded patients with the most severe acne who would be prescribed isotretinoin, helping to maintain a more comparable patient population between the pediatrician and dermatologist conditions [2].

Costs and outcomes are measured from the U.S. private payer perspective. Only direct medical costs are included in our base case simulation. Acne is treated as a binary variable, with "acne-free" following the definition normally used in clinical trials: a score of "clear" (0) or "almost clear" (1) on the Acne Global Assessment, a validated 0-5 scale [15]. Any score 2 or higher is treated as having acne for the given cycle. As acne vulgaris is a recurring disease, we chose a Markov model (**Figure 1**) for simulating the differences in costs and outcomes between the two treatment alternatives, dermatologist and pediatrician care.

Logic of the Markov model

All patients begin the model with acne and are initially prescribed a treatment, causing them to enter state "with acne – topical retinoid", "with acne – BP", or "with acne – antibiotic." The probability assignment of entering each of these treatment states (**Table 1**) are based on actual prescribing behavior observed in previously published data from the National Ambulatory Medical Care Survey (NAMCS), causing the transition probabilities to differ between the "dermatologist care" and "pediatrician care" scenarios. At the next cycle, the patient may become clear and remain on the same treatment as maintenance therapy; become clear and be recommended to stop therapy; continue to have acne and remain on the same treatment; continue to have acne and switch treatment; or be lost to follow-up (LTFU). LTFU is an absorbing state, and patients are assumed to continue to have acne for all remaining cycles if they enter that state. Patients who enter an acne-free state (with or without continued treatment) may relapse in any subsequent cycle, although they are considered more likely to relapse if they are not prescribed

Table 1. *Transition probabilities between health states for treatment by dermatologists and pediatricians. LTFU = Lost to follow up; NA/NT = No acne, no treatment; NA/ABX = No acne, antibiotics; NA/BP = No acne, Benzoyl peroxide, NA/TR = No acne, Topical retinoids; A/ABX = Acne, antibiotics; A/BP = Acne, Benzoyl peroxide; A/TR = Acne, Topical retinoids.*

Dermatologist	**To:**							
From:	LTFU	NA/NT	NA/ABX	NA/BP	NA/TR	A/ABX	A/BP	A/TR
A/TR	0.070	0.000	0.000	0.000	0.670	0.000	0.000	0.260
A/BP	0.070	0.000	0.000	0.390	0.000	0.000	0.216	0.324
A/ABX	0.070	0.200	0.000	0.000	0.000	0.183	0.183	0.365
NA/TR	0.070	0.315	0.000	0.000	0.315	0.000	0.000	0.300
NA/BP	0.070	0.315	0.000	0.315	0.000	0.000	0.300	0.000
NA/ABX	0.070	0.630	0.000	0.000	0.000	0.300	0.000	0.000
NA/NT	0.070	0.430	0.000	0.000	0.000	0.215	0.055	0.230
LTFU	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Pediatrician	**To:**							
From:	LTFU	NA/NT	NA/ABX	NA/BP	NA/TR	A/ABX	A/BP	A/TR
A/TR	0.070	0.251	0.000	0.000	0.251	0.000	0.000	0.428
A/BP	0.070	0.146	0.000	0.146	0.000	0.000	0.446	0.191
A/ABX	0.070	0.075	0.075	0.000	0.000	0.468	0.156	0.156
NA/TR	0.070	0.315	0.000	0.000	0.315	0.000	0.000	0.300
NA/BP	0.070	0.315	0.000	0.315	0.000	0.000	0.300	0.000
NA/ABX	0.070	0.315	0.315	0.000	0.000	0.300	0.000	0.000
NA/NT	0.070	0.430	0.000	0.000	0.000	0.355	0.085	0.060
LTFU	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

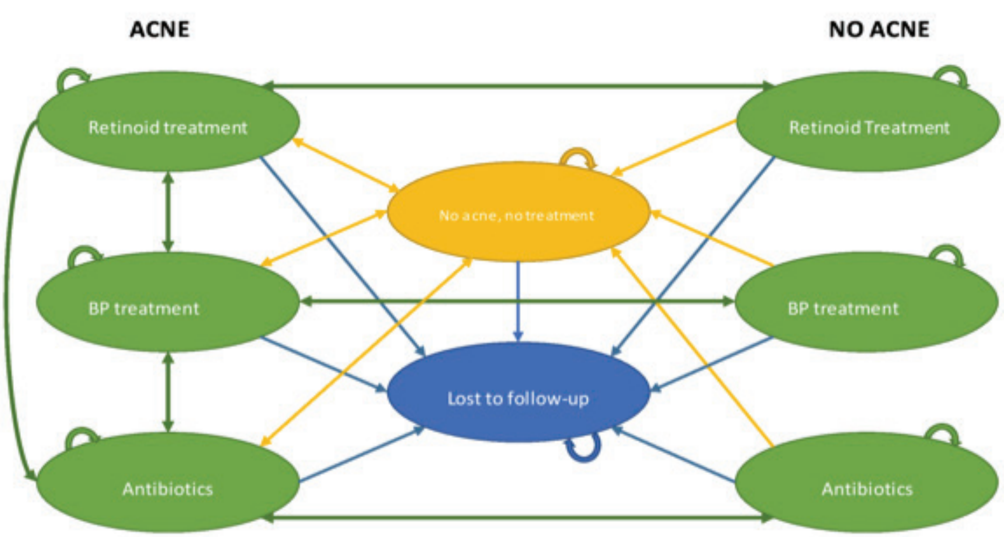

Figure 1. *Markov model describing progress of acne patients under dermatologist or pediatrician care. There are 4 acne states [retinoids, BP (benzoyl peroxide), antibiotics, and LTFU (lost to follow-up)] and 4 acne-free states (retinoids, BP, antibiotics, and no acne/no treatment). All patients initially enter one of the three acne states with treatment on the left side of the model.*

We assume that patients do not switch between seeing a dermatologist or pediatrician once they have entered the model. Since the purpose of the model is to inform the decision as to whether payers should direct new acne patients to a dermatologist or a pediatrician, the added complexity of allowing patients to switch providers midway through the model was left for future investigation.

Patients are not assumed to be adherent to their drug treatment. Probabilities of transitioning to an acne-free state are based on real-world effectiveness of drugs under conditions of typical adherence behavior, not efficacy under ideal conditions. However, we assume that in any given cycle, patients do not use a different treatment from the one they were prescribed. Reduction in QOL due to causes other than acne is not assessed, as similar impact across both cohorts could be expected.

The cycle length is set to 3 months, because that is the amount of time that an acne medication typically needs to be used to show improvement. Most acne medication trials in the literature have an endpoint at about 3 months to evaluate outcomes. We follow our acne patients over a two year time horizon of disease, treatment, and possible relapse, resulting in a total of eight cycles. We use a standard discount rate of 3% in our base case simulation to discount the costs and outcomes.

The primary outcome of this simulation is the amount of time spent in acne-free health states and the respective number of QALYs gained for both treatment alternatives. The advantage of using QALYs in this setting is that we can use official thresholds to determine whether dermatologist treatment is cost effective. Fifty thousand dollars per QALY is probably outdated, but is still widely used [16, 17]; $100,000/QALY may be more in line with the World Health Organization's recommended global best practice of estimating a threshold of about 3 times per capita GDP in the country being studied [18].

The main assumptions of this simulation can be summarized as follows:

No transitions between acne-free states; if a treatment produces clearance, either that same treatment is continued as maintenance therapy, or the patient is advised to stop treatment

No difference in QOL between different medication categories

Patients do not switch between seeing a dermatologist or pediatrician once they have entered the model

Patients who are LTFU continue to have acne for all remaining cycles, but incur no further treatment costs

Patients do not use a different treatment from the one they were prescribed

One physician visit per cycle, where at most one of the three alternative medications is prescribed

Patients have a usual pediatrician but have not been to a dermatologist before, therefore first dermatologist visit is coded as a new patient visit (CPT 99204)

In the base case we are assuming a medication adherence rate of 73% [19]

Model Input Parameters

Transition probabilities were estimated from effectiveness data in the literature, practice guidelines, and the published NAMCS data on prescribing patterns. We favored studies that reported the percentage of patients reaching success according to dichotomous success/failure criteria, preferably Acne Global Assessment (AGA) of 0 (clear) or 1 (almost clear). Some studies reported other dichotomous criteria such as "good to excellent global response", "moderate to excellent improvement", or "marked improvement [20, 21]." We considered the first two of these to be less stringent than the AGA of 0 or 1 criteria, and the last to be approximately equivalent. Studies that reported only continuous outcomes, such as reduction in total lesion counts, were considered unusable for the purpose of this study, since the Markov model necessitated a binary decision on whether the patient would move to an acne-free state or not. Our cohort contains patients with a typical distribution of acne, with mild acne being more common than moderate or severe acne. Many studies used only moderate acne, or moderate to severe acne, so there was a need to adjust their results accordingly to make them applicable to our cohort.

For topical retinoids, Troielli's estimate of 67% was considered the most accurate as it was derived from real-world experience in a community-based study [22]. Poulin's estimate of 70.7% over 24 weeks supports Troielli's estimate. The estimates of 30.1% (adapalene/BP) and 19.8% (adapalene only) by Gold [23], and 37.67% by Zhou [24], were considered too low, since Gold's study enrolled only moderate acne patients, and the meta-analysis by Zhou considered moderate-to-severe acne patients. Since the majority of patients in our cohort have mild acne, our cohort would be expected to reach clear or almost clear status more easily on average.

For BP, three relevant estimates were identified, 50% by Leyden [20], 41% by Lookingbill [21], and 22.2% by Gold [23]. Again, Gold's estimate was considered too low since Gold's study enrolled only moderate acne patients rather than a typical mix of mild and moderate. The other two estimates were considered somewhat high since Leyden counted success as "moderate to excellent" improvement and Lookingbill counted it as "good or excellent global response." It was considered that "moderate" improvement and "good" global response would not meet the definition of clearance – AGA of 0 or 1 – required to move to an acne-free state in our Markov model.

For antibiotics, three studies provided relevant estimates: 62% for BP/clindamycin and 60% for BP/erythromycin by Leyden [20], 39% for BP/clindamycin by Weiss [25], and 66% for BP/clindamycin and 36% for clindamycin alone by Lookingbill [21]. As above, Leyden's and Lookingbill's estimates were based on success being defined as "moderate to excellent" improvement and "good or excellent global response," respectively, which is a less stringent definition of success than we use. Weiss's estimate was appropriately defined using "marked" improvement, which seems approximately equivalent to our definition of success as AGA of 0 or 1. We have based our probabilities primarily on Weiss's data, but somewhat reduced because many patients are not using an antibiotic/BP combination product, and adherence is lower in real-world practice.

Additional assumptions made to estimate the transition probabilities were that dermatologists would always follow practice guidelines that dictate continuing topical retinoids and BP for at least one cycle of maintenance therapy after successful treatment, but discontinuing antibiotics as soon as clearance is achieved [2]. Due to less awareness of best practices among pediatricians, we assumed that pediatricians would follow the guidelines about half the time. Although guidelines are inconclusive about how long to continue maintenance therapy, we estimated that 50% of physicians in both conditions would continue the maintenance therapy for the next cycle after completion of one acne-free cycle, while the other 50% would stop the maintenance therapy. We assumed that both dermatologists and pediatricians would consider escalating to the first-line topical retinoids if BP failed, and would consider escalating to topical retinoids or BP if antibiotics failed. Neither provider would switch to a less recommended treatment (topical retinoids to BP or antibiotics, or BP to antibiotics). If topical retinoids failed, either provider might decide to switch to a different topical retinoid, which would still mean staying in the same state in our model. Owing to differences in patient education and resulting adherence to treatment, pediatricians would achieve about 75% the success rates that dermatologists achieved with the same treatment. LTFU would occur at identical rates of 7% in both conditions, based on the estimates of 13% [26] and 28% [27] of patients not attending their visit, and considering that only a fraction of nonattending patients are permanently lost.

Based on the NAMCS data, the model was initially populated with 46% of patients in the dermatologist condition being prescribed a retinoid, 11% being prescribed BP, and 43% being prescribed antibiotics. In the pediatrician condition, 12% were initially prescribed retinoids, 17% were prescribed BP, and 71% were prescribed antibiotics. Any patient who relapsed would also have these same probabilities of being prescribed each of the three treatments in the next cycle. Probabilities of relapse were estimated at 30% when maintenance therapy was prescribed, due to widespread nonadherence; and 50% when no maintenance therapy was prescribed.

Table 2. *Model inputs. Costs of medications are based on the average wholesale price (AWP) of the most common product in the class for base case analyses, subtracting a typical copayment of 15% that is not borne by the payer. For ranges, all products listed on Micromedex UpToDate are considered. LTFU, lost to follow-up; BP, benzoyl peroxide; NA, not applicable.*

Cost	Code	Base cost each (Payer costs only)	
Visits			
First office visit - Dermatologist	99204	$141.29	
First office visit - Pediatrician	99214	$91.66	
Subsequent office visits	99213	$62.12	
Medications		Total per cycle (Payer costs only)	Range of possible costs/ cycle
Retinoid Products			
Tretinoin		$214.02	$148.47 to $1552.81
Adapalene		$365.90	$365.90 to $977.85
Adapalene/BP		$700.30	NA (only one product available)
Tretinoin/Clindamycin		$493.60	$493.60 to $745.96
Weighted average of retinoid products		$482.77	
BP Products			
BP		$24.66	$6.98 to $706.44
Antibiotic Products			
Clindamycin topical		$106.66	$86.37 to $1785.23
Erythromycin topical		$58.36	$58.36 to $308.60
BP/Clindamycin topical		$395.90	$378.28 to $827.94
BP/Erythromycin topical		$207.82	$207.82 to $755.60
Doxycycline oral		$209.72	$209.72 to $4132.53
Minocycline oral		$316.21	$316.21 to $2114.72
Tetracycline oral		$1,047.09	$1047.09 to $2094.19
Weighted average of antibiotic products (Pediatrician condition)		$279.72	
Weighted average of antibiotic products (Dermatologist condition)		$287.00	
Utility values (QALYs)			
Acne states		0.938	0.938 to 0.99
Acne-free states		1	
Discount rate		3%	0% to 10%
Adherence rate		73%	40% to 100%
Percentage of cost excluded due to payer perspective		15%	0 to 15%
Effectiveness of topical retinoids		67%	39% to 67%

Model Inputs: Costs and Utilities

Input parameters also include information about the costs considered in this model and the QOL values attributed to acne vulgaris (**Table 2**).

Based on the US private payer perspective, the costs (**Table 2**) are one office visit per cycle in both conditions, unless the patient is lost to follow-up; and medication costs that depend on the medications prescribed in each cycle – topical retinoids, benzoyl peroxide (BP), or antibiotics. Office visits are assumed to be of moderate complexity (CPT code 99204 or 99214) for the first visit, and low complexity for all subsequent visits (CPT 99213). The first visit uses CPT code 99204 (new patient visit) in the dermatologist condition, because the patient is expected not to have visited the dermatologist before; and 99214 (established patient visit) in the pediatrician condition, because the patient is expected to have a usual pediatrician who has already been providing primary care to him or her.

Medication costs are assessed as a weighted average of costs of leading medications within the class of medications used, according to the previously published data on prescribing patterns. Medication costs were obtained as current average wholesale prices (AWP) from Micromedex UpToDate on October 27-28, 2014. Patients are assumed to obtain a 3-month supply of whichever medication was prescribed for that cycle, or no medication if none was prescribed. In the base case, they are assumed to obtain a new supply at each new cycle. Acne is estimated to cause about 0.124 QALYs lost over a 2-year period compared to perfect health, based on Chen's estimate of 0.938 QALYs (0.062 QALYs lost) per year [28]. Patients are assumed to pay a copayment of 15% of the medication's cost in the base case, leaving the rest of the cost to the payer. All costs are stated in 2014 US dollars using 2014 prices, so no inflation adjustments are necessary.

We modified the costs to incorporate a more accurate assessment of the types of medications being prescribed within the topical retinoid class today. Although the NAMCS data from 1996-2005 showed tretinoin and adapalene as the only commonly prescribed retinoid products [2], more recently adapalene/BP and tretinoin/clindamycin have been introduced to the market. We found data showing that the sales for adapalene/BP, tretinoin/clindamycin, adapalene, and tretinoin are now $199 million, $109 million, $87 million, and $29 million, respectively [29-32]. Based on these data together with the current prices we found, we calculated that current retinoid use would be about 32% adapalene/BP, 27% adapalene, 25% clindamycin/tretinoin, and 15% tretinoin.

We performed 7 one-way deterministic sensitivity analyses (DSA) to confirm our result from the base case scenario and check whether our estimate is robust against changes in important parameters.

Results

For a cohort of 1000 patients, the model parameterization produces a base case incremental cost-effectiveness ratio (ICER) for dermatologist treatment relative to pediatrician treatment of $40,000/QALY (**Table 3**). Total cost of dermatologist treatment was $2.33 million, conferring 1900 QALYs gained, while total cost of pediatrician treatment was $1.62 million, conferring 1883 QALYs gained. Our model produces an estimate of 42.3% of total time spent in acne-free states under the dermatologist condition, and 28.0% of total time spent in acne-free states under the pediatrician condition (**Table 3**).

Based on a threshold of $100,000/QALY that is widely used in practice, dermatologist care appears cost-effective in the base case scenario with costs of $40,000 per QALY gained.

Sensitivity Analyses

Sensitivity analyses revealed similar results (**Table 4**) to the base case, except when the QOL impact of acne was considered to be much lower in sensitivity analysis 2.

In the first DSA, we changed the costs of all medications to the maximum plausible value. Under this scenario, dermatologist treatment became dominant, costing slightly less than pediatrician treatment while producing the same number of incremental QALYs as in the base case. This occurred mainly because antibiotic treatment became very expensive, causing patients in the pediatrician condition to incur far more costs for antibiotic

Table 3. *Base-case results.*

Alternative	Time Spent in Acne-Free States	Costs	Total QALYs	Incremental Costs	Incremental QALYs	ICER
Dermatologist	42.3%	$2,330,112	1,900	$710,146	18	$40,000
Pediatrician	28.0%	$1,619,967	1,883	Referent	Referent	Referent

QALY, quality-adjusted life year; ICER, incremental cost-effectiveness ratio.

Table 4. *Sensitivity analyses. We tested the sensitivity of the results to the costs of medications, utility value of acne states, effectiveness of medications, discount rates, timing of cycle transition, change in perspective used, and amount of medication used. QALY, quality-adjusted life year; ICER, incremental cost-effectiveness ratio.*

	Percent of Time Spent in Acne-Free States	Costs	Total QALYs	Incremental Costs	Incremental QALYs	ICER
Sensitivity Analysis 1						
Dermatologist	42.3%	$5,022,873	1,900	$(50,149)	18	Dominant
Pediatrician	28.0%	$5,073,022	1,883	Referent	Referent	Dominated
Sensitivity Analysis 2						
Dermatologist	42.3%	$2,330,112	1,960	$710,146	3	$251,000
Pediatrician	28.0%	$1,619,967	1,957	Referent	Referent	Referent
Sensitivity Analysis 3						
Dermatologist	34.0%	$2,452,481	1,890	$720,960	12	$60,000
Pediatrician	24.2%	$1,731,521	1,878	Referent	Referent	Referent
Sensitivity Analysis 4 (Minimum)						
Dermatologist	42.3%	$2,356,561	1,928	$716,295	18	$40,000
Pediatrician	28.0%	$1,640,266	1,911	Referent	Referent	Referent
Sensitivity Analysis 4 (Maximum)						
Dermatologist	42.3%	$2,274,009	1,841	$697,101	17	$41,000
Pediatrician	28.0%	$1,576,908	1,824	Referent	Referent	Referent
Sensitivity Analysis 5						
Dermatologist	42.3%	$2,330,112	1,901	$710,146	17	$42,000
Pediatrician	28.0%	$1,619,967	1,885	Referent	Referent	Referent
Sensitivity Analysis 6						
Dermatologist	42.3%	$2,949,230	1,900	$839,951	18	$48,000
Pediatrician	28.0%	$2,109,279	1,883	Referent	Referent	Referent
Sensitivity Analysis 7 (Minimum)						
Dermatologist	42.3%	$1,430,041	1,900	$388,068	18	$22,000

Table 4. *(continued)*

	Percent of Time Spent in Acne-Free States	Costs	Total QALYs	Incremental Costs	Incremental QALYs	ICER
Pediatrician	28.0%	$1,041,974	1,883	Referent	Referent	Referent
Sensitivity Analysis 7 (Maximum)						
Dermatologist	42.3%	$3,066,534	1,900	$973,664	18	$55,000
Pediatrician	28.0%	$2,092,870	1,883	Referent	Referent	Referent

treatment than they did in the base case. The second DSA assumes that the utility value of acne states is 0.99, which was the median value cited by Chen for acne patients; our base case had used the mean value of 0.938 [28]. By causing the difference in QALYs between the two conditions to drop dramatically, this sensitivity analysis had the greatest impact on our results, increasing the ICER to $251,000/QALY. If the quality-of-life impact of acne is in fact as small as this, then we would expect dermatologist treatment not to be worth the additional cost. In this case, perhaps dermatologist treatment could be reserved for patients who have a more serious quality-of-life impact from acne than the typical patient.

In the third DSA, we changed the effectiveness of topical retinoids in the dermatologist condition to the minimum plausible value of 39%, the same as BP, while maintaining the assumption that pediatrician care would result in 75% as high a probability of success (29.25%). This increased the ICER to $60,000/QALY, still below our threshold of $100,000/QALY but above the threshold of $50,000/QALY used by many policymakers. Clearly, the practice of preferring topical retinoids should be questioned if they are no more effective than BP, but guidelines and evidence suggest there is a significant difference in effectiveness that justifies preferring topical retinoids. We varied the discount rates for costs and outcomes in the fourth DSA to the minimum value of 0% and to the maximum value of 10%. Due to the short time horizon of our study, changing the discount rates to 0% resulted in no change in the ICER after rounding to two significant figures, while using a 10% discount rate resulted in an increase of $1,000/QALY to $41,000/QALY. Therefore, the results are robust to the choice of discount rate. In the fifth DSA, we assumed that transitions occur in the middle of the cycle instead of at the beginning. Thus, the QALYs gained for a cycle were adjusted to 0.969 (midway between the full QALY decrement from having acne for a full state, and perfect health) when patients started the cycle in an acne state and ended it in an acne-free state, or vice versa. This sensitivity analysis changed the ICER to $42,000/QALY, a slight increase but still cost-effective under our threshold. We also considered a part of the societal costs of acne treatment in the sixth DSA, by including the 15% of the cost that was transferred to the patient as a copay. This increased the ICER to $48,000/QALY, which is still cost-effective. Thus, even when including the cost to the patient's family, dermatologist care remains cost-effective. In the last DSA, we varied the amount of medication used (adherence) from a low of 40% to a high of 100% to simulate uncertainty about the amount of drug not obtained and used due to non-adherence to treatment. The lowest level of medication use reduced the ICER to $22,000. Perfect medication use resulted in an increase in the ICER to $55,000 due to higher medication costs associated with obtaining more medication. The results of these

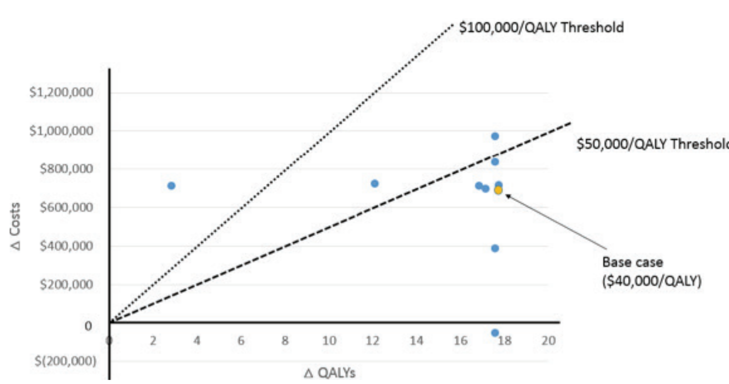

Figure 2. *Overview of deterministic sensitivity analyses. Most of the points were clustered near the base case of $40,000/QALY (quality-adjusted life years). The fact that most points were below the $50,000/QALY line suggests a high level of confidence that dermatologist treatment is cost-effective.*

DSA are illustrated in **Figure 2**.

Discussion

In our simulation, acne treatment by dermatologists leads to better outcomes (1900 versus 1883 QALYs and 42% acne free versus 28%) but also higher costs ($2.33 million versus $1.62 million) than acne treatment by pediatricians. In the base case scenario, an additional QALY gained comes with a cost of $40,000, which makes acne treatment by dermatologist cost effective compared to treatment by pediatricians, if applying either a $50,000 or $100,000 per QALY gained threshold. In most of the sensitivity analyses, the cost-effectiveness of dermatologist care remained in the cost-effective range. The only sensitivity analysis that suggested dermatologist treatment might not be cost-effective was the one in which quality-of-life impact of acne was much less than the base case estimate.

There are several limitations of our approach to be considered. The biggest limitation is that we partly had to rely on expert opinion to estimate some transition probabilities, especially for the pediatrician condition, since most of the effectiveness data were from trials done in dermatology clinics. However, our sensitivity analysis accounted for the possibility of retinoids being much less effective, but the ICER still rose only to $60,000/QALY even when retinoids were considered no more effective than BP, which is unlikely. Another limitation is that prescribing patterns have changed in recent years with the introduction of combination products like adapalene/BP and clindamycin/tretinoin, but the NAMCS data we used were from 1996-2005. We made an effort to remedy this by looking up the market shares of the four retinoid products for the most recent year possible, but we had to make assumptions about the uptake of the new products by dermatologists and pediatricians. In addition, some of our assumptions were required by the logic of the Markov model and not easily tested with sensitivity analysis. For example, the Markov model required us to assume that patients do not switch between pediatricians and dermatologists once they have entered the model, but patients suffering from severe acne are highly likely to switch to a dermatologist. The Markov model also requires a fixed cycle length with a fixed transition matrix in each condition, so we could not assess the possibility that patients might not be asked to return as frequently as every 3 months, or that visit schedules might differ by specialty. Our results may have limited generalizability to the Medicaid population, since we are not using Medicaid reimbursement rates and medical costs.

Conclusion

In spite of those limitations, we are fairly certain that the acne treatment by a dermatologist is cost effective using conventional thresholds. The cost-effectiveness may become even more obvious, now that generic topical tretinoin and adapalene are available, decreasing the cost of topical retinoid therapy. Prescribing antibiotics also has the negative externality of promoting antibiotic resistance, which was not considered in this analysis, but underscores the importance of avoiding unnecessary antibiotic use. Pediatricians could improve outcomes by bringing their prescription patterns more in line with what dermatologists prescribe. Based on the improved outcomes in terms of QALYs in this study, directing acne patients to a dermatologist should be a reasonable strategy for payers. Unfortunately, many payers still take a cost-minimization approach, which entails accepting worse outcomes to minimize costs. Our model incorporates the significant decrement in quality of life that adolescents experience due to acne, which includes depression, social anxiety, and loss of ability to participate in activities that they enjoy. Since topical retinoids are effective and well tolerated, the best strategy for payers might be to require providers to try prescribing topical retinoids first, before the payer will authorize treatment with antibiotics.

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