Mohs Versus Traditional Surgical Excision for Facial and Auricular Nonmelanoma Skin Cancer: An Analysis of Cost-Effectiveness

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OBJECTIVE To evaluate and compare Mohs micrographic surgery and traditional excision in terms of cost and outcomes.

DESIGN We developed a computer-simulation, probabilistic, decision model to perform a cost-effectiveness analysis, with each patient serving as his or her own control.

SETTING University of Connecticut dermatology clinic, a tertiary care referral center.

PARTICIPANTS Input data were derived from results of a consecutive sample of 98 patients with nonmelanoma skin cancer on the face and ears, estimates in the literature on 5-year recurrence rates, and a query of healthy focus-group participants.

INTERVENTION We considered Mohs and traditional excision strategies.

MAIN OUTCOME MEASURES Outcomes were measured in quality-adjusted life years, cost, and cost-effectiveness.

RESULTS The Mohs strategy was $292 less expensive than the traditional surgical strategy and was more effective by an incremental quality-adjusted life year of 0.056 (translating to approximately 3 weeks of optimal quality of life). Results were robust to subgroup and sensitivity analyses.

CONCLUSIONS Mohs may be more cost-effective than traditional excision in eradicating nonmelanoma skin cancer. Further investigation of costs from various geographic payment localities and assessment of quality-of-life outcomes from a population-based sample are needed.

The authors have indicated no significant interest with commercial supporters.

Nonmelanoma skin cancer (NMSC) is a frequent malignancy in the United States, with a yearly incidence of approximately 1 million tumors.[1] Basal cell carcinomas (BCCs) and squamous cell carcinomas (SCCs) account for approximately 80% and 20% of NMSCs, respectively.[2] NMSCs are capable of significant morbidity; approximately 65% of all BCCs and SCCs affect facial sites,[3] with cosmetic and functional sequela. There is insufficient evidence for recommending a single treatment strategy as superior.[4,5]

Results of previous studies have demonstrated that traditional surgical excision (TSE) and Mohs costs vary depending on the type of TSE section (permanent or frozen) and the type of setting (facility or office based).[6,7] Additionally, costs are sensitive to the type of repair chosen.[6] Our previous cost analysis

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ISSN: 1076-0512 • Dermatol Surg 2009;35:1776–1787 • DOI: 10.1111/j.1524-4725.2009.01291.x

found Mohs to be cost comparable with TSE in the office with permanent sections and much less costly than facility-based TSE with frozen sections[6]. Cook and Zitelli[7] found Mohs to be marginally more expensive than TSE in the office with permanent sections and less expensive than ambulatory surgery–based TSE with frozen sections.

A recent study by Essers and colleagues[8] compared the cost-effectiveness of Mohs with that of TSE exclusively for BCC (primary and recurrent) based on data from a randomized controlled trial. Avoidance of tumor recurrence (based on 30 months for primary tumors and 18 months for recurrent tumors) was the primary effectiveness measure. The authors determined that the incremental cost-effectiveness ratio, in 2001 dollars, was $32,844 for primary tumors and $9,094 for recurrent tumors.[8] The total costs of Mohs were significantly higher than those of TSE, but there was no statistically significant difference in recurrence rate (effectiveness), and thus the authors concluded it was not cost-effective to implement Mohs on a large scale. Our approach was different. We performed a cost-effectiveness comparison of Mohs and TSE for facial and auricular NMSC based on our previous cost-comparison study.[6] We incorporated 5-year recurrence rates from the literature into our model because this length of time is typically used to define recurrence rates. Our effectiveness measure was quality-adjusted life-years (QALYs) because this is the metric of effectiveness that the Panel of Cost Effectiveness in Health and Medicine, convened by the U.S. Public Health Service, recommends.[9]

We hypothesized that the treatment of facial and auricular NMSC with Mohs would be relatively cost-effective, given our previous finding that the strategies were cost comparable[6] and the fact that Mohs may have slightly lower 5-year recurrence rates.[4,10–12] Mohs is also believed to be superior for cosmetic outcomes,[13] although there is a lack of empirical evidence to support this.[14] To test our hypothesis, we designed our cost-effectiveness analysis (CEA) to simultaneously compare costs, efficacy, and quality-of-life (QOL) outcomes.

Methods

Model Overview

We developed a computer-simulation, probabilistic, decision model (basic structure shown in Figure 1), using TreeAge Data 4.0 and TreeAge Pro 2007 Software (Williamstown, MA). Costs, efficacy data, and probabilities of various events occurring were derived from our prospective trial of 98 patients with primary NMSC.[6] An otolaryngologist evaluated all 98 patients and anticipated the size of the margins and repair type he would use if the patient were to undergo TSE. Margin control of TSE was determined by comparing the theoretical margins with the actual Mohs margins. We assumed that if the Mohs margin analysis documented tumor at any point beyond the otolaryngologist's, the TSE margins would be inadequate. All deep margins for TSE were assumed to be clear because the depth of the theoretical cases could not be determined. Parameters from our previous study were incorporated in our model and are summarized in Table 1.

We calculated the marginal cost-effectiveness between our two therapeutic strategies as the difference in cost between the two procedures divided by the difference in patient outcomes in terms of QALYs. An explanation of our analytic approach follows.

Model Structure

Several assumptions were made and incorporated into the structure of our model. To compare Mohs with TSE in each patient, we assumed that each patient simultaneously received Mohs surgery (arm 1) and TSE (arm 2) for the same (location, size, subtype) NMSC (Figure 1). In arm 1, the patient received Mohs with negative margins and reconstruction of the surgical defect (granulation, primary closure, local flap, graft). The patient receiving Mohs was subject to an assumed 1% 5-year recurrence rate.[12] (See below for recurrence rate assumptions.) In arm 2, the same patient received theoretical TSE: the otolaryngologist designated a type of margin control (permanent section [PS] or frozen section

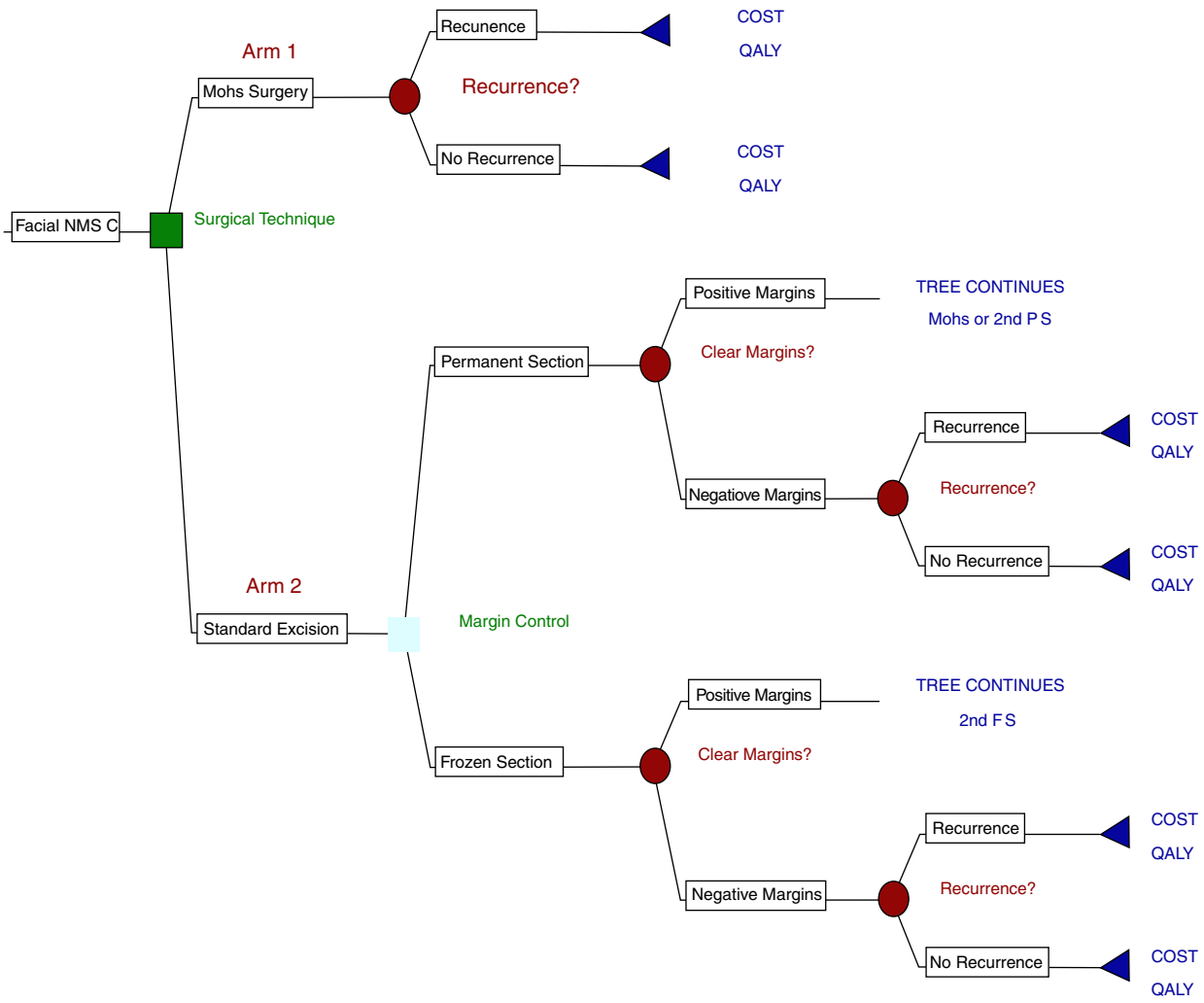

Figure 1. Decision model structure.

[FS], a repair type, and a setting [office, ambulatory surgical center, or formal operating room]).[6] Patients receiving TSE were subject to an assumed 5% 5-year recurrence rate.[4] Our model also assumed that, if the TSE margins were inadequate, a second TSE or Mohs procedure would be employed. Positive margins after TSE with FS were assumed to be treated using a second FS procedure. Positive margins after TSE with PS were treated with a repeat TSE with PS or a Mohs procedure. Because neither pathway differed significantly from a single Mohs surgery with regard to cost ($p = .16$ and $p = .53$, respectively),[6] we considered that all PS-positive margins were treated with Mohs in the base-case analysis.

Costs

Our previous cost analysis[6] provides a complete explanation of the derivation of costs used in the current study. Briefly, direct costs were derived from American Medical Association Current Procedural Terminology (CPT) codes converted into dollar amounts using 2002 Connecticut Medicare reimbursement rates.[15,16] The costs of initial evaluation and biopsy were excluded, because these costs were equal in the TSE and Mohs approaches. The total Mohs costs were determined from the actual CPT codes used in each case, and the costs for TSE were based on the theoretical plan.

TABLE 1. Model Inputs Derived from Prospective Cost Analysis[6]

Technique (Proportion)	*Excision Cost, $ Mean (95% CI)*	*Margin: Proportion (95% CI)**	*Repair Type: Proportion (95% CI)*	*Repair Cost, $†*
Mohs	745.47 (703.75, 787.19)		Granulation: 0.45 (0.35, 0.55)	79.96
			1° Closure: 0.49 (0.39, 0.59)	253.70
			Flap: 0.04 (0.0, 0.08)	660.39
			Graft: 0.02 (0.0, 0.05)	745.29
TSE FS (0.32)	1st: 1,043.92 (928.62, 1159.22)	Positive: 0.39 (0.29, 0.49)	Granulation: 0.08 (0.03, 0.13)	39.98
	2nd: 188.82		1° Closure: 0.17 (0.10, 0.24)	217.35
			Flap: 0.75 (0.66, 0.84)	641.89
			Graft: 0.0	728.10
		Negative: 0.61 (0.51, 0.71)	Granulation: 0.05 (0.01, 0.09)	39.98
			1° Closure: 0.42 (0.32, 0.52)	217.35
			Flap: 0.48 (0.38, 0.58)	641.89
			Graft: 0.05 (0.01, 0.09)	728.10
TSE PS (0.68)	408.02 (348.29, 467.74)	Positive: 0.32 (0.23, 0.41)	Granulation: 0.23 (0.15, 0.31)	39.98
			1° Closure: 0.64 (0.55, 0.74)	217.35
			Flap: 0.09 (0.03, 0.15)	641.89
			Graft: 0.04 (0.0, 0.08)	728.10
		Negative: 0.68 (0.59, 0.77)	Granulation 0.11 (0.05, 0.17)	39.98
			1° Closure 0.67 (0.58, 0.76)	217.35
			Flap 0.22 (0.14, 0.30)	641.89
			Graft 0.0	728.10

*Proportion of positive and negative margins after traditional surgical excision (TSE) with frozen sections (FS) and TSE with permanent sections (PS).
TSE margins were considered positive (inadequate) when Mohs margin analysis exceeded the otolaryngologist's estimate.
†Reimbursement rates with minimal variation.
CI = confidence interval.

We categorized costs into two relevant aspects of the Mohs and TSE procedures: excision and repair. For Mohs, the excision component was represented under a single code (17304–17307 or 17310) and included removal of all gross tumor, excision of tissue specimens, mapping, color coding of specimens, microscopic examination of specimens, and complete histopathologic preparation. Each progressive stage of Mohs had an added cost. The corresponding excision component for TSE was represented under several separate codes, 1164X for the excision; 88305, 88331, 88332 for pathology; and facility fees corresponding to the codes when indicated. Reconstruction series for TSE and Mohs were 1205X for primary closure, 140XX for flap, and 152XX for graft repair. For Mohs, two follow-up visits were billed (two units of code 99212). When the otolaryngologist chose healing by granulation, only one follow-up visit (99212) was charged because the TSE had a 10-day global period.

For TSE, the excision and reconstruction costs were appropriately reduced when a facility fee was charged, and the excision or reconstruction costs were reduced according to the multiple surgery reduction policy. For each FS examination (88331, 88332), a PS examination and report (88305) was also generated, according to the standard of care.

Health-Related QOL Data

Data linking perceived health status to the states defined by our model were obtained from querying a

focus group of five healthy nonexperts with a mean age of 40. We developed two health states for the type of repair and subsequent scar after facial and auricular NMSC surgery and reconstruction. We condensed simple repairs (granulation and primary closure) into one health state (simple scars) and complex repairs (local flap and graft) into a second health state (complex scars). We calculated our utilities using the time trade-off (TTO) method. We posed the health status question, "How much time in terms of years, months, and days would you give up to never have had NMSC or the experience of going through the surgery for your facial NMSC?" This question was followed by, "How much time would you give up to never have had the (simple or complex) scar from your cancer surgery?" to capture the extent that NMSC affects QOL. Possible responses of time were in terms of years, months, weeks, and days on a continuous scale. These were then converted to quality weights (utilities) using a TTO calculator. QOL was measured in terms of utility loss resulting from various states in the model. For example, utility from excision of NMSC, utility from repair type (simple vs complex), and utility from potential recurrence were each subtracted from a baseline utility of 1. These were the utility losses considered. These utility losses were then subtracted from the assumed baseline utility of each patient of 1. The resulting utilities for each state in the model were combined with the average life expectancy for our cohort (approximately 16 years) so that QALYs could represent the effectiveness of each state in the model.

Tumor Recurrence

Estimates for 5-year tumor recurrence rates incorporated in the model were derived from the literature,[4,10–12] where the rates ranged from 5% to 18% for TSE and from 1% to 5% for Mohs. A published systematic literature review estimated a 5.3% TSE 5-year recurrence rate for primary BCC.[4] TSE 5-year recurrence rates for SCC ranged from 5% for low-risk lesions to 10.9% and 18.7% for high-risk lesions on the lip and ear, respectively.[10] Mohs had 5-year recurrence rates of 1% for primary BCC[12] and from 3.1% (skin and lip) to 5.3% (ear) for SCC.[10] For the base case, we incorporated the most recent estimates in the literature that would apply to the majority of our patient population: 5-year recurrence rates of primary BCC of 1% after Mohs[12] and 5% after TSE.[4] All recurrences were assumed to be treated using the same procedure as used in the original extirpation: Mohs with the selected repair type.

Subgroup Considered

In addition to considering the base case for which all model input was used for the calculation of the cost-effectiveness, we performed a subgroup analysis based on the results of our previous study,[6] which demonstrated that the TSE with PS was more cost comparable with Mohs than TSE with FS, which was significantly more costly.

Sensitivity Analyses

Sensitivity analyses were performed to determine which assumptions, if any, were not robust in our model. The inputs in the model were varied to the upper and lower bounds of their 95% confidence intervals (Table 1) in univariate sensitivity analyses. The recurrence rates derived from the literature, which were incorporated in the base case, were varied to the higher-end estimates in the literature, to incorporate estimates for higher-risk SCCs of the ear after Mohs (5%) and TSE (18%),[10] although these recurrence rates would have applied to only a few of our patients. Utilities were varied across the range estimated by the focus group.

In addition to the univariate analyses, we performed a probabilistic sensitivity analysis using the Monte Carlo simulation. This type of sensitivity analysis allows for the variation of all assumptions simultaneously according their probability distributions or their ranges defined by upper and lower bounds. We chose to perform this type of analysis to further test the robustness of our results by simultaneously drawing values from distributions for excision

component of cost, probability of recurrence, and utilities. This allowed for repeated calculations of the cost-effectiveness ratio by using various sets of parameter values randomly sampled from specific distributions. One thousand simulations, a standard number for this kind of analysis, were performed.

We were able to determine the percentage of incremental cost-effectiveness ratios (ICERs) in which Mohs was more cost-effective than TSE for the base case and subgroup analysis by constructing scatterplots. The scatterplots displayed the incremental costs and effectiveness of Mohs compared with TSE according to the following four possibilities. (1) TSE was less costly and more effective than Mohs. (2) TSE was more costly but also more effective than Mohs, meaning that ICERs would be useful in examining the difference in costs relative to the differences in effectiveness and exploring whether the lower costs of Mohs added enough value that the loss in effectiveness when Mohs was used may be justified. (3) Mohs was less costly and more effective than TSE. (4) Mohs was more costly but also more effective than TSE. ICERs would be useful in examining the difference in costs relative to the difference in effects and exploring whether the added effectiveness of Mohs may be worth the added cost of Mohs.

The acceptability of a strategy that is more costly but more effective depends on the threshold under which society considers the ICERs to be cost-effective. This may be considered as the added amount that society is willing to pay for the added effect resulting from the more expensive strategy. Strategies exceeding the accepted threshold may not be recommended for use, even if they provide some added effectiveness because the additional expenditures are not considered to be worth incurring if they exceed the threshold that is acceptable to decision-makers.

We constructed cost-effectiveness acceptability curves that represent this concept, for the base case and subgroup, to determine the probability of Mohs being more cost-effective than TSE at various hypothetical ICER threshold values, ranging from $0 to $50 K. In the acceptability curve, Mohs was considered more cost-effective than TSE when it was less costly and more effective; when it was more costly and more effective than TSE, but the ICER was within the threshold range (or the hypothetical value of society's willingness to pay extra for the added effect); or when TSE was more costly and more effective, but the ICER was not within the threshold range (the added cost for the improved effectiveness of TSE relative to Mohs was beyond the arbitrary value society was willing to pay, leaving Mohs as the preferred option).

Results

Patients

We enrolled 98 consecutive patients with a primary diagnosis of NMSC on the face and ears. Mean age was 67.8. The sample consisted of 56 men (57%) and 42 women (43%). The study population represented 77 BCCs and 21 SCCs, all undergoing the Mohs procedure. The average number of Mohs stages was 1.5 (range 1–5 stages). Most NMSCs were located in the nasal/perinasal region (41%), cheek (16%), auricular or periauricular area (15%), and forehead (12%), with the rest located on the canthus or periorbital region (7%), temple (7%), and lip (2%). Most of the hypothetical TSE procedures were performed in an office (57%), many took place in an ambulatory surgery center (39%), and a few occurred in the operating room (4%). The repair types used in Mohs versus TSE, respectively, were granulation (45% vs 12%), primary closure (49% vs 56%), flap (4% vs 30%), and graft (2% vs 2%).

QOL Measures: Utilities

The mean utility for an excision procedure using Mohs or TSE was 0.996 (range 1–0.984), corresponding to 1 month of life traded. The mean utility for simple closure (granulation or primary closure) was 0.984 (range: 1–0.974), corresponding to 3 months traded. The mean utility for complex closure (flap or graft) was 0.974 (range: 1–0.953), corresponding to 6 months traded. The utility value

incorporated for recurrence was 0.984 (range: 1–0.949), corresponding to 3 months traded.

Base-Case CEA: Study Population

In the study population, the Mohs strategy was associated with a projected quality-adjusted life expectancy, from age 68, of 15.67 QALYs, with an average cost of $957 per person. The TSE strategy was associated with a projected discounted quality-adjusted life expectancy, from age 68, of 15.61 QALYs, with an average cost of $1,248 per patient. The base-case CEA demonstrated that Mohs was $292 less costly than TSE and that Mohs was more effective than TSE by an incremental QALY of 0.056, and thus Mohs was less costly and more effective than TSE.

Subgroup CEA

We eliminated TSE with FS, which cost an average of $1,399, as an option in the decision tree, to compare Mohs with TSE with PS only. We examined two hypothetical scenarios for positive margins in the TSE with PS treatment strategy. When positive PS margins were treated using Mohs, Mohs was less costly and more effective than TSE, but when positive PS margins were treated using a second TSE with PS, the ICER for Mohs relative to TSE was $509 per QALY (Mohs was more effective than TSE but required an added cost of $509 over TSE for the added amount of effectiveness). Because the cost of Mohs was closest to that of TSE with PS followed by a second TSE for positive margins, this scenario was incorporated in the subgroup sensitivity analyses.

Sensitivity Analyses: One-Way

Base Case Our evaluation was robust to all one-way analyses (the alteration of each variable one at a time). As long as the utility loss from simple closure was less than or equal to that of complex closure, Mohs was still less costly and more effective than TSE. Increasing Mohs or TSE recurrence rates to the higher-range estimates in the literature (5% for Mohs, 18% for TSE) did not affect base-case findings. Varying the proportion of positive margins after TSE within the 95% confidence interval (CI) had no effect. When Mohs repair costs were kept at 100%, Mohs was still less costly and more effective than TSE, even when the costs of TSE repair choices were reduced to 30% of their original value. Mohs only became less cost effective than TSE when the TSE reconstruction costs were reduced to 24% of their original value.

Subgroup Results (Table 2) demonstrate that the subgroup analysis (where the costs of Mohs and TSE strategies were more comparable) was more sensitive to variations in the cost-related parameters than the base case. Mohs was overall more effective but more costly than TSE, but when the Mohs excision component of cost was reduced to the lower bound of the 95% CI or the TSE excision cost was increased to the upper bound of the 95% CI, the Mohs strategy became less costly than TSE and remained more effective than TSE. Variations in utility had little effect unless the utility loss of complex closure became less than that of simple closure, in which case, TSE became the more effective option.

The univariate subgroup analyses displayed in Table 2 demonstrate that alteration of the variables causing Mohs to become even more costly than TSE while remaining more effective than TSE increases the ICERs to values that are still typically considered very low in these types of analyses (well below the commonly accepted $50 K threshold).

Sensitivity Analysis: Probabilistic

Base-Case Results of a 1,000-simulation Monte Carlo scatterplot analysis (Figure 2A) revealed that Mohs was less costly and more effective than TSE in 80% of ICERs and more costly but also more effective in 6.8% of ICERs. Conversely, TSE was less costly and more effective in just 1.2% of the simulated samples and more costly but also more effective in 12% of ICERs.

Acceptability curves are displayed in Figure 3A. For varying levels of the cost-effectiveness threshold, from $0 to $50 K, for an added amount of

TABLE 2. Subgroup Sensitivity Analyses Results

	Mohs		*TSE Permanent Section*		
Variable	*Cost, $*	*Effectiveness*	*Cost, $*	*Effectiveness*	*ICER**
Excision cost					
Lower bound 95% CI: Mohs	914.40	15.6672	938.00	15.6348	TSE dominated by Mohs
Upper bound 95% CI: Mohs	998.70	15.6672	942.10	15.6348	$1,742.94
Lower bound 95% CI: TSE	956.50	15.6672	861.20	15.6348	$2,938.56
Upper bound 95% CI: TSE	956.60	15.6672	1,018.90	15.6348	TSE dominated by Mohs
Repair type					
Lower bound 95% CI: Mohs granulation (0.35), PC (0.59)	974.10	15.6672	940.10	15.6348	$1,049.36
Upper bound 95% CI: Mohs granulation (0.55), PC (0.39)	939.01	15.6672	940.06	15.6348	TSE dominated by Mohs
Recurrence rate					
Recurrence: upper bound Mohs (0.05)	974.90	15.6621	940.10	15.6348	$1,272.19
Recurrence: upper bound TSE (0.18)	956.60	15.6672	1,077.60	15.6023	TSE dominated by Mohs
Utility simple closure					
0.96	956.60	15.300	940.10	15.319	Mohs dominated by TSE
0.97	956.60	15.45066	940.10	15.44844	$7,442.27
0.98	956.60	15.6011	940.10	15.5778	$710.90
0.99	956.60	15.7515	940.10	15.7073	$373.28
1.00	956.60	15.9019	940.10	15.8367	$253.08
Utility complex closure					
0.95	956.60	15.644	940.10	15.562	$200.73
0.96	956.60	15.6541	940.10	15.5929	$269.58
0.97	956.60	15.6637	940.10	15.6235	$410.30
0.98	956.60	15.6733	940.10	15.6541	$858.42
0.99	956.60	15.68288	940.10	15.68465	Mohs dominated by TSE

*"TSE dominated by Mohs" refers to a strategy in which Mohs is less costly and more effective than traditional surgical excision (TSE). "Mohs dominated by TSE" refers to a strategy in which TSE is less costly and more effective than Mohs.CI = confidence interval; PC = primary closure.

effectiveness, Mohs was more cost-effective than TSE in approximately 90% of samples.

Subgroup When Mohs was compared with TSE with PS only (Figure 2B), Mohs was less costly and more effective than TSE in 47.7% of the sample simulations and more effective but more costly in 44.1% of sample simulations. TSE was less costly and more effective than Mohs in just 4.7% of simulations and more costly but less effective in 3.5% of samples.

The acceptability curve (Figure 3B) demonstrates that, when the cost-effectiveness threshold is $0 (when society is unwilling to pay for added effectiveness of a strategy), Mohs is more cost-effective than TSE in just over 50% of cases. However, if the cost-effectiveness threshold increases above $5 K or $10 K, approximately 75% or 90% of ICERs, respectively, become more cost-effective for Mohs than TSE.

Discussion

Our results indicate that treatment with Mohs had greater effectiveness than TSE by 0.06 QALYs, or approximately 3 weeks of optimal quality of life at a cost nearly $300 less than TSE. Our analysis was

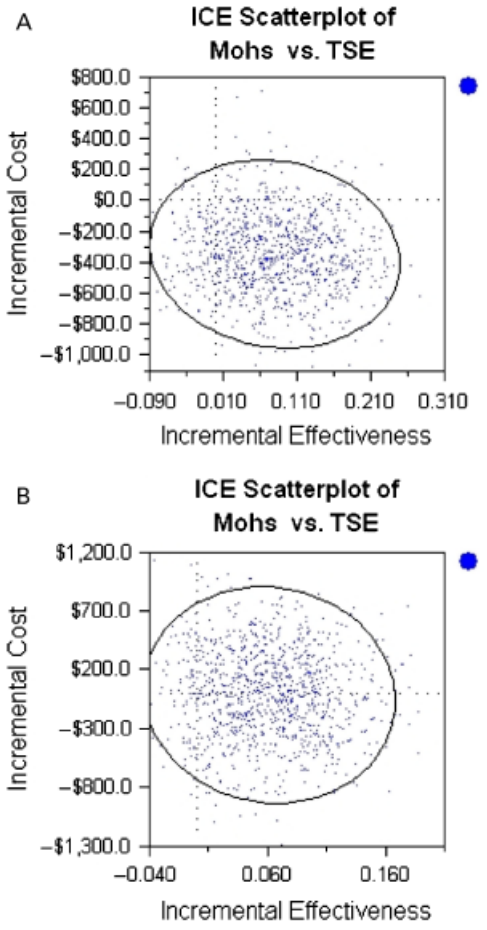

Figure 2. Scatterplots of incremental cost-effectiveness (ICE) from 1,000-simulation Monte Carlo analyses and 95% confidence ellipses. Each point represents ICE of Mohs relative to traditional surgical excision (TSE) for a hypothetical sample. (A) Mohs versus all TSE; (B) Mohs versus TSE with permanent section only (subgroup).

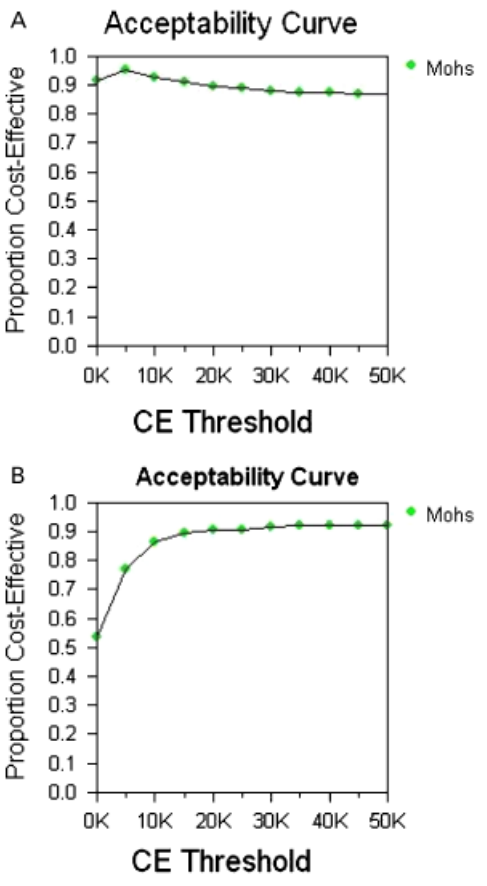

Figure 3. Acceptability curves from 1,000-simulation Monte Carlo analyses. Y-axis depicts proportion of samples for which Mohs had greater cost-effectiveness (CE) than traditional surgical excision (TSE). X-axis depicts cost-effectiveness threshold. (A) Mohs versus all TSE; (B) Mohs versus TSE with permanent section only (subgroup).

robust to all sensitivity analyses. In probabilistic sensitivity analysis of the base case, results revealed that just 11.6% of simulations favored TSE over Mohs at a cost effectiveness threshold of $50 K per QALY. Because approximately 90% of simulations preferred Mohs over TSE, we conclude that further trials with similar model input would provide little value.[17] The overall importance of our findings is that Mohs was lower in cost and had greater effectiveness than TSE, and this remained a robust finding in our sensitivity analyses.

Because granulation was associated with lower costs than the other repair options and a higher utility value than complex closure, a technique that used proportionately more granulation repairs (Mohs in our study) seemed most likely to be more cost-effective. Although the distribution of Mohs repair type in our patient sample was 45% granulation, 49% primary closure, 4% flap, and 2% graft, a reported distribution of Mohs repair types used in Houston, Texas, in 3,937 consecutive patients undergoing Mohs surgery was 11% granulation, 69% primary closure, 14% flap, and 6% graft.[18] A recent national survey of Mohs surgeons in the United States reported similar results, with the majority of defects closed primarily.[19] We substituted the Mohs repair type distribution recognized by Kimyai-Asadi

and colleagues[18] in the base-case analysis, and although it increased the cost of the Mohs strategy to $1,077 (compared with $957 in the base case), Mohs remained less costly and more effective than TSE. In conclusion, our distribution of repair types differed from those previously published,[18,19] and thus may limit the generalizability of our findings. However, our sensitivity analysis allowed for alteration of the distribution, and we found that allowing for the majority of defects to be closed primarily did not alter our outcomes.

Our findings differed from those of Essers and colleagues,[8] who performed a CEA of Mohs versus TSE and found that Mohs was significantly more expensive than TSE, although the outcomes were comparable. The difference between their findings and ours is most likely due to the difference in settings and methodologies. Essers and colleagues performed their cost analysis in the outpatient clinic of the University Hospital Maastricht in The Netherlands using the micro-costing method, with volume-of-use information obtained from the hospital information system and unit costs from the financial department. They found that the mean cost of Mohs was significantly higher than TSE, primarily because there were higher personnel costs (estimated according to empirical surgical times documented at the start and end of each procedure) and higher costs of pathology. Essers and colleagues calculated that the mean personnel cost of Mohs was $254, whereas that for TSE was $100; they determined that the mean cost of the pathologic examination for Mohs was $112, whereas that for TSE was $74. These differences were the major factors accounting for the higher cost of Mohs in the Essers and colleagues study.

In our analysis, the use of a patient as his or her own control precluded documentation of the exact starting and ending times of each procedure because TSE was only hypothetical. This is an important limitation in our model that may have accounted for differences in our findings from those of Essers and colleagues. However, the relationship between procedure time and personnel cost in real practice may be more complicated than a direct relationship, particularly in a fee-for-service reimbursement setting. Multiple Mohs procedures may be scheduled in the same time frame, or varying numbers of assistants may be employed at different pay rates depending on the clinical setting. In our study, the setting of the procedure influenced physician fees. They were lower if the procedure was performed in a facility (ambulatory surgery center or operating room) than if it was performed in an office-based setting according to the Medicare reimbursement rates. Separate facility costs were incurred for any TSE performed in a facility, adding to greater overall costs of the TSE procedure in some cases. The Mohs procedure is generally performed in the office-based setting and thus does not have a facility fee. In contrast, the Essers and colleagues study applied general hospital overhead costs to the direct costs of each procedure as an additional 35% of the overall costs, according to Dutch guidelines.

Furthermore, unlike the Essers and colleagues analysis, we were unable to directly compare pathology fees of Mohs and TSE. Medicare reimburses pathology fees for Mohs as part of the overall Mohs excision fee but reimburses pathology fees for TSE separately from the excision component. In the TSE procedure, in which FS margin analysis was an option, the FS margin analysis had first-time pathology fees that were approximately $170 more expensive than PS margin analysis fees, indicating that TSE could potentially incur much higher fees than Mohs if FS were selectively chosen over PS.

The differences between our results and those of Essers and colleagues underscore the sensitivity of the results to different settings, where there may be varied unit costs based on predetermined costing systems or payment rates. Because costs influenced our results more than effectiveness, it is likely that our results would change should the reimbursement rates or regulations through Medicare change. For example, Medicare recently changed the reimbursement of Mohs surgery and reconstruction so that, when the excision and reconstruction components of

the procedure are performed on the same day, the lower-value procedure will be reimbursed at 50% of its contracted rate. This change would probably decrease the importance of repair type in determining the overall cost of the procedure.

Although a randomized trial such as the study performed by Essers and colleagues is generally considered a superior methodology, a potential limitation of this design in this setting, as recognized by Essers and colleagues, is time constraints leading to estimates of recurrence rates at intervals shorter than 5 years. A major strength of our analysis is that we were able to incorporate previously published 5-year recurrence rates.

Limitations specific to our study design, in which patients served as their own controls, included an inability to directly compare personnel or time-related costs, as discussed previously, as well as an inability to examine the difference between the outcomes of the tumor or its therapy directly by administering disease-specific QOL instruments to patients who received Mohs and TSE and comparing results. However, when we assumed that the utilities of simple and complex closures were equivalent, our findings did not change. It was only when the utility loss of simple closures became greater than that of complex closures that the Mohs strategy became less effective than TSE. Additionally, the assumption of deep margins being clear may have underestimated the TSE positive-margin rate and the corresponding number of extra procedures required and thus may have underestimated the overall TSE costs. However, this underestimate would further strengthen our findings. In addition, as discussed in the editorial review of our original cost analysis,[20] we may have been limited by our inability to capture hidden costs of care, such as prophylactic antibiotic use or additional follow-up visits after the global surgery period after TSE.

The construction of our model required some assumptions and, as such, served only to simulate reality. One of our assumptions was that SCCs and BCCs could be lumped together for the analysis, despite the fact that recurrence rates for SCCs are higher than for BCCs. Another assumption was that utilities from primary closures and granulation would be similar and could be considered together as a "simple scar" utility. However, in reality, healing by granulation often causes changes in contour and atrophy that may be avoided through primary closure or possibly even through some flaps, so there may be more effect of healing by granulation on QOL outcomes than we had initially anticipated. Although it is possible that, if the model distinguished these scenarios, we may have come to different conclusions, we highly doubt it, given the range of assumptions in our sensitivity analyses. As for the recurrence rates, increasing them to the higher-range estimates in the literature did not affect our base case findings, even when we increased them to 18.7%, which only applies to high-risk SCC lesions of the ear[10] and thus pertained to only six of our 98 subjects. Although healing by granulation was categorized as a simple scar, it may have been more similar to what we had defined as a complex scar with contour changes and atrophy. However, we doubt that distinguishing granulation from primary closures would have made a significant difference, given that utilities were varied to the point that simple and complex scars were the same without any effect on our findings.

We recognize that the preferred methodological design would be a 5-year randomized controlled trial, but our prospective design with 98 consecutive patients, with each patient serving as his or her own control, was selected because of time constraints and a limited number of patients. Our results provide preliminary evidence that Mohs may be more cost-effective than TSE when 5-year recurrence rates are considered and in particular cost settings. The applicability of this work on a national level to other groups of patients is unknown. To evaluate the cost-effectiveness of widespread implementation of Mohs versus TSE for NMSC treatment, investigation is needed of costs from various geographic payment localities. Additionally, the QOL-related effective-

ness of each strategy should be further assessed on a population level before recommendations on the preferential use of Mohs are set forth.

Acknowledgments **Funding:** This project was supported in part by an American Skin Association Health Services Research Grant and an Emory Skin Disease Research Center Pilot and Feasibility grant (P30AR42687) from the National Institute on Arthritis and Musculoskeletal and Skin Disease (NIAMS), National Institutes of Health (NIH). Dr. Bramlette was supported by a National Research Service Award Training Grant (T32 AR07587) from the NIH. Dr. Chen was supported in part by a Mentored Patient Oriented Career Development Award (K23AR02185-01A1) from NIAMS, NIH, as well as a Network 7 Veterans Integrated Service Network Veterans Association Career Development Award.

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