The characteristics of Mohs surgery performed by dermatologists who learned the procedure during residency training or through postgraduate courses and observational preceptorships

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Little is known about the practice characteristics of Mohs surgery performed by physicians who learned the procedure during their dermatology residency training or through postresidency courses and observational preceptorships. All published reports have investigated Mohs surgeons trained in postresidency fellowships. This report presents the results of a multicenter prospective cohort study evaluating 1834 consecutive Mohs surgery cases performed during the same 6-month period by 9 Mohs surgeons who learned the technique in residency or in postresidency courses and observational preceptorships. One major complication was reported, a hematoma requiring outpatient drainage in an emergency room. There were 54 (2.9%) short-term complications, including 20 (1.1%) infections, 17 (0.9%) wound dehiscences, 9 (0.5%) cases of skin flap necrosis, and 8 (0.4%) hematomas or postoperative bleeding episodes. These complication rates and the data evaluating tumor type, anatomic location, primary vs. recurrent tumor status, tumor size, postoperative wound size, number of Mohs surgery stages, and repair type compare favorably to previously published reports.

Mohs micrographic surgery (MMS) is a widely practiced skin cancer treatment that is safe, tissue sparing, effective, and economical (1–11). All published reports supporting these conclusions evaluated Mohs surgeons trained in postresidency fellowships. Many physicians receive their MMS training outside of postresidency fellowships (3). No published studies could be found assessing the practice characteristics of MMS performed by non–fellowship-trained Mohs surgeons. This study reports the results of a 6-month prospective cohort study of 1834 consecutive MMS cases performed by 9 non–fellowship-trained Mohs surgeons at nine locations. The practice characteristics of these Mohs surgeons are analyzed and compared with previously published reports.

METHODS

Study approval was obtained from the Scott & White institutional review board and exempted from further oversight. STROBE guidelines for patient series were adhered to. Nine non–fellowship-trained Mohs surgeons with differing methods of MMS training and levels of experience volunteered to submit all cases they performed between August 1, 2012, and January 31, 2013. No cases were excluded. They received MMS training in residency, postresidency courses followed by observational preceptorships, or postresidency courses alone.

Each Mohs surgeon provided his or her date of birth, gender, residency completion year, MMS training method, practice setting, geographic location, years of MMS experience, and total number of MMS cases performed. Cases performed in residency and before course and preceptorship training were excluded.

Each Mohs surgeon submitted a case log documenting tumor type, anatomic location, primary vs. recurrent tumor status, tumor size, postoperative wound size, number of MMS stages, and repair type. All identifiable patient data were removed, and the institutional review board required no study consent forms. Participants reported all major complications, defined as adverse events requiring an emergency room visit or hospital admission within 48 hours of the procedure. All short-term, minor postoperative complications were reported, including wound infections (defined as a postoperative wound the Mohs surgeon felt required oral antibiotic therapy), wound dehiscence (partial or complete), bleeding, hematoma, seroma, and flap necrosis. Participants were not asked to track long-term adverse sequelae, including scars requiring revision, permanent sensory or motor nerve damage, or tumor recurrence.

RESULTS

Nine dermatologists with different forms of MMS training and levels of experience submitted 1834 MMS cases. Six (66%) received their training in residency, 2 (22%) through courses followed by observational preceptorships, and 1 (11%) from course training alone. Ages ranged from 38 to 64 years (average, 52 years). Eight were male and one was female. All were board-certified dermatologists practicing in the United States: three (38%) from the Midwest, three (38%) from the Southwest, two (25%) from the West, and one (13%) from the Southeast. Participants completed their MMS training an

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Table 1. The training method, practice setting, career and case experience, and number and percentage of cases submitted by each Mohs surgeon

Surgeon	Training method*	Practice setting	Career cases	Career experience (years)	Cases submitted (n = 1834)	Percent of cases
1	R	Solo practice	>5000	20	97	5.3%
2	R	Academic group	>5000	20	54	3.0%
3	CP	Solo practice	1000–2500	8	311	16.9%
4	R	Dermatology group	>5000	16	328	17.9%
5	CP	Solo practice	>5000	8	394	21.5%
6	R	Multispecialty group	500–1000	2	147	8.0%
7	R	Solo practice	500–1000	12	129	7.0%
8	C	Solo practice	>5000	3	300	16.3%
9	R	Solo practice	250–500	15	74	4.0%
Practice setting		Solo practice (67%)			1305	71%
		Dermatology group (11%)			328	18%
		Multispecialty group (11%)			147	8%
		University/academic (11%)			54	3%
Career case experience			>5000		1173	64%
			1000–2500		311	17%
			500–1000		276	15%
			250–500		74	4%

*CP indicates course followed by preceptorship; C, Course; R, Residency.

average of 11.6 years (range, 2–20 years) before the onset of the study. The training method, practice setting, career experience, and number and percentage of cases submitted by each Mohs surgeon are shown in *Table 1.*

Of the 1834 tumors treated, 1207 (65.8%) were basal cell carcinoma, 503 (27.4%) were squamous cell carcinoma, and 116 (6.3%) were squamous cell carcinoma in situ. Thirteen (0.7%) basosquamous cell carcinomas were categorized as squamous cell carcinomas. Four tumors (0.2%) were atypical fibroxanthomas, and four (0.2%) were other rare tumors. None of the participants treated melanocytic tumors with MMS. Overall, 96.4% of tumors were primary and 3.6% were recurrent.

In terms of location, 1509 (82.2%) tumors were located on the face, 100 (5.5%) on the scalp, 82 (4.5%) on the extremities, 58 (3.2%) on the neck, 42 (2.3%) on the trunk, 40 (2.2%) on the hands, and 3 (0.2%) on the feet. The mean tumor size was 1.22 cm^2 (standard deviation [SD] 1.71 cm^2), with a median of 0.8 cm^2. The mean final wound size was 3.77 cm^2 (SD 5.68 cm^2) with a median of 2.25 cm^2. The average number of MMS stages to obtain clear margins was 1.66 (SD 0.82); 909 (49.6%) cases were cleared after 1 stage, 718 (39.1%) after 2 stages, 140 (7.6%) after 3 stages, 49 (2.7%) after 4 stages, and 18 (0.9%) after 5 or more stages.

Of the surgical defects, 1029 (56.1%) were repaired linearly, 512 (27.9%) with local cutaneous flaps, 123 (6.7%) by secondary intention, 85 (4.6%) with skin grafts, 6 (0.3%) with partial repairs, 6 (0.3%) with a combination of techniques, and 1 with a porcine xenograft. A total of 72 cases (3.9%) were referred to other surgeons for repair.

Fifty-five (3.0%) adverse events were reported. One (0.05%) major complication was reported in a patient with a hematoma requiring drainage in an emergency room. The 54 (2.9%) short-term complications included 20 (1.1%) infections, 17 (0.9%) wound dehiscences, 9 (0.5%) cases of skin flap necrosis, and 8 (0.4%) hematomas or bleeding episodes. The anatomic distribution of infections was face (70%), scalp (15%), neck (5%), and extremities (15%); 86% of the wound dehiscences were on the head or neck.

DISCUSSION

Physicians receive various forms of MMS training (3). Previously published MMS case series evaluated only fellowship-trained Mohs surgeons. To our knowledge, this is the first report assessing non–fellowship-trained Mohs surgeons.

Our study involved 1834 cases from 9 non–fellowship-trained Mohs surgeons from the same 6-month period. Merritt et al (2) studied 1792 cases from 13 fellowship-trained Mohs surgeons with the same general design and scope. Alam et al (1) conducted a comprehensive study of 20,821 cases from 36 Mohs surgeons, focusing primarily on adverse effects. Recurrence rates were not evaluated in any of these studies, as 5-year follow-up data are considered the minimum duration necessary for accurate recurrence assessment (12, 13). All three studies were conducted before current MMS appropriate use criteria were published (14). Thus, clinical data permitting a

Table 2. Tumors treated with Mohs surgery: study data versus previous reports

	Tumor types				
First author, year (ref)	BCC	SCC	SCCis	Other	Total cases
Study data	66%	27%	6.3%	0.4%	1834
Cook, 1998 (20)	77%	16%		7.5%	400
Cook, 2003 (9)	68%	29%			1343
Bialy, 2004 (21)	68%	32%			98
Kimyai-Asadi, 2005 (7)	72%	21%		6.7%	3937
Casey, 2009 (8)	76%	22%		2.0%	N/A
Alam, 2010 (22)	73%	27%			2000
Martin, 2010 (15)	64%	28%		8.0%	950
Merritt, 2012 (2)	61%	31%		8.3%	1792
Alam, 2013 (1)	63%	35%		2.4%	20,821

BCC indicates basal cell carcinoma; SCC, squamous cell carcinoma; SCCis, squamous cell carcinoma in situ.

Table 4. Number of Mohs surgery stages to obtain clear margins: study data vs. previous reports

	Number of Mohs surgery stages					
First author, year (ref)	1	2	3	4	>5	Average
Study data	50%	39%	7.6%	2.7%	0.9%	1.7
Cook, 1998 (20)	67%	23%	4.0%	3.5%	3.0%	1.5
Kimyai-Asadi, 2005* (7)						1.7
Casey, 2009* (8)						1.8
Alam, 2010 (22)	42%	41%	12%	4.0%	1.8%	1.9
Martin, 2010* (15)						1.4
Rogers, 2010* (16)						1.4
Merritt, 2012* (2)						1.6
Lilly, 2012* (19)						1.3

* Only average of total stages reported.

determination of whether study cases complied with these criteria were not obtained.

Of the 9 Mohs surgeons evaluated, 6 (55%) were in solo practice and 1 each (11%) were in academic, dermatology group, and multispecialty group practices *(Table 1)*. Campbell (13) surveyed 303 fellowship-trained Mohs surgeons and reported a distribution of 30% in solo practice, 21% in academic practice, 39% in dermatology group practice, 9% in multispecialty group practice, and 1% listed as "other." The differences in practice setting distribution may reflect a sampling bias or that more non–fellowship-trained Mohs surgeons are in solo practice.

The percentage and distribution of tumor types treated in this study is very similar to that of previous reports *(Table 2)* (1, 2, 7–9, 15, 20–22). Fewer recurrent tumors (4%) were treated than in previous reports. Ravitskiy et al (11) reported on 379 tumors and found that 10% were recurrent. Cook and Zitelli (20) analyzed 400 consecutive cases and found that 16% were recurrent. These differences possibly suggest that non–fellowship-trained Mohs surgeons receive fewer outside referrals for treatment of recurrent cancers. This study data showed a low percentage of tumors (0.4%) that were not basal cell carcinoma, squamous cell carcinoma, or squamous cell carcinoma in situ. Other studies have reported ranges of 2% to 8% of rarer tumor types *(Table 2)*. This may indicate that fellowship-trained Mohs surgeons are more prepared to manage rarer tumor types with MMS. The anatomic distribution of tumors treated in the study is also similar to that of previously published series *(Table 3)* (2, 7, 8, 16, 19, 20, 22).

The average number of MMS stages required to achieve tumor clearance was 1.66. This value and the distribution of required stages is very similar to previous reports *(Table 4)* (2, 7, 8, 15, 16, 19, 20, 22). This study's mean preoperative tumor size of 1.2 cm^2 is similar to that reported by Kimyai-Asadi (1.0 cm^2) (7) and Merritt (1.1 cm^2) (2). The average postoperative wound size (3.8 cm^2) was between the values reported by Kimyai-Asadi

Table 3. Anatomic distribution of tumors treated with Mohs surgery: study data versus previous reports

First author, year (ref)	Face	Scalp	Neck	Head & neck	Trunk	Ext.	Trunk & ext.	Hands & feet	Ext. & genitalia	Genitalia	Other
Study data	82%	5.5%	3.2%		2.3%	4.5%		2.4%			
Cook, 1998 (20)				87%	8.0%				5.5%		
Kimyai-Asadi, 2005* (7)	76%	5.6%	3.7%		4.8%	7.6%		1.8%		0.2%	
Casey, 2009*† (8)	83%	4.5%	3.4%				8.0%	2.0%			
Alam, 2010* (22)	80%	5.4%	2.2%		3.6%	7.5%					1.0%
Rogers, 2010* (16)				73%	9.3%	17%					
Merritt, 2012* (2)	68%	7.0%	4.0%		8.0%	10%		3.0%		0.2%	
Lilly, 2012 (19)				86%	4.0%	10%					

Ext. indicates extremities.
*Data for some anatomic areas combined.
†2000–2006 data only.

Table 5. Surgical repair methods after Mohs surgery: study data versus previous reports

First author, year (ref)	Surgical repair methods						Number of cases
	2nd intention	Linear	Flaps	Graft	Referred	Other	
Study data	6.7%	56.1%	27.9%	4.6%	3.9%	0.6%	1834
Futoryan, 1995 (18)	3.4%	53.0%	26.0%	17.0%		0.1%	530
Cook, 1998 (20)	39.0%	37.0%	10.0%	13.0%		0.8%	400
Kimyai-Asadi, 2005 (7)	11.0%	69.0%	14.0%	6.2%	0.4%		3937
Maragh, 2008* (17)	6.8%	53.0%	27.0%	14.0%			1115
Casey, 2009 (8)	18.0%	44.0%	19.0%	9.0%	10.0%		N/A
Alam, 2010 (22)	10.0%	50.0%	21.0%	8.7%	10.3%		20,821
Martin, 2010 (15)	3.0%	62.0%	18.0%	7.0%	6.0%	4.0%	950
Rogers, 2010 (16)	10.0%	74.0%	13.0%	2.9%		0.7%	1204
Merritt, 2012 (2)	18.0%	54.0%	9.3%	12%†	6.5%		1792
Lilly, 2012 (19)	6.4%	65.0%	14.0%	6.1%	5.7%	2.3%	670

*Includes 32 cases treated with "slow-Mohs" (permanent section margin control) for melanoma in situ.
†Includes 0.7% that were porcine xenografts.

(7) (4.3 cm^2) and Merritt (2) (1.9 cm^2) and similar to other reports (15, 19). The types and distribution of wound repairs are summarized in *Table 5* and are in line with the results of multiple previous reports (2, 7, 8, 15–20, 22).

Of the cases reported, 116 (6.3%) were squamous cell carcinoma in situ. The authors could find no other prospective multicenter cohort MMS studies distinguishing squamous cell carcinoma in situ from other tumor types treated. Of these, 97% were primary tumors, 80% were on the face or scalp, and 9% were on the extremities. Leibovitch et al (23) reported a 9-year prospective multicenter case series of all squamous cell carcinoma in situ treated with MMS. Of 270 cases, 49.2% were primary and 93.4% were on the head and neck. Chuang et al (24) reported a single center prospective study of consecutive squamous cell carcinoma in situ tumors treated with MMS. Of 29 cases, 79.3% were on the head and neck and 20.6% were on the extremities. Unlike squamous cell carcinoma and basal cell carcinoma, it is generally recognized that squamous cell carcinoma in situ can often be managed by surgical and nonsurgical modalities other than MMS (25).

Several MMS studies have focused on the frequency of adverse events (1, 2, 4, 9, 15–19). This study's results compare favorably with those of previous reports *(Table 6).* The study's one major complication is comparable to previous reports (1, 2, 7). The study's low infection rate (1.1%) is in line with previous series *(Table 6)* (4, 9, 15, 17–19). The anatomic distribution of infections of face (70%), scalp (15%), neck (5%) and extremities (15%) is similar to other large series (16–18). Tumors >2.1 cm in diameter had a higher infection rate than lesions <1.25 cm

Table 6. Complication rates associated with Mohs surgery: study data versus previous reports

First author, date (ref)	Complications							Number of cases
	Hematoma	Bleeding	Hematoma/ bleeding	Necrosis	Infection	Dehiscence	Impaired healing	
Study data			0.40%	0.50%	1.10%	0.93%		1834
Futoryan, 1995 (18)					2.45%			530
Cook, 2003 (9)	0.50%	0.15%		0.82%	0.07%	0.10%		1343
Maragh, 2008* (17)					0.07%			1115
Martin, 2010 (15)					0.90%			950
Rogers, 2010 (16)					0.91%			1204
Merritt, 2012 (2)	0.17%	1.23%		0.29%	0.94%	0.33%		1792
Elliott, 2012 (4)					0.21%			954
Lilly, 2012 (19)					1.49%			670
Alam, 2013 (1)			0.10%		0.40%		0.14%	20,821

*Mohs surgery and "slow-Mohs" (permanent section margin control) procedures.

(P = 0.01). Merritt (2) reported a greater overall complication rate (not only infections) for tumors >1.6 cm vs. 1.12 cm (P = 0.0001). A nonsignificant trend in increased wound infections in this study was noted with increasing number of MMS stages performed from 2 through 4 stages, yet no cases requiring ≥5 stages developed infections. This may be due to a small sample size of 17 of 1834 cases (0.9%) requiring five or more stages. No data were collected on the use of prophylactic postoperative antibiotics, which might have been used more frequently with tumors requiring ≥5 MMS stages. The overall dehiscence rate of 0.93% was higher than that reported by Cook (0.10%) (9) and Merritt (0.33%) (2).

Limitations in the study include the fact that only 9 Mohs surgeons were evaluated, there was a gender bias with eight males and one female, and there was a bias towards participants in private solo practice. A disproportionate number of cases was submitted by Mohs surgeons with >5000 cases of career experience, and the number of cases submitted by participants varied significantly. Compliance with appropriate use criteria was not assessed. The determination of an infection was left to each surgeon's clinical assessment without the requirement of bacterial culture confirmation.

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