A Prospective Evaluation of the Incidence of Complications Associated With Mohs Micrographic Surgery

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Background: Because outpatient surgery is being increasingly scrutinized in the lay press, it is important that dermatologists and dermatologic surgeons accurately characterize the safety of office-based surgery. Although there is abundant anecdotal evidence to support the inherent safety of dermatologic surgery, there are few data that support the safety of Mohs micrographic surgery (MMS) as performed by appropriately trained dermatologic surgeons in outpatient settings.

Design: All patients presenting for MMS micrographic surgery during the calendar year 2000 were prospectively enrolled in this study designed to evaluate the incidence of multiple complications associated with scalpel-based cutaneous surgery (postoperative hemorrhage, hematoma formation, wound infection, wound dehiscence, and flap/graft necrosis).

Setting: An academic MMS practice.

Patients: A total of 1052 patients (1358 MMS cases) were prospectively enrolled. Complete follow-up information was available for 1343 cases (98.9%).

Results: Complications associated with MMS were very infrequent, with an overall complication incidence of 1.64% (22/1343). Most surgical complications involved difficulties with hemostasis. No complications were significant enough to involve the assistance of another specialist or to require the hospitalization of the patient.

Conclusions: Mohs micrographic surgery is a very safe outpatient procedure when performed by appropriately trained physicians. The types of complications seen in our patients were identical to those seen in hospitalized patients described in previous studies. Our complication rates were equal to or lower than the published complication rates from specialists in other surgical disciplines.

Arch Dermatol. 2003;139:143-152
This year-long study was performed at the Dermatologic Surgery Unit of the Duke University Medical Center, Durham, NC, an outpatient skin cancer treatment center staffed by a single attending physician (J.L.C.). The attending physician’s dermatologic practice is devoted exclusively to MMS and the subsequent reconstructive procedures, we designed a prospective study of the incidence of patient complications occurring in association with MMS as performed in an outpatient treatment center. By thoroughly assessing the safety of these procedures, we hope to begin to offer conclusive evidence to support the appropriateness of skin cancer surgery performed by properly trained dermatologic surgeons in an office-based setting.

METHODS

This year-long study was performed at the Dermatologic Surgery Unit of the Duke University Medical Center, Durham, NC, an outpatient skin cancer treatment center staffed by a single attending physician (J.L.C.). The attending physician’s dermatologic practice is devoted exclusively to MMS and the subsequent repair of surgical wounds. To assess the incidence and nature of complications associated with MMS, all patients undergoing MMS at Duke University from January 1, 2000, to December 31, 2000, were prospectively enrolled in this study, which was approved by the Institutional Review Board of the Duke University Medical Center. No patients were excluded. A single surgeon (J.L.C.) performed all procedures (tumor extirpations and surgical reconstructions). Rotating dermatology residents physicians participated in patient care as surgical assistants, but the attending physician functioned as the primary physician for all patients.

After the completion of each surgical procedure performed during the year, the attending physician (J.L.C.) assessed the incidence of 6 common complications associated with scalpel-based cutaneous surgery: postoperative hemorrhage, hematoma formation, wound dehiscence, wound infection, flap necrosis, and skin graft necrosis. Each surgical procedure was evaluated in the immediate and delayed postoperative periods. The immediate postoperative period was defined as the first 24 hours after completion of the surgery. Complications were considered delayed if they occurred more than 24 hours after the surgical procedure. Follow-up care was provided at suture removal and at subsequent appointments, typically 6 to 8 weeks after tumor extirpation. In those very few cases in which patients returned to local physicians for all follow-up care, we contacted the patients by telephone for an investigation of any associated surgical complications. When a surgical complication occurred in a patient who was unavailable for follow-up care in the Duke University MMS unit, the treating physician’s medical record was also reviewed to assess the nature and the management of the complication.

To standardize the collection of data, we elected to assess the incidence of complications by using carefully defined traditional surgical concepts. We defined postoperative hemorrhage as any occurrence of bleeding that required physician intervention (either at the MMS unit or at another medical facility) to obtain hemostasis. Postoperative bleeding that was controlled by the application of direct pressure by the patient or by a family member was not considered to represent a medically significant postoperative hemorrhage. For the purposes of this study, we defined a hematoma as a rapidly expansive, painful, violaceous mass in the operative field. After hematomas were identified, they were typically explored to confirm the nature and location of the associated hemorrhage. Hemostasis was subsequently achieved, and the wound was resutured. Wound dehiscence was defined as any partial or complete separation of previously approximated wound edges. A surgical wound infection was suspected in patients who exhibited any combination of warmth, erythema, purulent drainage, pain, or unexplained delayed healing of the surgical site. When a suspicion of infection was entertained, appropriate wound cultures were obtained. For this study, wound infection was defined by culture confirmation of a clinically suspected infection. The viability of skin flaps and skin grafts was typically evaluated at the time of suture removal. Skin flap or skin graft necrosis was defined as a partial- or full-thickness loss of tissue viability of any portion of a flap or graft. The clinical appearance of devitalized tissue was often that of a dark, densely adherent eschar. On rare occasions, tissue viability could not be definitively determined at the time of suture removal because the healing flap or skin graft appeared intensely violaceous (but lacked an eschar). In these instances, the sutures were removed, and the skin flap or graft was reevaluated within 2 weeks. The presence of any contour irregularities, textural changes, or alterations in the outline of the predicted scar was then determined to represent some degree of prior skin graft or flap necrosis.

All cases of MMS performed in the dermatologic surgery unit during the study period were recorded in a commercially available database (Microsoft Access; Malachite Corp, Durham, NC) that was designed to be uniquely suitable for MMS practices. Before the initiation of any care, a preoperative consultation with the attending physician was undertaken to determine the appropriateness of the proposed surgical procedure. Unique preoperative information, including medications, medical history, a review of systems, and relevant social and family history, was obtained from all patients, and this information was then entered into the MMS database. Any information that might provide a more accurate prediction of subclinical tumor extension or increased tumor aggression (eg, central facial location, aggressive histologic pattern, or history of previous treatment) was also obtained. Factors that could have contributed to an increased risk of surgical complications (eg, bleeding diatheses, immunosuppression, tobacco abuse, or his-
An individualized operative report was created in the database for each patient on the day of the procedure, with distinct records produced for each surgical site. After the completion of the surgery, the attending physician (J.L.C.) entered details regarding the nature of the surgical procedure into the database. The tumor type (including histologic subtype), tumor location, tumor size, number of stages required for extirpation, size of final surgical defect, type and size of repair, prescribed medications, and information regarding scheduled follow-up care were entered into the database. A separate area of the database was designed to follow the incidence of surgical complications. Information regarding the details of each distinct surgical procedure was imported into the complications area of the database. To assess for the presence of any unanticipated postoperative events, binary (yes/no) radio buttons were present in the database screen for the most common complications of scalpel-based cutaneous surgery. Textboxes were also available for the entry of detailed descriptions of postoperative events or for the recording of unusual occurrences for which radio buttons did not exist.

In an attempt to limit the incidence of surgical complications, several preoperative interventions were performed in all patients undergoing MMS. Using a medical screening questionnaire, the nursing staff identified all patients who used antiplatelet or anticoagulant drugs before their surgical appointments. These patients were asked to consult with their prescribing physicians regarding the appropriateness and safety of perioperative discontinuation of the drug treatment. If the prescribing physicians determined that temporary discontinuation of the drug therapy was medically appropriate, the use of aspirin and warfarin was discontinued for 7 to 10 days and 3 to 4 days, respectively, before surgery. Patients were also asked to limit their intake of vitamin E to less than 400 IU/d for 7 days before surgery. Patients who were taking nonsteroidal anti-inflammatory drugs were asked to stop taking these agents for 3 to 4 times the length of the drug’s half-life before surgery because of their possible effects on platelet aggregation. Patients were instructed to resume taking these medications approximately 2 days after undergoing MMS. In a further attempt to limit postoperative hemorrhage, meticulous intraoperative hemostasis was achieved with the use of an electrosurgery apparatus. Conventional pressure dressings were used in all patients after surgery. Pressure dressings were not considered to be an adequate substitute for intraoperative hemostasis because pressure provided by these dressings has been shown to rapidly decrease with time. Pressure dressings were constructed with a layer of nonadherent material (Telfa; Tyco Healthcare, Mansfield, Mass) overlaid by absorbent cotton gauze and a water-vapor-permeable, high–tensile-strength adhesive tape (Hypafix; BSN Medical, Hamburg, Germany). To minimize the likelihood of postoperative bleeding and swelling, patients were urged to limit strenuous activity for several days after the procedure. Absorbable gelatin sponge dressings (Gelfoam; Pharmacia & Upjohn, Kalamazoo, Mich) were applied postoperatively to selected sites (such as the conchal bowl) deemed to be at high risk for hemorrhage.

Selected interventions were also taken to minimize the risk of postoperative wound infections. The Mohs extirpation of all tumors was performed in a clean environment. Tumor removal was performed with sterile instruments, a sterile paper drape, and clean (nonsterile) surgical gloves. The surgeon, nurses, and assistants wore surgical masks. Patients were bandaged with clean, dry dressings between surgical stages. After tumor removal, reconstructive procedures were performed with strict adherence to sterile technique by the use of an appropri-
ate scrub preparation of the surgical site, sterile surgical gloves, and sterile instruments. All repairs were done in a treatment room dedicated solely to the sterile performance of reconstructive procedures (though not a room certified by the Accreditation Association for Ambulatory Health Care, Wilmette, Ill).

The American Heart Association’s recent recommendations for the prevention of bacterial endocarditis were used to determine the necessity of prophylactic (preoperative) antibiotic therapy. Given the rather narrow range of structural heart lesions requiring antibiotic prophylaxis, relatively few patients required preoperative antibiotics. Empiric antibiotics (antibiotics administered postoperatively when the risk of a wound infection was determined to be significant), however, were frequently prescribed. All patients who underwent a flap or graft repair were given an antistaphylococcal cephalosporin for 7 days after surgery. Also, a postoperative cephalosporin was prescribed if the location of the surgical procedure was in the axilla or groin, as these sites have been considered to have a higher risk of wound contamination. Areas with a high density of sebaceous glands (eg, the nose) have been shown to have high levels of aerobic gram-positive cocci and Propionibacterium acnes. Because colonization with these bacteria may be considered a potential marker for other, more clinically relevant organisms, the very sebaceous nose was also considered to represent a site with a higher likelihood of surgical wound infection, and patients with wounds on sebaceous noses were also given antibiotics after surgery. Penicillin-allergic patients were given either clindamycin hydrochloride or azithromycin dihydrate. If the integrity of the auricular perichondrium was compromised, a 7-day course of ciprofloxacin was used to minimize the risk of Pseudomonas-associated chondritis. This precaution was also taken because surgical procedures on the ear have been shown to be more frequently complicated by wound infections that could conceivably lead to chondritis. Patients healing by secondary intention or with linear repairs on nonhair-bearing skin did not receive empiric antibiotic therapy.

To minimize the risk of tissue ischemia, appropriate surgical planning was considered to be critically important. Delicate operative technique was also used to lessen the chance of tissue necrosis. Bolster dressings were not used for skin graft repairs, as data have suggested that they may not be necessary to secure full-thickness skin grafts to reduce the chance of graft necrosis. Also, attention was given to the previously reported adverse relationship between tobacco use and the outcome of cutaneous surgical procedures. To minimize the potential development of tissue necrosis in our patients, we requested that patients limit cigarette smoking and the use of other tobacco products for 1 week before surgery and for the immediate postoperative period (1-2 weeks). Predictably, patients rarely complied with suggestions to abstain from the use of tobacco.

To minimize the incidence of anesthesia-associated postoperative complications, all MMS cases were performed exclusively under local anesthesia, typically 1% lidocaine hydrochloride with epinephrine. No patients were sedated with intravenous medications, and no routine patient monitoring (other than preoperative and postoperative vital signs) was undertaken. Oral anxiolytics (benzodiazepines) were frequently used, but they were occasionally required for the management of preoperative anxiety. When benzodiazepines were used, the doses were small and not associated with patient sedation.

After the completion of all surgical procedures, the patients were given wound care instructions tailored to the type of repair they received. Both verbal and written wound care instructions were provided. Generalized instructions included retention of the original dressing until the morning after the surgery and wound cleaning with hydrogen peroxide or saline 3 to 4 times daily, followed by the application of an antibiotic or petrolatum ointment and a nonstick dressing. The patients were instructed to follow wound care guidelines until suture removal. Suture removal was performed between 5 and 14 days after surgery, depending on the surgical site and type of repair.

The vast majority of patients were scheduled for postoperative suture removal and follow-up care in the MMS unit. A distinct minority of patients were seen by a referring physician for suture removal and follow-up care. Follow-up care was deferred to the referring physician only if the patient lived a great distance from Duke University or had transportation difficulties. In the infrequent event that the patient returned to a referring physician for all postoperative care, the patient or the referring physician was contacted to ensure that adequate follow-up data had been obtained.

The primary surgeon was made aware of all complications by the patients, rather than by an answering service or an on-call resident physician. The patients were given clear, written instructions that described several means of contacting the attending physician after routine clinic hours. Attending physician availability to patients in the postoperative period was nearly continuous; therefore, the likelihood that any surgical complications remained unreported was quite low. In the very uncommon event that the attending physician was unavailable, patients were referred to a dermatology resident physician or a plastic surgery attending physician. The senior author (J.L.C.) subsequently discussed any patient complications with these physicians.

Patients who experienced symptomatic postoperative complications contacted the attending physician directly, and appropriate management was immediately undertaken. The presence of a hematoma, postoperative hemorrhage, wound dehiscence, or other adverse event on the day of surgery was recorded using the database system. When possible, all patients were returned to the surgical unit for treatment of their day-of-surgery complication. At the time of suture removal or at a later postoperative follow-up visit, additional information regarding hematoma development, delayed postoperative hemorrhage, wound dehiscence, wound infection, and flap or graft failure was also entered into the unique database.

RESULTS

All patients presenting to Duke University’s MMS unit during the calendar year 2000 (n = 1052) were prospectively enrolled for this evaluation of the incidence of surgical complications, including postoperative hemorrhage, hematoma formation, wound dehiscence, wound infection, and flap/graft necrosis. These patients accounted for 1358 MMS procedures, 1261 (92.86%) of which represented referrals to Duke University for consideration of MMS. The remaining 97 surgical cases (7.14%) were generated from the senior author’s continuity clinic. Complete follow-up information was available for 1343 (98.9%) of the 1358 cases; 14 patients (15 surgical cases, 1.1%) were unavailable for follow-up. Multiple attempts to contact these patients by telephone were unsuccessful. Cases that were unavailable for follow-up were representative of the entire study group, with a variety of tumor types, number of surgical stages, wound sizes, and repair strategies represented.

The ages of the 1052 patients ranged from 24 to 96 years, with a mean age of 64.6 years. Six hundred twenty-five patients were representative of the entire study group, with a variety of tumor types, number of surgical stages, wound sizes, and repair strategies represented.
Table 1. Locations and Types of Treated Tumors

<table>
<thead>
<tr>
<th>Location</th>
<th>Tumor Location or Type</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face (not nose, ear, lip, eyelid)</td>
<td>Merkel cell carcinoma</td>
<td>1</td>
</tr>
<tr>
<td>Nose</td>
<td>Basal cell carcinoma</td>
<td>927</td>
</tr>
<tr>
<td>Ear</td>
<td>Squamous cell carcinoma</td>
<td>391</td>
</tr>
<tr>
<td>Lip</td>
<td>Basosquamous cell carcinoma</td>
<td>16</td>
</tr>
<tr>
<td>Eyelid</td>
<td>Keratoacanthoma</td>
<td>5</td>
</tr>
<tr>
<td>Scalp</td>
<td>Lentigo maligna</td>
<td>4</td>
</tr>
<tr>
<td>Neck</td>
<td>Dermatofibrosarcoma protuberans</td>
<td>3</td>
</tr>
<tr>
<td>Trunk</td>
<td>Atypical fibroxanthoma</td>
<td>2</td>
</tr>
<tr>
<td>Extremity (not hand or foot)</td>
<td>Appendageal tumor</td>
<td>2</td>
</tr>
<tr>
<td>Hand</td>
<td>Extramammary Paget disease</td>
<td>2</td>
</tr>
<tr>
<td>Genitalia</td>
<td>Sebaceous carcinoma</td>
<td>2</td>
</tr>
<tr>
<td>Foot</td>
<td>Cutaneous leiomyosarcoma</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Malignant granular cell tumor</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Merkel cell carcinoma</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Trichilemmal carcinoma</td>
<td>1</td>
</tr>
</tbody>
</table>

*Both primary and recurrent tumors included.

Of the 1358 surgical cases, 1014 (74.67%) were reconstructed immediately after tumor extirpation. The reconstructive modalities used included simple and complex linear closures, full- and split-thickness skin grafts, and a variety of random and axial patterned cutaneous flaps (Table 2). Complete data regarding the incidence of complications were available for 1343 (98.9%) of the 1358 cases. It is these 1343 cases that are further examined in this study.

Postoperative complications that were evaluated included events that occurred on the day of surgery (hematoma formation, postoperative hemorrhage, and wound dehiscence) and events that occurred in the later postoperative periods (hematoma formation, postoperative hemorrhage, wound dehiscence, wound infection, flap failure, and graft failure). A total of 22 surgical complications were identified (Table 3). The overall complication rate was 1.64% (22/1343). Surgical wound infection and wound dehiscence were particularly uncommon, with only a single incident of each complication identified. The majority of complications in both the immediate and the delayed postoperative periods involved difficulties with hemostasis. The MMS procedures were well tolerated by all patients, and there were no complications that required hospitalization of the patient or consultation with another physician.

Four complications (0.30%) developed on the day of surgery. One patient experienced postoperative hemorrhage, and 3 patients developed hematomas. Eighteen patients (1.34%) experienced a delayed surgical complication. These 18 complications included 6 episodes of partial or total full-thickness skin graft necrosis, 5 cases of distal flap necrosis, 4 instances of hematoma formation, and a single occurrence each of delayed hemorrhage, wound infection, and partial wound dehiscence.

To determine if there were any common characteristics among patients who demonstrated surgical complications, we further examined all complications occurring in both the immediate and the delayed postoperative periods. Two episodes of postoperative hemorrhage requiring physician intervention (0.15%) occurred, one on the day of surgery and one during the week following MMS. The hemorrhage that occurred on the day of surgery developed in a patient with hypertension who elected to allow a conchal bowl wound to heal by secondary intention. When simple compression did not provide sufficient hemostasis, the patient appropriately sought medical attention. Because of geographic constraints, the patient was seen by a local physician for control of hemorrhage. The patient had stopped taking his daily aspirin 6 days before surgery, rather than the recommended 7 to 10 days. The significance of this shorter-than-ideal discontinuance of aspirin use is unknown, although it is likely to be minimal. The patient’s hypertension may have been an additional risk factor in the development of postoperative bleeding; however, this is also of unclear significance in this case, as the patient’s hypertension was well controlled on the day of the surgical procedure. The single case of delayed hemorrhage occurred at a skin graft donor site on the preauricular area of the cheek 2 days after surgery. The hemorrhage was controlled with the placement of several interrupted epidermal sutures. The patient involved had discontinued his use of daily aspirin 7 days before surgery; however, he had continued the use of clopidogrel bisulfate (Plavix) during the perioperative period. Clopidogrel has been shown to increase the bleeding time, and it has been associated with postoperative hemorrhage. The patient also had a history of hypertension, but no other risk factors for bleeding were identified.

Seven hematomas developed following MMS: 3 patients (0.22%) returned to the MMS unit with hematomas on the day of surgery, and 4 patients (0.30%) presented with hematomas at the suture removal visit. The hematomas identified at the time of suture removal were ones that had clearly developed early in the postoperative period, but for which the patients failed to seek more immediate medical attention. Each patient was seen in the surgical unit for appropriate treatment of the hematoma. Hematomas detected on the day of surgery were drained and irrigated, and the wounds were sub-
suspended. Two of the 4 patients had a history of hyper-
tension. No other risk factors for bleeding were identi-
fied on the day of surgery had any identifiable risk factors for postoperative hemorrhage other than hypertension.

Of the 4 hematomas discovered in the late postoperative period (at the time of suture removal or at the follow-up appointment), 3 involved wounds that were re-
paired with linear layered closures (2 on the cheek, 1 on the clavicle), and 1 was located under a rotation flap (temple). Hematomas detected at the time of suture removal were treated with simple observation and occa-
sional aspiration. One of the 4 patients with hematomas had discontinued his daily aspirin therapy only 2 days before surgery. Another patient was taking daily warfa-
rin and aspirin; however, the patient did not indicate whether use of the medications had been temporarily suspended. Two of the 4 patients had a history of hyper-
tension. No other risk factors for bleeding were identi-
fiable in any of these 4 patients. The wounds of all 4 pa-
tients with hematomas that were discovered at the time of suture removal eventually healed without further complications, and the hematomas did not have signifi-
cantly adverse influences on the final appearances of the surgical sites.

Among the 1358 MMG cases, a total of 1014 wounds were repaired in the dermatologic surgery unit. Two-
hundred sixty-two wounds were allowed to heal by sec-
ondary intention, and 92 underwent reconstruction by consultative surgeons. Seven repaired wounds occurred among the 15 patients who were unavailable for follow-
-up. Among the 1007 repaired cases for which complete follow-up data were available, 1 patient (0.10%) suf-
f ered a partial central wound dehiscence. The dehisced wound was a large (12-cm), clavicular, layered, linear closure under moderately high wound tension. The patient was noncompliant with physician instructions to rest for several days after surgery, and he elected to participate in extremely vigorous physical activity (rowing) the day after his surgical procedure. Not surprisingly, the low wound tensile strength of his nascent repair did not sup-
port such vigorous activity, and a 4- to 5-mm area of cen-
tral wound dehiscence was detected at the time of su-
ture removal. The wound granulated unevenly after suture removal.

A postoperative wound infection occurred in a single case (1/1343, or 0.07%). The infection involved a large scalp wound that was covered with a porcine xenograft following partial purse-string closure. The patient had not been provided with empiric antibiotics. At a fol-
low-up visit 10 days after surgery, purulent debris was noted under the porcine xenograft. After appropriate micro-
bial cultures were obtained, oral cephalaxin therapy (500 mg 3 times a day) was initiated. A bacterial culture confirmed the clinical suspicion of infection, demon-
strating growth of methicillin-resistant *Staphylococcus au-
reus* and nonhemolytic *Streptococcus* (a probable contaminant). The patient’s antibiotic regimen was changed to trimethoprim-sulfamethoxazole when the re-
sults of susceptibility testing revealed that drug to be more appropriate. The clinical infection resolved with a 1-week course of antibiotics, and the wound healed without fur-
ther complications.

Flap and skin graft necrosis was defined as full- or partial-thickness tissue loss of any portion of a flap or graft. One observer (J.L.C.) visually estimated the sur-
face area of necrotic involvement for each involved flap or skin graft. Typically, tissue necrosis was manifested as the presence of an eschar at the site of the skin graft or at the distal end of a flap. Because the depth of tissue necrosis could not be reliably identified by visual inspection, flaps and grafts with adherent eschars were not debrided. Patients were encouraged to continue conserva-
tive wound care to allow subsequent secondary-
intention healing. Overall, some degree of necrosis was seen in 11 (1.9%) of 578 full-thickness skin grafts, split-
thickness skin grafts, and cutaneous flaps.

A total of 362 flap reconstructions were per-
fomed, and complete follow-up information was avail-
able for 361 flaps (99.7%) (1 patient with a medial canthal advancement flap was unavailable for follow-up). A wide variety of flaps were used during the year 2000.

Table 2. Flap Types Used in Reconstruction

<table>
<thead>
<tr>
<th>Type of Flap</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advancement</td>
<td>80</td>
</tr>
<tr>
<td>Rhombic transposition</td>
<td>79</td>
</tr>
<tr>
<td>Island pedicle</td>
<td>46</td>
</tr>
<tr>
<td>Bilobed transposition</td>
<td>40</td>
</tr>
<tr>
<td>Rotation</td>
<td>39</td>
</tr>
<tr>
<td>Dorsal nasal rotation (Rieger)</td>
<td>13</td>
</tr>
<tr>
<td>Nasolabial transposition</td>
<td>10</td>
</tr>
<tr>
<td>Perialar crescentic advancement</td>
<td>10</td>
</tr>
<tr>
<td>Dog-ear rotation</td>
<td>9</td>
</tr>
<tr>
<td>Chondrocutaneous advancement</td>
<td>7</td>
</tr>
<tr>
<td>Pedicled nasolabial interposition</td>
<td>6</td>
</tr>
<tr>
<td>Nasolabial transposition with cartilage graft</td>
<td>5</td>
</tr>
<tr>
<td>O-T rotation</td>
<td>5</td>
</tr>
<tr>
<td>Pedicled mastoid advancement</td>
<td>4</td>
</tr>
<tr>
<td>O-Z rotation</td>
<td>3</td>
</tr>
<tr>
<td>Mucosal advancement</td>
<td>2</td>
</tr>
<tr>
<td>Paramedian forehead</td>
<td>2</td>
</tr>
<tr>
<td>Bilateral advancement</td>
<td>1</td>
</tr>
<tr>
<td>Bipedicled advancement</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3. Complications on the Day of Surgery and Delayed Complications

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. (%) of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hematoma formation</td>
<td>3/1343 (0.22)</td>
</tr>
<tr>
<td>Postoperative hemorrhage</td>
<td>1/1343 (0.07)</td>
</tr>
<tr>
<td>Total</td>
<td>4/1343 (0.30)</td>
</tr>
<tr>
<td>Delayed</td>
<td></td>
</tr>
<tr>
<td>Graft necrosis</td>
<td>6/216 (2.78)</td>
</tr>
<tr>
<td>Flap necrosis</td>
<td>5/361 (1.40)</td>
</tr>
<tr>
<td>Hematoma formation</td>
<td>4/1343 (0.30)</td>
</tr>
<tr>
<td>Postoperative hemorrhage</td>
<td>1/1343 (0.07)</td>
</tr>
<tr>
<td>Postoperative infection</td>
<td>1/1343 (0.07)</td>
</tr>
<tr>
<td>Wound dehiscence</td>
<td>1/1007 (0.10)</td>
</tr>
<tr>
<td>Total</td>
<td>18/1343 (1.34)</td>
</tr>
</tbody>
</table>

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Five (1.4%) of the 361 flaps showed evidence of distal necrosis at the patients’ return visits: 1 rhombic transposition flap on the temple, 1 bilobed transposition flap on the nose, 2 advancement flaps (1 on the cheek and 1 on the neck), and 1 pedicled nasolabial interpolation flap. All patients with flap failure had taken a daily aspirin, with temporary suspension of the medication during the perioperative period. The significance of this association is unclear.

A total of 205 full-thickness and 11 split-thickness skin graft reconstructions were performed, with 6 grafts showing evidence of partial or complete necrosis (6/216, or 2.78%). Of these 6 failed grafts (all full-thickness grafts), 3 were placed on the ear, and 3 were placed on the nose. In 2 of the 6 cases, exposed cartilage was present beneath the full-thickness skin grafts, and perfusion of these grafts was therefore less than ideal. However, these patients had refused recommended flap repairs because of their concerns regarding the possibility of increased surgical morbidity associated with more involved flap reconstructions. Three of the 6 cases of graft necrosis resulted in significant graft failure (>75% graft loss). All wounds created by failed grafts were allowed to heal by secondary intention. These wounds subsequently granulated uneventfully, although the final aesthetic appearances of the wounds were compromised by the grafts’ failures.

COMMENT

To our knowledge, this is the first comprehensive, prospective study to evaluate the incidence of numerous complications associated with MMS as performed in the outpatient setting. The recent barrage of criticism in the popular media directed toward outpatient surgery has made the determination of patient safety vital to the preservation of the abilities of dermatologic surgeons to continue their office-based practices. This study demonstrated the extreme safety of appropriately performed MMS.

It is not sufficient simply to report that appropriately trained dermatologic surgeons can safely perform MMS. To counter suggestions that dermatologists should limit their use of office-based surgery, it is imperative that Mohs surgeons compare their complication rates with those of other specialists performing similar tumor excision and wound reconstruction procedures. While we realize that direct comparisons between our results and the results of other specialists are inherently difficult and that many study discrepancies likely exist, we generally agree that all physicians performing cutaneous surgery have inadequately examined the incidence of surgical complications associated with the use of these procedures. Although there are abundant anecdotal suggestions that the types of procedures performed by typical Mohs surgeons are undeniably safe, there is a surprising paucity of available published data concerning the safety of many commonly performed outpatient procedures, including those performed by dermatologic surgeons.

From a plastic surgery perspective, Smyth19 prospectively studied 134 patients who underwent excision of facial lesions. Among other clinical observations, Smyth evaluated the incidence of various surgical complications in 136 cases. The procedures were performed in an inpatient setting with local or general anesthesia, and they involved excisions of both benign and malignant lesions. Repair methods included direct closure (n=77), flaps (n=40), and split- (n=9) thickness skin grafts. A total of 8 complications (6%) occurred, including wound infection (n=4), hematoma formation (n=2), partial flap necrosis (n=1), and complete split-thickness skin graft failure (n=1). Potentially clinically relevant details concerning risk factors for the development of surgical complications were not provided.19

Because the cases in Smyth’s study involved hospitalized patients, it is possible that they were inherently more difficult than those in our study; nonetheless, we believe that it is important to recognize that the incidence of complications among our patients was also very low. Furthermore, the types of surgical complications observed in our outpatient setting were identical to those observed in Smyth’s hospitalized surgical patients. Our complication rates are likely equal to or lower than those of specialists in other disciplines, but direct comparisons of such highly varied studies are obviously difficult.

In the dermatologic literature, Otley et al20 retrospectively reviewed postoperative complications (excluding wound infection) in 653 patients who underwent either MMS or excisional surgery. Their primary intent was to determine the effects of anticoagulant and antiplatelet medications on the incidence of postoperative complications. They defined surgical complications as mild, moderate, or severe. Complications that were described as mild in Otley and colleagues’ study (eg, ecchymosis and crusting) would not have been identified by our study, and they are therefore excluded from this discussion. Moderate complications in Otley and co-workers’ study included dehiscence (<2 mm), serous oozing for more than 24 hours, and superficial slough of the flap or graft. Severe intraoperative or postoperative bleeding, bleeding for more than 1 hour (that could not be stopped with direct pressure), hematoma formation, flap or graft necrosis, and wound dehiscence of more than 2 mm were considered severe complications. Twenty-five moderate or severe complications occurred in 546 patients (patients both taking and not taking anticoagulant and antiplatelet medications) who underwent MMS, yielding a complication rate of 4.58%.20 Their study is important because it began the arduous process of demonstrating that complications seen by dermatologists performing cutaneous surgery can certainly be as infrequent as those seen by other physicians performing similar procedures. Our current large-volume study of the incidence of complications associated with MMS confirms the inherent safety of this procedure when it is performed by appropriately trained physicians.

As previously mentioned, the majority of surgical complications identified in our patients involved postoperative hemorrhage. Because clinical experience has demonstrated that the majority of complications associated with dermatologic, scalpel-based surgery involve difficulties with hemostasis, we prospectively limited our
patients' use of anticoagulant and antiplatelet medications, theoretically to lower the risk of postoperative hemorrhage. However, there has been recent debate in the dermatologic surgery community regarding the appropriateness of the perioperative suspension of the use of warfarin, aspirin, and other antiplatelet medications in patients undergoing dermatologic surgery. Well-described cases of thrombotic complications (including strokes) in patients who have temporarily discontinued anticoagulation therapy in the perioperative period have recently been published.

In light of these recent case reports, we are reconsidering our current practice of discontinuing the use of these medications in our patients prior to MMS, despite the fact that by doing so, the patients might theoretically experience more postoperative bleeding complications. We are unaware of any thrombotic complications associated with the perioperative discontinuation of anticoagulant or antiplatelet therapy in the patients who were included in the present study; however, we did not specifically inquire about the incidence of thrombotic complications in each patient. The study of Otley et al\(^{20}\) suggests, however, that the perioperative suspension of the use of warfarin, aspirin, or nonsteroidal anti-inflammatory medications is not associated with a significant reduction in the incidence of serious surgical complications.

Some additional data regarding the incidence of bleeding complications associated with MMS are available from Billingsley and Maloney's\(^{22}\) prospective evaluation of the incidence of bleeding complications in MMS cases involving patients who were taking warfarin, aspirin, or other nonsteroidal anti-inflammatory drugs. Several subsets of patients were excluded from their study (eg, patients with bleeding diatheses or unclear medication histories), and bleeding complications were detected in 8 (2.5%) of 322 total patients. Again, no statistically significant difference in the incidence of postoperative complications was detected when patients who were taking anticoagulant and antiplatelet medications were compared with controls. These 2 studies\(^{20,22}\) have initiated a continuing debate in the dermatologic surgery community regarding the appropriateness of perioperative discontinuation of the use of antithrombotic medications.

To determine if our flap and graft necrosis rate was comparable to that of other office- and hospital-based specialists, we again attempted to extract meaningful data from the available medical literature. Within our own specialty, the rates of flap and full-thickness skin graft tissue necrosis have not been adequately assessed in large prospective trials. There are several published studies that examine the necrosis rates of particular flaps (such as the bilobed\(^{23}\) or the nasolabial transposition\(^{24}\) flap); however, there have been few large studies of failure rates of a broad selection of flaps and grafts published in the dermatology literature. Despite these limitations, some meaningful data can be extracted from several previously published studies involving dermatologic surgeons and other physicians. Most prior studies were designed to evaluate the influence of independent risk factors (such as smoking and application of topical medications) on the viability of cutaneous flaps and grafts. Even so, we attempted to gather some data regarding the incidence of tissue necrosis by examining both the cohort and the control groups of these previous studies.

Several studies examining the complication rates of cutaneous surgery have frequently examined the potential adverse role of tobacco use on tissue survival and wound healing. Smoking may be an important risk factor in undesired outcomes of cutaneous surgery. Otolaryngologists performed a retrospective study of patients who underwent reconstruction of facial defects with skin flaps and sought to determine the potential effects of smoking on surgical complication rates.\(^{25}\) The majority of the patients involved had tumors extracted using the Mohs technique, and the patients subsequently underwent repair by an otolaryngologist. One hundred eight consecutive patients were eligible for the study; however, 12 were excluded because of the presence of comorbidities that might negatively impact wound healing (eg, diabetes mellitus or previous radiation treatment). Five more patients did not have adequate follow-up, leaving 91 patients. Axial-patterned flaps were performed in 39 patients, and random-patterned flaps were used in 52 cases. Surgical complications assessed in the study included tissue necrosis and cyanosis, cellulitis, and hematoma/seroma formation. A total of 23 complications (25%) occurred, with an increased incidence of complications in smokers (37%) compared with nonsmokers (17%). The rate of partial- or full-thickness skin flap necrosis was 12.1% (11/91).\(^{25}\) The patients who were included in the otolaryngologists' study may differ substantially from the cohort examined in our current study. Because of the involvement of an operating room–based surgical colleague, it is possible that these wounds differed in size and complexity from typical Mohs surgical wounds. These potential discrepancies may unfairly bias the results of the otolaryngology-based study,\(^{22}\) as the authors demonstrated an increased likelihood of complications associated with larger flap surface areas. Because wounds closed by Mohs surgeons in office-based practices might conceivably be smaller and less complicated than the wounds closed by otolaryngologists, lower complication rates might be expected.

In the dermatologic literature, Goldminz and Bennett\(^{26}\) reported on a retrospective study that evaluated the effects of cigarette smoking on tissue survival in wounds repaired after Mohs extirpations. In their smoking and nonsmoking patients, they found some degree of tissue necrosis in 44 (4.8%) of 916 flaps and full-thickness grafts performed during a 10-year period. Each of the patients with evidence of necrosis was age and gender matched with controls to determine the possible effects of tobacco abuse on flap or graft viability. Heavy smokers (1 or more packs per day) developed tissue necrosis at a rate that was approximately 3-fold higher than that of controls. Former smokers and lighter smokers did not have a statistically significant difference in the risk of developing tissue necrosis compared with patients who had never smoked.\(^{26}\) Interestingly, the flap and graft necrosis rate (4.8%) in Goldminz and Bennett's study was higher than the rate (1.9%) seen in our current study. The reason for our lower flap and graft complication rate cannot be determined from a review of Goldminz and
Bennett’s article. In any event, both studies offer evidence of the inherent safety of skin cancer surgery as practiced by Mohs surgeons. Dunn et al defined a prospective, double-blind trial of the efficacy of a single postoperative application of 2% nitroglycerin ointment in the prevention of tissue necrosis; their study also provides some comparison data. Only flap and graft failures were tallied; no other postoperative complications were reported. A total of 173 flap and skin graft repairs after MMS were included in the study. All skin grafts were secured with bolster dressings. Some degree of tissue necrosis developed in 18 (10.4%) of the 173 cases. Of the 85 patients in the control group (those who did not receive topical nitroglycerin), 7 (8%) developed tissue necrosis. Skin graft necrosis was seen in 4 (6%) of 64 control-group grafts in the study. Flap necrosis was seen in 3 (14%) of 21 control cases, all of which exhibited only tip necrosis (this figure was calculated from available data in the article). A total of 38 flaps were performed in the study, with 3 instances of some degree of tissue necrosis (8%) (this figure was also calculated from data available in the article). Why the rate of tissue necrosis in our study was lower than the rate demonstrated in Dunn and colleagues’ study is unclear; however, their small study size may be inadequate for meaningful comparison.

A modest amount of literature is available regarding the characterization of wound infections associated with dermatologic surgery. One retrospective review sought to determine the wound infection rate in general dermatologic surgery. A total of 1047 dermatologic surgery cases, of which 530 were Mohs procedures, were reviewed. A total of 24 infections (2.3%) were recorded (13 [2.5%] after a Mohs procedure). Patients who took prophylactic antibiotics were excluded from the study; however, figures denoting the number of patients receiving empiric (postoperative) antibiotics were not provided. The wound infection rate demonstrated in our study is well within the acceptable guidelines for operative procedures. Clean procedures are those that use a total aseptic technique. Acceptable rates of wound infection for clean procedures are between 1% and 3%. Clean contaminated procedures are those with minor breaks in aseptic technique. The Mohs extirpation of cutaneous tumors as performed in this study is more correctly classified as a clean contaminated procedure, for which acceptable infection rates are 5% to 15%. Our policy of giving empiric antibiotics to all patients with flap or graft repairs or with repairs on rhinophymatous skin produced a very low incidence of infection, but it should also be noted that many of our patients who underwent cutaneous surgery but who were not provided with postoperative antibiotics also had an amazingly low incidence of clinically apparent wound infections. In view of the low incidences of wound infections demonstrated in previous studies and in our current work, we strongly suggest that the closely protected sterility of an operating room environment is not required for the safe use of MMS and the subsequent reconstructive procedures.

In comparison to the available medical literature examining the incidence of complications associated with cutaneous surgical procedures, the present study demonstrates that MMS (at least as practiced in our setting) offers the patient exquisite safety despite the fact that the procedure is performed in an outpatient setting. Whether our data can be extrapolated to other MMS practices remains to be determined. Like any other surgical procedure, MMS requires appropriate training and experience, and it comes as no surprise that other surgical specialties have demonstrated crucial differences between high- and low-volume practices. For example, it has been shown that the incidence of complications associated with coronary artery bypass grafting surgical procedures is lower at centers that perform higher numbers of these procedures. For that reason, additional, confirmatory studies examining complications associated with MMS need to be performed at a variety of surgical centers involving several different physicians. Particular attention should be paid in any future studies to including lower-volume MMS practices.

The limitations of this study are easily apparent. Because the MMS unit at Duke University is a single-physician practice, the senior author (J.L.C.) both performed all procedures and evaluated all complications. This method obviously introduces bias, but we elected to examine well-defined, easily identifiable surgical complications in order to eliminate the ambiguity associated with assessing other complications, such as the quality of the aesthetic outcome. Ideally, a separate physician would have examined the patients for the presence of any surgical complications, but this was not possible in our practice setting.

Mohs micrographic surgery has previously been well established as a scientifically valid, therapeutically efficacious, and cost-effective treatment of nonmelanoma skin cancer. Evaluation of 1358 consecutive cases in the Duke University MMS unit revealed a low incidence of surgical complications (1.6%). The complication rates published herein are equal to or lower than those published in reports on similar procedures performed by other surgical specialists. In our opinion, MMS properly belongs in an outpatient setting because of the extremely low incidence of surgical complications as documented in the present study. By safely providing skin cancer surgery in the outpatient setting, dermatologic surgeons are appropriately positioned to deliver high-quality care in cost-competitive outpatient facilities. According to data from the Centers for Medicare & Medicaid Services (previously known as the Health Care Financing Administration, Baltimore, Md), dermatologists performed more excisions of benign and malignant skin lesions, MMS procedures, complex layered repairs, and even adjacent tissue transfer (flap) procedures than any other specialty group during 1999. Dermatologists and dermatologic surgeons are already providing care for the majority of patients with skin cancer in the United States. With such experience and knowledge, dermatologists are particularly well suited for this clinical responsibility. Any efforts to limit the use of outpatient facilities will have enormous ramifications on Medicare’s spending for the treatment of nonmelanoma skin cancer. Dermatologic surgery has grown in popularity and in stature during the past several decades, and the continued flourishing of the subspecialty can be assured only by appropriate ex-
amination of the safety and successes of our surgical procedures. Only then can dermatologic surgeons bolster their arguments that current legislative efforts to severely limit the practice of outpatient surgery are emotionally and financially, rather than scientifically, based.

Accepted for publication June 11, 2002.

This work was presented at the Second Annual Combined Meeting of the American Society for Dermatologic Surgery and the American College of Mohs Micrographic Surgery and Cutaneous Oncology, Dallas, Tex, October 27, 2001.

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