FEATURE ARTICLE

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Mohs Micrographic Surgery

A Guide for Dermatology Nurses

Nicole Mastacouris and Mariam Mafee

ABSTRACT: Mohs micrographic surgery is a specialized surgical technique that involves serial excision of locally invasive, recurrent, or ill-defined skin cancers with complete histological examination of surgical margins. Originally developed by Dr. Frederic E. Mohs in the 1930s, it began as in situ tissue fixation with zinc chloride and healing by secondary intention and has evolved to fresh tissue surgical excision with subsequent reconstruction. Despite continuous advancements made in the field, the underlying principle of Mohs surgery remains the same: one surgeon acting as a pathologist to ensure complete tumor removal while minimizing the resection of healthy tissue. Mohs surgery is considered the gold standard for treatment of various cutaneous tumors and can be performed on an outpatient basis within a single day. The tumor is excised, mapped, and processed with frozen, horizontal sections for immediate histological evaluation and subsequent surgical staging in the location of a positive margin. This article serves as a review of Mohs surgery for dermatology nurses and offers an overview of the history of the procedure, clinical indications, preoperative assessments, surgical technique, reconstructive modalities, and postoperative care.

Key words: Mohs Micrographic Surgery, Frederic E. Mohs, Skin Cancer Treatment, Reconstruction, Basal Cell Carcinoma, Squamous Cell Carcinoma

Mohs micrographic surgery (MMS) was developed by Dr. Frederic E. Mohs in the 1930s at the University of Wisconsin-Madison (Broadland, 2000). While studying the effects of various chemical injections on cancer in rats, Dr. Mohs observed that tissues treated with zinc chloride yielded exceptional preservation of histological structure under the microscope (Brodland et al., 2000). This important finding laid the foundation for the practice of chemosurgery, a technique characterized by chemical in situ fixation and subsequent surgical excision to remove cancerous neoplasms in a controlled, serial manner (Brodland et al., 2000). The original fixed-tissue technique involved the application of zinc chloride paste to cancerous tissue 24 hours prior to the first excision specimen (Brodland et al., 2000). The first layer was taken the following day and processed using standard paraffin sections (Brodland et al., 2000). The presence of a positive margin led to additional rounds of treatment until complete tumor clearance was attained.

Dr. Mohs started treating patients with chemosurgery in 1936 and published his findings in the *Archives of Surgery* in 1941 (Mohs, 1941). His initial article reported 440 skin cancers treated with the technique at a 93% cure rate (Mohs, 1941). Despite facing skepticism from his general surgery colleagues, he persisted in his technique and captured the interest of dermatologists at the American Academy of Dermatology meeting in 1946 (Trost & Bailin, 2011). Eventually, the medical community became more accepting as additional data validated high cure rates and reports demonstrated acceptable aesthetic results from healing by secondary intention (Trost & Bailin, 2011).

Dr. Mohs began to alter his method in 1951, when his trainee Dr. R. R. Allington demonstrated his technique for first debulking a cancer and then using dichloroacetic acid to achieve hemostasis (Brodland et al., 2000). While filming an instructional video of the removal of a pigmented basal cell carcinoma (BCC) of the lower eyelid, Dr. Mohs successfully used local anesthesia without any chemical fixation to save time, a process known as the fresh-tissue technique (Brodland et al., 2000). This modification yielded improved efficiency and comparable efficacy, further inspiring Dr. Mohs to more broadly implement this methodology for the treatment of skin cancers of the eyelid.

The fresh-tissue technique gained additional popularity and acceptance through the work of dermatologists Dr. Theodore Tromovitch and Dr. Samuel Stegman,

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who successfully applied the technique to skin tumors of varying size and anatomic location (Tromovitch & Stegeman, 1974). In a series of 102 patients in the *1974 Archives of Dermatology,* the efficacy of the technique was validated and demonstrated additional advantages over the fixed-tissue technique such as reduced patient discomfort and improved reconstructive outcomes (Tromovitch & Stegeman, 1974). Dr. Mohs continued to validate this technique, and it is still the fundamental basis of Mohs surgery today.

In 1985, the procedure was officially named "Mohs Micrographic Surgery" (MMS), and the following year the American College of Chemosurgery was renamed as the American College of Mohs Micrographic Surgery and Cutaneous Oncology (Hanke et al., 1985). Fellowship training programs were instituted in the early 1980s to replace the existing informal preceptors. MMS now serves as the treatment of choice for many forms of primary and recurrent skin cancers and offers some of the highest cure rates compared with other surgical methods (McLeod et al., 2012). Although the field of Mohs surgery continues to evolve, the use of fresh-tissue technique, horizontal tissue sectioning, and total margin control before reconstruction remain the cornerstone of practice (E. Chen et al., 2018).

INDICATIONS AND APPROPRIATE USE CRITERIA

MMS is considered for various contiguous cutaneous tumors, depending on clinical appearance, size, location, histological findings, prior treatment, and patient characteristics, such as history of immunodeficiency or genetic syndrome (Asgari et al., 2012). Generally, tumors that qualify for MMS include poorly defined tumors, recurrent tumors or those with aggressive histological subtypes, and large tumors (>2 cm) (Asgari et al., 2012). From an aesthetic perspective, MMS is essential for tumors whose treatment may result in cosmetic or functional impairment, such as those located on the head and neck or involving the hands, feet, and genital regions (Asgari et al., 2012). Mohs surgery is considered superior in these clinical scenarios because there is a more accurate picture of tumor projections, making recurrence and surgical revision less likely (Asgari et al., 2012).

In an effort to unify treatment guidelines in MMS, appropriate use criteria (AUC) were developed in 2012 by the American Academy of Dermatology, the American College of Mohs Surgery, the American Society for Dermatologic Surgery Association, and the American Society for Mohs Surgery. The AUC is a systematic review of 270 clinical scenarios for which MMS is frequently considered based on tumor characteristics, body area, and patient characteristics (Table 1). The review is based on published data, clinical practice expertise, and expert judgment (Ad Hoc Task Force et al., 2012). These criteria can be accessed through a complimentary phone application, where one can easily enter various patient factors to determine if they qualify for MMS (Figure 1). The tumors most commonly treated with MMS include BCC and squamous cell carcinoma (SCC). Other rarer tumors can be treated with MMS as specified in Box 1.

Box 1: Tumors that may be treated with MMS.

Basal cell carcinoma
Squamous cell carcinoma
Lentigo maligna/melanoma in situ
Dermatofibrosarcoma protuberans
Microcystic adnexal carcinoma
Atypical fibroxanthoma
Malignant fibrous histiocytoma
Merkel cell carcinoma
Leiomyosarcoma
Sebaceous carcinoma
Extramammary Paget disease
Eccrine carcinoma
Mucinous carcinoma
Desmoplastic trichoepithelioma
Angiosarcoma

The AUC rating of each indication follows a 9-point scale with three major subsets: inappropriate, uncertain, and appropriate (Ad Hoc Task Force et al., 2012). Examples of scoring through the phone application are shown in Figure 2, and an anatomical representation of AUC criteria is demonstrated in Figure 3. Although the AUC provides valuable information on the appropriateness of MMS, it is important to note that treatment choice ultimately depends on the physician's clinical judgment and the patient's preferences. The AUC does not compare the efficacy between various treatment methods and does not establish which treatment is preferable (Ad Hoc Task Force et al., 2012).

Mohs for Nonmelanoma Skin Cancer

The two main tumors treated with MMS are BCC and SCC (Mcleod, 2012). From the period of 1976–1984 to 2000–2010, BCC incidence increased by 145%, and SCC incidence increased by 263% (Muzic et al., 2017; Rogers et al., 2015).

Basal Cell Carcinoma

BCC is the most common form of cutaneous malignancy (Migden et al., 2018). Typically, BCCs have a slow clinical course and low risk of mortality but can cause significant morbidity through local tissue destruction (Migden et al., 2018). According to the AUC, Mohs surgery is appropriate for patients with recurrent BCC of any size; BCC with an unexpected positive margin on excision; or primary aggressive, nodular, or superficial BCC of any size in area H or area M, except primary superficial BCC in area M that is ≤0.5 cm in diameter in otherwise healthy patients (Ad Hoc Task Force et al., 2012). The AUC guidelines also note that, in area L, Mohs is considered appropriate for aggressive or nodular BCC that is recurrent or that had unexpected positive margins and for primary aggressive BCC ≥0.6 cm

TABLE 1. Appropriate Use Criteria

Body areas	Area H	Central face, eyelids, eyebrows, nose, lips, chin, ears, preauricular Genitalia (perineal, perianal) Nipples/areola, hands, feet, ankles, nail units
	Area M	Cheeks, forehead scalp neck, jawline Pretibial surface
	Area L	Trunk and extremities (excluding pretibial surface, hands, feet, ankles, nail units)
Patient characteristics	Immunocompromised	Human immunodeficiency virus, organ transplant, hematologic malignancy, pharmacologic immunosuppression
	Genetic syndromes	Basal cell nevus syndrome, xeroderma pigmentosum, other syndromes at high risk for skin cancer
	Healthy	No immunosuppression, prior radiation therapy, chronic infections, or genetic syndromes
	Prior radiated skin	Skin has been treated with therapeutic radiation
	History of high-risk tumors	Patient is known to have a history of aggressive tumors
Tumor characteristics	Positive margin on excision	Tumor involvement at lateral and/or deep margins after excision
	Aggressive features	Basal cell carcinoma (BCC): morpheaform, fibrosing, sclerosing, infiltrating, perineural, metatypical, keratotic, micronodular
		Squamous cell carcinoma: sclerosing, basosquamous (excluding keratotic BCC), small cell, poorly or undifferentiated, perineural, perivascular, sprinkle cell, pagetoid, infiltrating, keratoacanthoma type: central facial, single cell, clear cell, lymphoepithelial, sarcomatoid, Breslow depth 2 mm or greater, Clark level IV or greater

Note. Adapted from Ad Hoc Task Force et al. (2012).

in diameter and primary nodular BCC >2 cm in diameter in healthy patients or ≥1.1 cm in diameter in immunocompromised patients (Ad Hoc Task Force et al., 2012). Lastly, the AUC states that Mohs is also considered appropriate for the treatment of primary BCC arising in previously radiated skin, traumatic scars, areas of osteomyelitis, areas of chronic inflammation/ulceration, and patients with genetic syndromes (Ad Hoc Task Force et al., 2012; Table 2).

Squamous Cell Carcinoma

SCC is the second most common skin malignancy; however, there is a higher risk for metastasis compared to BCC (Nouri & Rivas, 2004). The following is a summary of the AUC guidelines for the treatment of SCC with MMS. Treatment is considered appropriate for recurrent SCC with or without aggressive features, as well as keratoacanthoma (KA)-type SCC in all areas, and appropriate in area H for recurrent verrucous SCC (Ad Hoc Task Force et al., 2012).

Primary aggressive SCC of any size is also appropriate for all locations in both healthy and immunocompromised patients (Ad Hoc Task Force et al., 2012). Primary SCC without aggressive histological features is appropriate in areas H and M for any size of tumor and appropriate in all locations when >2 cm in healthy patients (Ad Hoc Task Force et al., 2012). For immunocompromised patients, primary SCC without aggressive histological features is appropriate in areas H and M when ≤1 cm and appropriate in all locations when >1 cm in healthy patients (Ad Hoc Task Force et al., 2012). Primary verrucous SCC of any size is appropriate in area H. Primary KA-type SCC (not central facial) is deemed appropriate in areas H and M when ≤1 cm, and appropriate in all locations when >1 cm in healthy patients (Ad Hoc Task Force et al., 2012). For immunocompromised patients, primary KA-type SCC (not central facial) is appropriate in areas H and M when ≤0.5 cm and appropriate in all locations when ≥0.6 cm (Ad Hoc Task Force et al., 2012). Primary in situ SCC/Bowen disease in healthy patients is appropriate in areas H and M when ≤2 cm and appropriate in all locations when >2 cm. For immunocompromised patients, primary in situ SCC/Bowen disease is appropriate in areas H and M for tumors of any size and appropriate in all locations when >1 cm (Ad Hoc Task Force et al., 2012; Table 3).

Lentigo Maligna

MMS is used by some Mohs surgeons to treat the lentigo maligna subtype of melanoma; however, special immunohistochemical staining is typically required. This topic is out of the scope of this review.

RECURRENCE RATES

Basal Cell Carcinoma

Mohs surgery has superior long-term cure rates compared with other treatment modalities and is the treatment of

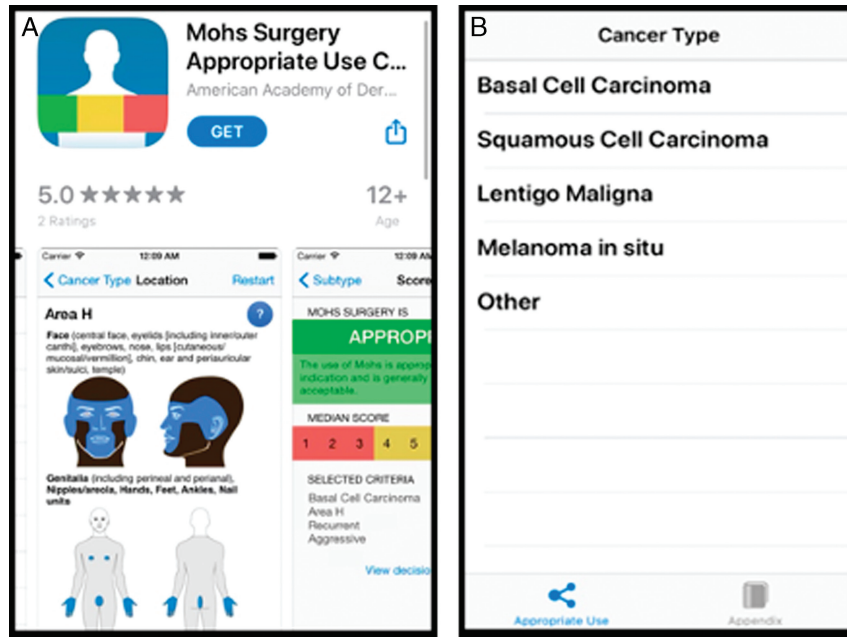

FIGURE 1. Views of appropriate use criteria (AUC) application, developed by the American Academy of Dermatology. (A) Mohs surgery AUC application download display. (B) Mohs surgery AUC application search function.

choice for high-risk and recurrent BCCs (Kim et al., 2019). Because of the slow growth rate of BCCs, recurrences are most likely to be diagnosed after 5 years (Kim et al., 2019). A retrospective study of head and neck BCC by Kuiper et al. (2018) found that aggressive histopathological subtype, residual BCCs, and recurrent BCCs were significant factors that were predictive of a higher risk of recurrence after MMS, with the risk of recurrence for aggressive BCCs being more than four times greater than that for primary nonaggressive BCCs.

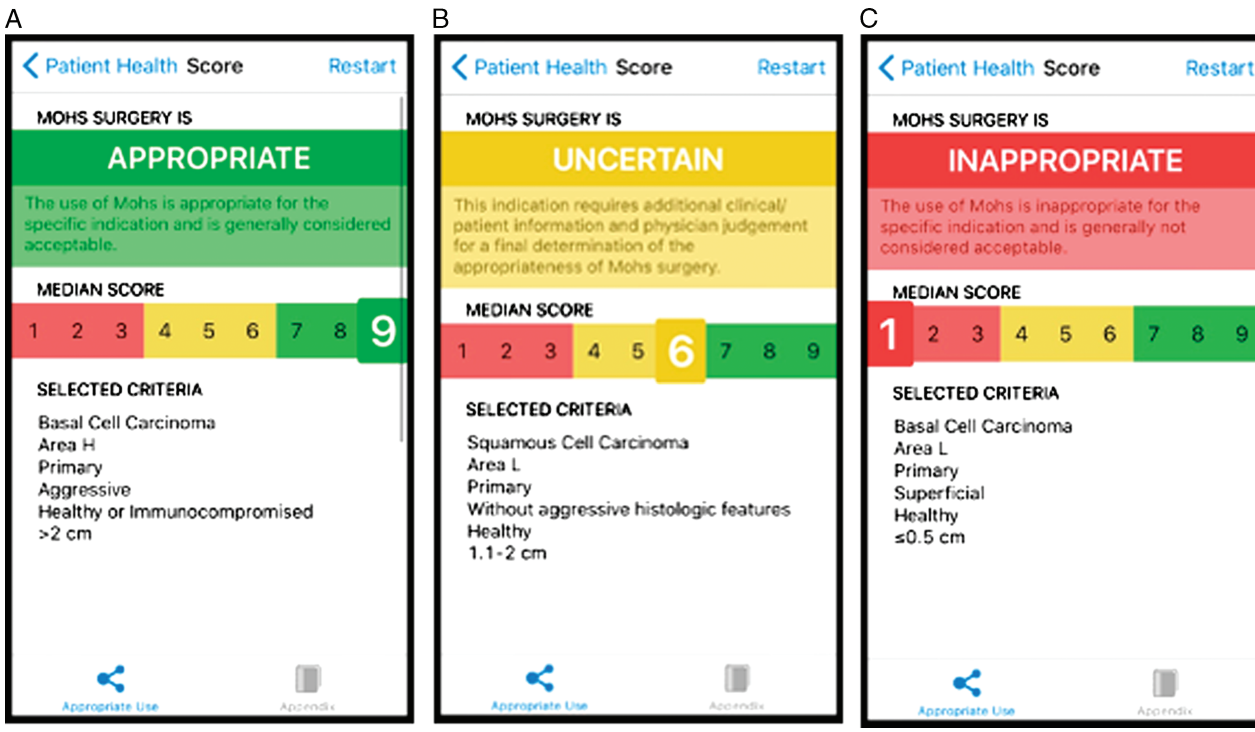

FIGURE 2. Mohs surgery appropriate use criteria (AUC) application grading. (A) Mohs surgery AUC application example of appropriate indication. (B) Mohs surgery AUC application example of uncertain indication. (C) Mohs surgery AUC application example of inappropriate indication.

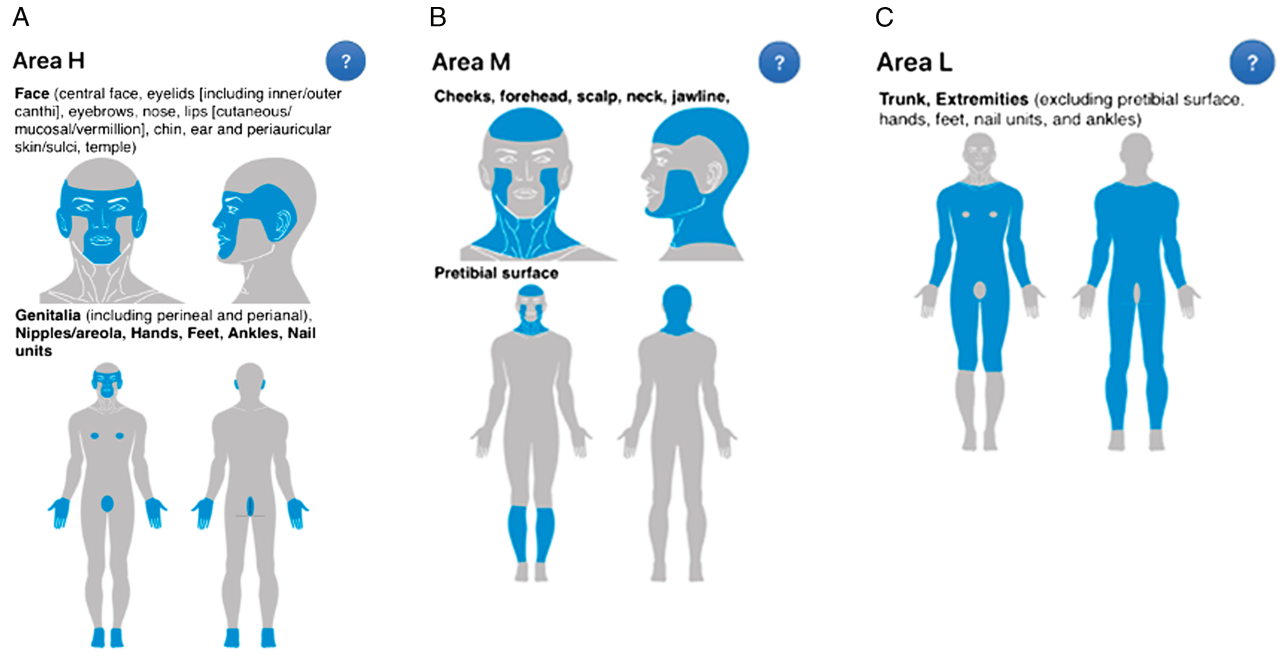

FIGURE 3. Body areas defined by appropriate use criteria (AUC) criteria. (A) Diagram of body areas defined by AUC criteria: Area H. (B) Diagram of body areas defined by AUC criteria: Area M. (C) Diagram of body areas defined by AUC criteria: Area L.

The 5-year recurrence rate for primary BCC treated with MMS is 1% compared with 10.1% for standard excision with postoperative margin assessment (SEPMA; Rowe et al., 1989). In a recurrent BCC, the 5-year recurrence rate is 5.6% if the tumor is treated with MMS versus 17.4% in SEPMA (Rowe et al., 1989). There is one randomized control trial that found that 10-year recurrence rates in primary facial BCCs were 4.4% for MMS and 12.2% for SEPMA (p = .10). In the same study, it was found that, for recurrent BCC, the 10-year recurrence rates were 3.9% for MMS and 13.5% for SEPMA (p = .023; van Loo et al., 2014).

Squamous Cell Carcinoma

High-risk cutaneous SCC (cSCC) may be treated with MMS, standard excision with wider margins, or radiation

TABLE 2. Appropriate Use Criteria for Basal Cell Carcinoma

Area	Appropriate	Uncertain	Inappropriate
H	Primary or recurrent: Aggressive Nodular Superficial		
M	Recurrent or primary: Aggressive Nodular Superficial (IC) Primary: Superficial ≥0.6 cm	Primary: Superficial ≤0.5 cm	
L	Recurrent: Aggressive Nodular Primary: Aggressive ≥0.6 cm Nodular >2 cm Nodular (IC) ≥1.1 cm	Primary: Aggressive ≤0.5 cm Nodular 1.1–2 cm Nodular (IC) 0.6–1 cm Superficial (IC) ≥1.1 cm	Recurrent: Superficial Primary: Nodular ≤1 cm Nodular (IC) ≤0.5 cm Superficial Superficial (IC) ≤1 cm

Note. Listed indications are for both healthy and immunocompromised (IC) patients and tumors of any size unless otherwise specified. Adapted from Ad Hoc Task Force et al. (2012).

TABLE 3. Appropriate Use Criteria for Squamous Cell Carcinoma

Area	Appropriate	Uncertain	Inappropriate
H	Primary or recurrent: Aggressive Nonaggressive[a] Verrucous KA-type SCC[b] In situ SCC/Bowen		Primary or recurrent: AK with focal SCC in situ
M	Primary or recurrent: Aggressive Nonaggressive[a] KA-type SCC[b] In situ SCC/Bowen		Primary or recurrent: AK with focal SCC in situ
L	Primary or recurrent: Aggressive Recurrent: KA-type SCC[b] Nonaggressive[a] Primary >2 cm Nonaggressive[a] In situ SCC/Bowen Primary ≥1.1 cm: Nonaggressive (IC)[a] KA-type SCC[b] In situ SCC/Bowen (IC) KA-type SCC (IC) ≥0.6 cm[b]	Recurrent: SCC in situ/Bowen Primary: 1.1–2 cm Nonaggressive[a] SCC in situ/Bowen Primary ≤1 cm: Nonaggressive (IC)[a] Primary 0.6–1 cm: SCC in situ/Bowen (IC) Primary ≤0.5 cm: KA-type SCC (IC)[b]	Primary or recurrent: AK with focal SCC in situ Primary ≤1 cm: Nonaggressive[a] KA-type SCC[b] SCC in situ/Bowen Primary ≤0.5 cm SCC in situ/Bowen (IC)

Note. Listed indications are for both healthy and immunocompromised (IC) patients and tumors of any size unless otherwise specified. KA = keratoacanthoma; SCC = squamous cell carcinoma; AK = actinic keratosis. Adapted from Ad Hoc Task Force et al. (2012).

[a]SCC without aggressive features, <2-mm depth without other defining features, Clark level ≤ III.

[b]Not central facial.

therapy. High-risk cSCC has been defined by factors associated with recurrence, metastasis, and disease-specific death (Schmults et al., 2013). A 10-year retrospective cohort study by Schmults et al. (2013) determined that there were five factors contributing to high-risk cSCC: a tumor diameter of at least 2 cm; poor differentiation; depth of invasion beyond the subcutaneous fat; perineural invasion; and location of the ear, temple, or anogenital region. Immunosuppression has also been associated with poor cSCC outcomes in other studies.

A series of 3,299 SCCs were analyzed by Mohs himself, including cases with metastatic SCC and extensive local growth (Shriner et al., 1998). In this study, for SCCs smaller than 2 cm in diameter, there was a 99% 5-year cure rate with MMS. In addition, tumors between 2 and 3 cm in diameter had an 82% 5-year cure rate, and tumors larger than 3 cm had the lowest cure rate at 59% (Shriner et al., 1998). Importantly, 95% of SCCs that recur locally or metastasize tend to do so within the first 5 years postoperatively (Rowe et al., 1992).

There are few prospective studies comparing standard excision with MMS. A meta-analysis by Rowe et al. (1992) showed lower recurrence rates with MMS compared with standard excision, with 3.1% versus 8.1% for primary tumors and 10% versus 23.3% for locally recurrent tumors. A more recent retrospective study by van Lee et al. (2019) showed that there was a lower recurrence risk of cSCC of the head and neck after MMS (3%) than after standard excision (8%) during a median follow-up of 5 years. When adjusted for tumor size and deep tumor invasion, cSCC treated with MMS was found to be at a three times lower risk of recurrence than standard excision, with the difference likely being underestimated because not all high-risk tumor characteristic could be adjusted for (van Lee et al., 2019).

PREOPERATIVE ASSESSMENT AND SURGICAL CONSIDERATIONS

A thorough preoperative evaluation is crucial to ensure patient safety and attain high-quality outcomes in MMS. The primary goal is to evaluate, educate, and obtain informed consent. A preoperative assessment is completed during the patient's surgical consultation, which can take place prior to or on the same day as the surgical procedure. During the consultation, an updated history is obtained, with particular emphasis on medical conditions affecting surgery, including history of hypertension and cardiovascular disease, hepatitis/HIV infection, organ transplantation, prosthetic devices, inherited bleeding disorder, implanted

devices, underlying pregnancy, and tobacco/alcohol consumption (Christensen & Aasi, 2012). The patient's medications, including blood thinners, allergies, previous infections, and hospitalizations, and need for preoperative imaging/consultation with other surgical specialists should also be reviewed and updated. Of particular importance is any indication for antibiotic prophylaxis (AP); anticoagulant therapy (including herbal supplements); and allergy to anesthetics, antibiotics, adhesive tape, or latex (Christensen & Aasi, 2012). The procedure is completed under local anesthesia; however, if the patient is apprehensive, preoperative anxiolytic agents (e.g., lorazepam and diazepam) can be discussed and considered for the day of the procedure (Greenway, 2005).

Next, a focused skin examination is performed, and if available, photo documentation of the patient's biopsy site is reviewed and clinically correlated. The pathology report should also be reviewed, and if the diagnosis appears questionable, histological sections may be reexamined before proceeding with surgery (Greenway, 2005). After the initial medical evaluation, the Mohs surgeon should review therapeutic options with corresponding risks and benefits and then obtain informed consent (Greenway, 2005). The patient should be made aware of the steps involved and the anticipated time to complete the procedure. The surgeon should adequately understand the patient's aesthetic expectations and review potential repair options. If the patient prefers to take an anxiolytic or if cancer is near the eye, it may be recommended that the patient have a driver after surgery.

Antibiotic Prophylaxis

The majority of MMS procedures do not require AP, but it may be indicated in some scenarios. Patients may require AP if there is high risk for surgical site infection based on location (lips, ears, nose, groin, or lower extremities) and technique used (skin flaps or grafts) and for patients with extensive inflammatory skin disease (Rosengren et al., 2012).

Revised guidelines published by the American Heart Association in 2008 can be extrapolated to cutaneous surgery. For patients with high-risk cardiac conditions or in certain patients with prosthetic joints at high risk for hematogenous total joint infection, AP is recommended if the surgical site is infected or when the procedure involves breach of the oral mucosa (Wright et al., 2008). These high-risk patients include those with prosthetic heart valves, congenital heart disease, or a history of infectious endocarditis and transplant recipients who have developed heart valve disease (Wilson et al., 2008).

As recommended by the American Heart Association, adult patients requiring AP should receive 2 g of amoxicillin by mouth 30–60 minutes prior to the procedure to allow for adequate distribution at the time of incision (Wilson et al., 2008). Alternative options include cephalexin (2 g by mouth) or clindamycin (600 mg by mouth) if the patient has a penicillin allergy (Wilson et al., 2008). If the antibiotic was missed, it can still be beneficial if administered up to 2 hours following the procedure (Benedetto & Poblete-Lopez, 2011).

Anesthetic Considerations

The most commonly used anesthetic in Mohs surgery is a mixture of 1% lidocaine and 1:100,000 epinephrine, which may be buffered with sodium bicarbonate in a ratio of 1:10 to lessen patient discomfort by increasing the pH of the solution (Collier & Hruza, 2009). If the patient has a true allergy to amide anesthetics, an ester anesthetic such as tetracaine can be substituted (Collier & Hruza, 2009). The safety of lidocaine plus epinephrine in outpatient dermatology clinics was recently validated in a large retrospective chart review of 1,127 MMS cases. In this study, there were no serious acute events requiring the use of advanced cardiac life support or a crash cart despite an elderly patient population with various significant comorbidities (Hirshburg et al., 2020). In addition, a recent study by McLawhorn et al. has shown that systemic reactions to epinephrine from local anesthetics are an infrequent event in MMS cases, with the data suggesting the absolute dose of local anesthetic with epinephrine not correlating with the risk of developing an epinephrine reaction (McLawhorn et al., 2020). For cases in which longer term pain control may be a concern, liposomal bupivacaine (a longer acting local anesthetic) may be administered starting 20 minutes after the final dose of lidocaine (Sorenson & Chesnut, 2019).

Implantable Devices

It is imperative to minimize potential electromagnetic interference with electrosurgical equipment in patients who have implantable electrical devices, such as a pacemaker or a defibrillator. Clinicians should identify all patients with implanted cardiac devices during the preoperative evaluation (Christensen & Aasi, 2012). The cardiologist of these patients could be contacted for the review of the patient's device if there is uncertainty (Matzke et al., 2006).

Heat cautery can be used instead of electrodessication or electrocoagulation to avoid interference with the patient's implantable device. However, a 2012 study by Weyer et al. found that electrodessication with a Hyfrecator on maximal settings can be used safely beyond a 3-cm radius around the implanted device. The hyfrecator can also safely be used beyond a 1-cm radius with standard settings (Weyer et al., 2012). To improve the safety of the hyfrecator, the operator can use short bursts of electricity to decrease the possibility of prolonged periods of inhibition (approximately 1 second bursts; Matzke et al., 2006). In patients who are oxygen-dependent, oxygen flow should be temporarily discontinued while using electrical means of hemostasis because the spark could ignite a fire (Weyer et al., 2012).

Anticoagulants

Approximately 46% of patients who undergo cutaneous surgery are taking at least one anticoagulant or antiplatelet agent (Brown et al., 2015). Overall, the risk of severe complications among patients who are taking oral anticoagulants or antiplatelets is low; however, the risk of thromboembolic events increases even after a short disruption of therapy (Bunick & Aasi, 2011). Because of the severe consequences that may ensue from discontinuing anticoagulant medications, dermatologic surgeons often choose to have patients remain on their therapy in the vast majority of surgical procedures (Bunick & Aasi, 2011).

Current guidelines recommend continuing warfarin, clopidogrel, and aspirin during cutaneous surgery (Otley, 2003). Novel oral anticoagulants (NOACs), including dabigatran, apixaban, and rivaroxaban, are increasing in prevalence as they have shown to have efficacy equal or superior to warfarin (Eilers et al., 2018). Patients who are taking NOACs should also be advised to continuously take their medication when undergoing MMS, unless otherwise indicated by their Mohs surgeon. Of note, a study by Eilers et al. (2018) at the University of California San Diego found that patients treated with NOACs at the time of MMS had a statistically significant greater risk for developing postoperative hemorrhagic complications compared to patients treated with traditional oral anticoagulants, although more studies are warranted to validate this finding. Overall, patients who are taking anticoagulants should be counseled on the signs and symptoms of postoperative bleeding and hematoma formation (Bunick & Aasi, 2011).

Anticoagulant medications may be interrupted for MMS in certain scenarios. If the patient is taking aspirin or another nonsteroidal anti-inflammatory drug (NSAID) for pain relief, NSAIDs can be discontinued for 1 week before and 2 days after the procedure (Bunick & Aasi, 2011). If the patient requires a substitute for pain, acetaminophen is recommended. Patients may also discontinue aspirin if it is taken for primary prevention and there is no prior history of a thrombotic event (Bunick & Aasi, 2011). Usually, if a complex surgical procedure is planned, preoperative international normalized ratio is taken to rule out supratherapeutic international normalized ratio (>3.5), and further management may be discussed with the patient's cardiologist (Bunick & Aasi, 2011).

STANDARD SURGICAL EXCISION VERSUS MMS

MMS and standard surgical excision are highly effective treatment options that are chosen depending on skin tumor characteristics. Standard surgical excision involves the removal of a tumor by predefined clinical margins, whereas Mohs surgery provides precise and comprehensive evaluation of the tumor margin, maximizing normal tissue preservation (S. Chen, 2018; Figure 4). There is added convenience to the patient in MMS because pathological evaluation is immediate. Furthermore, when MMS is chosen for an appropriate indication, the average cost to the healthcare system is often less (S. Chen, 2018). Although there are many advantages to the procedure, some disadvantages include the requirement of contiguous tumors. In addition, improper surgical removal or poor histological staining could lead to specimens that are difficult to read, leading to decreased pathological sensitivity (S. Chen, 2018).

SURGICAL TECHNIQUE

MMS is traditionally performed in an outpatient setting in a nonsterile procedure room. Following informed consent and identification of the biopsy site, the patient is placed in a recumbent position, and the clinically evident tumor boundary or biopsy scar edges are marked with a surgical pen. Next, the operative field is cleansed with an antiseptic, such as chlorhexidine gluconate or povidone-iodine, and the patient is draped (Collins et al., 2015) (Wong et al., 2019). Of note, it is important to mark the surgical site prior to anesthetic infiltration to prevent margin distortion.

Once the site is anesthetized, the surgeon may elect to use curettage to debulk the tumor. This technique is used more often when operating on BCCs and SCCs, as the cancerous tissue is usually more friable than the surrounding skin (Wong et al., 2019). Although curettage may increase the size of the initial defect, studies have shown that it may decrease the number of surgical layers or "Mohs stages" (Chung et al., 2005). Following tumor debulking, the surgeon removes the tumor typically 1–2 mm from the debulked edge (Wong et al., 2019). Reference points are typically placed at 3, 6, 9, and/or 12 o'clock positions to ensure orientation by making superficial nicks on the patient correlating to the tissue being removed (Mansouri et al., 2017). Mapping and division of the specimen is further detailed in Figure 5.

The first layer is removed using a 45° beveling technique of the scalpel blade, which allows for proper alignment of the peripheral edges of the tissue specimen during histological preparation (Mansouri et al., 2017). Care is taken to remove the specimen in a flat horizontal plane immediately below the depth of the previous curettage, facilitating proper horizontal processing of the tissue onto slides (Mansouri et al., 2017). After achieving hemostasis, the patient is temporarily bandaged and may wait in a comfortable area until tissue processing is complete.

Following surgical excision, the tissue specimen is placed on surgical gauze with attention to maintain the anatomic orientation. In the histology laboratory, the Mohs map is produced and serves to correlate the surgical site, tissue specimen, and histological slides produced. Furthermore, the map guides subsequent stages of tumor removal if positive margins are present. The specimen may be cut into multiple pieces, and based on the initial nicks, the margins are inked with different colored dyes to provide accurate orientation (Wong et al., 2019). The histotechnician freezes the tissue using a cryostat and embeds the tissue with the deep surface

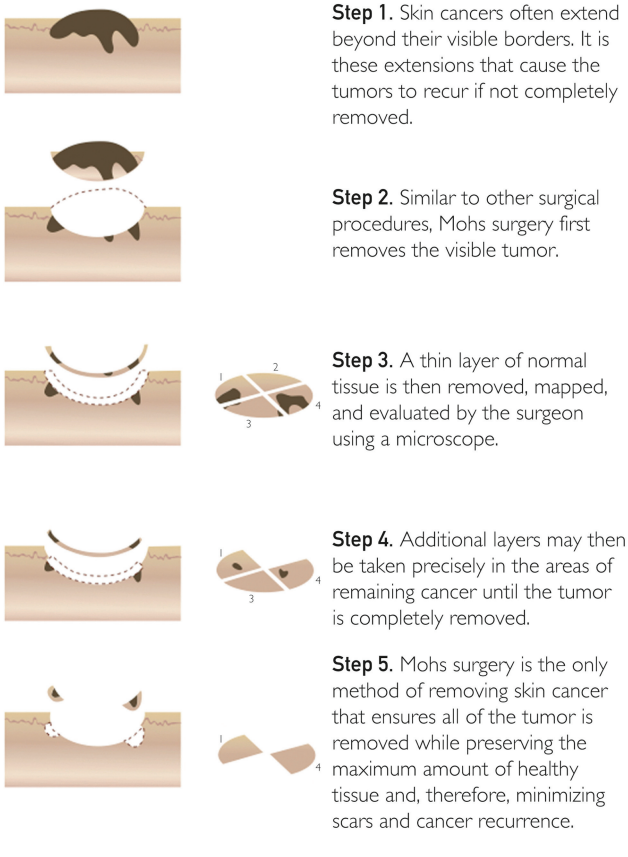

FIGURE 4. (A) Comparison of Mohs microsurgery technique and (B) standard wide local excision with bread loafing. Reprinted from Tolkachjov et al. (2017), with permission from Elsevier.

facing up within the embedding medium. The frozen slides are sectioned on a microtome and mounted onto glass slides and stained, most commonly with hematoxylin–eosin or toluidine blue. If there is a more aggressive tumor, immunohistochemistry or other tumor markers may be used (Wong et al., 2019).

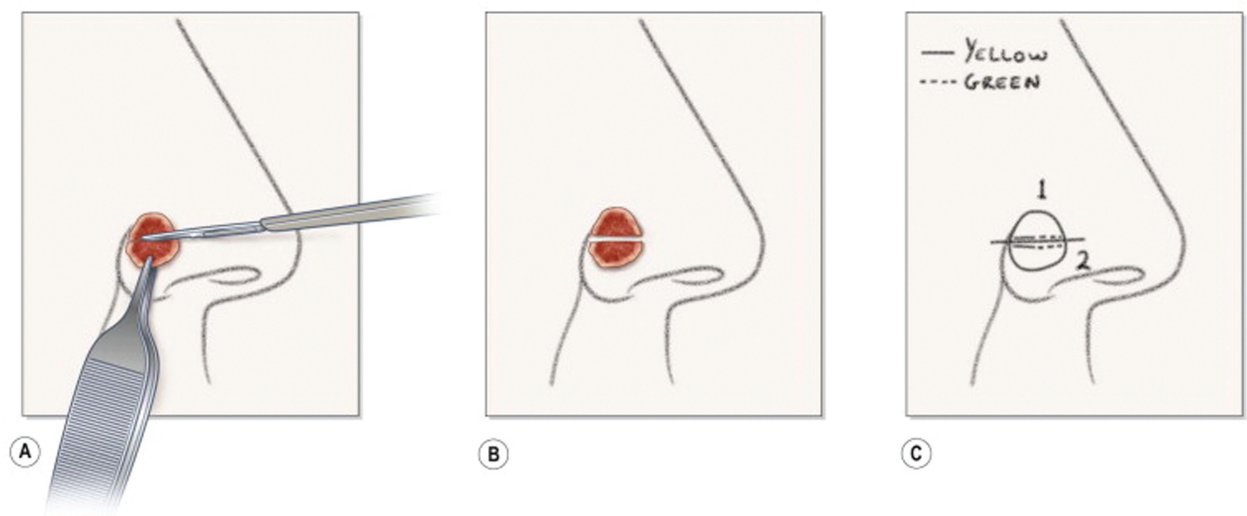

FIGURE 5. Mapping and division of the specimen. (A) Division of specimen using scalpel and forceps. (B) Divided specimen showing orientation. (C) Map orienting tissue specimen and denoting dye marking of nonepidermal margins. Reprinted from Greenway (2005), with permission from Elsevier.

Once tissue slides are prepared, the frozen sections are examined under the microscope by the Mohs surgeon, who also functions as the pathologist. To ensure tumor clearance, it is important that the excision has a margin of normal skin beyond the observed neoplasm. A second stage is required if the tumor is identified at the margins or if there is poor visualization of the specimen. Any layer taken after the initial excision is specific to the site of the positive margin. The specimen containing the area of residual tumor and about 1–2 mm of surrounding tissue is removed, oriented, mapped, and processed (Wong et al., 2019). Once clear margins are confirmed, the defect should be measured, and the patient will typically undergo reconstruction on the same day. Although Mohs surgeons are well trained to perform complex closures, sometimes there is collaboration with otolaryngology, ophthalmology, or plastic surgery in more complicated cases.

RECONSTRUCTIVE OPTIONS

There is a wide spectrum of reconstructive techniques used in Mohs surgery. The type of reconstruction method chosen is influenced by the size and location of the defect, characteristics and preferences of the patient, and the experience of the surgeon. General reconstructive options include healing by secondary intention (granulation), primary (linear) closure, skin flaps, and grafts (Thornton, 2018a). There are also various cellular and tissue-based products that can temporize wounds and provide a final reconstruction for selected wounds (Thornton, 2018a). Understanding various closure methods is critical to the dermatologic nurse, as each method differs in wound care requirements and potential postoperative complications.

Secondary Intention Healing

Healing by secondary intention is the simplest of the reconstructive options and is especially useful in older patients with increased skin laxity (Cosulich, 2018). The skin defect heals as a result of proliferation or migration of epidermal cells associated with the wound and contracts under the influence of myofibroblasts within granulation tissue (Boyce & Shokrollahi, 2006). Wound edges are not brought together by external means. This option is advantageous because there is optimal skin cancer surveillance; simple wound management; and the avoidance of complex, time-consuming reconstructive procedures (Lam et al., 2015). Disadvantages include prolonged healing time and daily wound care (Lam et al., 2015). Although cosmetic outcomes may be unpredictable, results are often excellent especially in concave anatomic locations (Lamel, 2015).

Primary Closure

Primary closure is the workhorse reconstructive technique in dermatologic surgery and refers to linear or side-to-side closure of a wound with sutures (Cosulich, 2018). Depending on the size, location, and tension of the wound, typically a combination of deep and superficial layers of sutures will be placed. Layered closure allows the surgeon to recreate the tissue planes that have been disrupted and provides strength to the wound as it heals (Cosulich, 2018). Multiple suturing techniques are described in the literature, but in any case, the technique that is chosen varies on the location and tension of the wound.

Local Flaps

Local flaps are often used in MMS and can provide immediate wound closure, but at the expense of creating distant incisions. Rotation, advancement, and transposition flaps are the most commonly referred to in head and neck reconstruction. Rotation and advancement flaps differ in their design, but both involve a sliding motion into the defect (Thornton, 2018b). A transposition flap is created where the donor site is remote from the defect and the flap is moved about the pedicle or transposed over intervening normal tissue into the defect (Thornton, 2018b). The advantage of local flaps is the ability to efficiently provide color and texture matched skin. Disadvantages include the induction of incisions distant from the defect, the possibility of irreversible anatomic distortion, and potential flap failure (Thornton, 2018b). All flaps are sutured into place with at least two distinct layers of tissue closure, and sometimes, tacking sutures are used to anchor the flap to an underlying immobile structure (Thornton, 2018b). When designed meticulously, flap repairs can yield superior results to second intention healing or skin grafts.

Split-Thickness and Full-Thickness Skin Grafts

In contrast to skin flaps, skin grafts are completely removed from their blood supply (Prohaska & Cook, 2020). Split-thickness skin grafts (STSGs) are composed of the epidermis and a superficial part of the dermis with few or no adnexal structures, whereas full-thickness skin grafts (FTSGs) contain the full epidermis and dermis with preservation of adnexal structures (Prohaska & Cook, 2020). Composite grafts involve skin plus a second type of tissue, usually cartilage (Prohaska & Cook, 2020).

STSGs can generally provide very large volumes of thin color-matched skin (>5 cm), with acceptable donor-site healing (Braza & Fahrenkopf, 2020). There is also increased likelihood of graft survival since nutrient support for thin tissue is generally reduced (Braza & Fahrenkopf, 2020). STSGs are generally better for tumor surveillance than a thicker FTSG, which may mask the recurrent tumor (Braza & Fahrenkopf, 2020). FTSGs are generally used for smaller areas than STSGs and have a better overall appearance because they have improved functionality of sweat glands, hair growth, and pigment production (Acosta, 2015). The increased thickness of FTSGs usually results in a smoother contour and less wound contracture (Acosta, 2015). Usually a bolster dressing is placed with

tie-over sutures; however, this is not always necessary if the graft is small and in a stable location. The bolster has a thick layer of antibiotic ointment or petrolatum over the graft followed by a nonadherent contact layer (Acosta, 2015). The final layer is made up with bulky material such as dental roll, layered gauze, or foam. In an FTSG, the donor site is typically repaired in a layered fashion, but in an STSG, a moist occlusive dressing is applied with ointment and a polymer film to allow it to heal by secondary intention (Acosta, 2015).

Postoperative counseling and education are imperative to prevent risk of graft failure. The patient should be instructed to avoid shearing forces so that neovascularization can occur appropriately (Acosta, 2015). Strenuous exercise should be avoided so that physical stress is not placed on the graft; elevation of blood pressure can rupture vessels that should remain coagulated (Acosta, 2015). If the patient had an STSG, the donor site dressing may require more frequent dressing changes because of drainage, as it is left to heal by secondary intention. The FTSG or STSG site should be kept dry for 3–7 days, at which point the bolster and sutures are typically removed and Vaseline ointment is used for the duration of healing (Acosta, 2015).

POSTOPERATIVE CONSIDERATIONS

Before the patient is sent home after their MMS procedure, they should receive counseling on any activity restrictions or limitations, wound care, pain control, as well as the anticipated timeline for healing. It is very helpful for the patient to have written instructions and a phone number to call in the event of an emergency.

Bandaging

The surgical site should be cleansed with saline to remove any antiseptic prior to bandaging, as it can cause local irritation under the bandage. Petroleum jelly or petroleum-impregnated gauze can be placed over the suture line or the open wound (if healing by second intent), and a nonadherent pad can be placed over the petrolatum. A pressure or compression dressing is then placed with rolled up gauze or dental rolls and firm tape to minimize postoperative bleeding.

Wound Care

For many wounds, the postoperative compression bandage is typically kept on for 48–72 hours. The wound can then be cleansed daily with soap and water or saline. Some surgeons will recommend cleansing the area with diluted white vinegar. Once dried, the wound should be kept moist with petroleum jelly until healed. Antibiotic ointment may be used at the discretion of the surgeon but may cause local irritant or contact dermatitis.

Bleeding

Patients should be counseled on how to handle bleeding from the wound. Bleeding is at highest risk in the first 48 hours, especially for those on blood thinners. If patient notes bleeding through the bandage, they should apply very firm pressure over the bandage for at least 20 minutes. Once bleeding has stopped, they can reinforce the bandage or very carefully replace the bandage. However, immediately replacing the bandage may cause the bleeding to recur.

Hematoma

In addition, patients at risk for developing a hematoma should be counseled on the signs and symptoms to watch for. Active bleeding under the sutures can create a pocket of blood that can be painful and feel like intense pressure. In certain areas, it can be an emergency, such as around the neck or eyes, as it can compress important structures. If a patient is developing a hematoma, the hematoma needs to be evacuated by opening the wound, and the bleeding should be stopped. The wound may be resutured after bleeding is mitigated.

Pain

Acetaminophen is often recommended as it is very effective for postsurgical pain and does not thin the blood. Although previously thought to be high risk for bleeding, NSAIDs, in combination with acetaminophen, have now been found to be a very effective and safe method of pain management (Oltman et al., 2017). One study has shown that the combination of acetaminophen and NSAIDs was more effective than opiates (Oltman et al., 2017). There may be certain instances requiring prescription opiates for pain management, which would be at the discretion of the surgeon.

Sleeping

Surgical sites on the head can cause swelling, especially around the eyes. It is advised for the patient to sleep with the head elevated at a 30° angle to minimize swelling in the morning.

Activity Restrictions

Typically, patients are advised to avoid heavy lifting (>10 lbs) and bending over for surgical sites on the head/neck. For sites on the back and extremities, it is important to minimize twisting, pushing, and pulling. For sites on the hands and lower extremities, patients should be advised to elevate the limb to help to decrease swelling. Often times, the surgeon will request that the patient wear an ACE bandage or compression stocking for surgical sites below the knee.

Follow-Up

The timeline for immediate follow-up ultimately depends on the method of closure and location of the wound, as previously specified. The location of the wound will dictate suture removal. Sutures are typically removed between 4 and 7 days postoperatively for the head and neck and 10–14 days for the scalp, trunk, and extremities (Levin, 2015)

In any case, it may be prudent to see the patient at least once in the 6-week postoperative period after suture removal to ensure proper wound healing and contraction (Greenway, 2005). This is an ideal time for the Mohs surgeon to intervene if there is a spitting suture, flap tip necrosis, hypertrophic scarring, or an unexpected complication (Greenway, 2005). Follow-up may be scheduled 3 months postoperatively for additional monitoring and patient education (Greenway, 2005). It is important to educate the patient that wound healing can take up to 1 year; therefore, the wound and scar will mature over that time. Depending on the tumor removed, the patient should also be scheduled for routine skin cancer surveillance and monitoring with their general dermatologist.

In summary, MMS involves broad applications for the treatment of a variety of skin malignancies. Through a sequence of reproducible steps, a high cure rate can be achieved for even the most complex tumors. The demand for MMS has increased substantially with the continued rise of skin cancer incidence. To optimize patient care and education, it is crucial for dermatologic nurses to be well versed in general Mohs surgery techniques and reconstructive procedures.

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