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ORIGINAL PAPER

Staged melanoma excision requires larger margins for tumor clearance and results in low rates of recurrence

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Abstract

There is controversy regarding the optimal surgical modality and ideal recommended margins for treating melanoma in situ (MIS) and invasive melanoma (IM). Although wide local excision is recommended, staged excision offers excellent margin control and low recurrence rates. In this manuscript, we reviewed a 10-year experience of staged excisions for the treatment of MIS and IM. A retrospective review was performed of 130 MIS and 32 IM cases treated with staged excision from April 2012 to April 2022. Staged excision was performed on the head and neck in 102 (79%) MIS and 23 (72%) IM cases. Approximately 10% of cases required surgical margins above the current recommendations (11 (9%) MIS and 6 (19%) IM). Twenty-three (19%) MIS and 7 (22%) IM cases required more than one excision to obtain clearance. Recurrence rates among MIS and IM were 0.0% and 0.6%, respectively. Upstaging occurred in 5 (4%) MIS and 7 (22%) IM cases. Complex repairs were performed on 82 (63%) MIS and 17 (53%) IM cases. Our findings revealed that staged excision provides effective margin control and low recurrence rates. Approximately 10% of patients required margins greater than the current recommendations, leading to larger defects and more complex repairs.

Keywords Staged excision · Melanoma in situ · Invasive melanoma · Treatment

Abbreviations

MIS	Melanoma in situ
IM	Invasive melanoma
MMS	Mohs micrographic surgery
NCCN	National Comprehensive Cancer Network
cm	Centimeters
BD	Breslow depth
mm	Millimeter
NYU	New York University
AJCC	American Joint Committee
AIMP	Atypical intraepidermal melanocytic proliferation

Introduction

The treatment of cutaneous melanoma can be challenging as tumors may present with ill-defined clinical and histopathological margins, especially among elderly patients with chronically photodamaged skin [1]. Surgical excision with histologically negative margins is the standard of care. Wide local excision, staged excision, and Mohs micrographic surgery (MMS) are procedures commonly performed by dermatologic surgeons to treat MIS and IM. However, the best surgical modality for treatment, as well as the optimal margins for clearance, remains controversial.

Current guidelines from the Nation Comprehensive Cancer Network (NCCN) recommend wide local excision for the removal of MIS and IM. These guidelines do not recommend staged excision or MMS due to lack of randomized controlled trials comparing these treatment modalities [2]. For MIS, margins of 0.5 cm (cm) to 1 cm are recommended. For IM, margins are based upon Breslow depth (BD). Margins of 1 cm are recommended for a BD < 1 mm (mm). Margins of 1–2 cm are recommended for BD of 1–2 mm, and margins of 2 cm are recommended for BD > 2 mm [2].

Previous studies have reported that the currently recommended margins for wide local excision of MIS and IM may

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be inadequate for tumor clearance [3–7]. Furthermore, when compared to wide local excision, staged excision and MMS have shown to provide superior margin control leading to lower recurrence rates and improved cosmetic outcomes [3, 6, 8–11]. The use of MMS is becoming more widely available. However, meticulous tissue sectioning, proper immunohistochemical staining, and comfort among Mohs surgeons in identifying atypical melanocytes on frozen sections is necessary to ensure appropriate treatment [6, 12]. Staged excision may be considered an alternative to MMS and has a similar advantage of obtaining histopathologic clearance prior to reconstruction. With good communication between a dermatopathologist and dermatologic surgeon, the staged excision technique is simple to execute and does not require a Mohs laboratory, making it an ideal treatment among various surgical settings.

In this longitudinal study of 10 years, we highlight New York University (NYU) experience with staged excisions for the treatment of MIS and IM. Secondary objectives include to 1) offer our technique and protocol for staged excision and 2) identify tumor characteristics, recurrence rates, surgical margins, and common repair methods of cutaneous melanoma treated with staged excision.

Materials and methods

Data collection and statistical analysis

This is a retrospective chart review study that includes 162 patients with MIS and IM treated with staged excision between April 2012 and April 2022. All staged excisions were performed by three board-certified dermatologic surgeons. Three board-certified dermatopathologists reviewed all internal and externally referred biopsies and staged excisions.

Electronic medical records, including photographs, notes, and pathology reports were reviewed. Data collected includes patient demographics, lesion characteristics, treatment, and prognosis. Lesions were classified as MIS or IM. Further subtyping of MIS was not performed at the time of diagnosis by the dermatopathologist, and therefore was not included in this study. IM cases were sub-classified based upon the American Joint Committee (AJCC) on Cancer 8th edition staging system. For incompletely excised lesions, the original surgical margin was added to the subsequent surgical margin(s) to determine the final margins to clearance.

Descriptive statistics were used to assess patient demographics, tumor characteristics, treatment, and prognosis. Continuous data were analyzed and described as mean with standard deviation and median with ranges. Spearman correlation coefficients were used to assess a correlation between two subgroups of continuous ranked data. The Wald χ^2 test was used to assess a correlation between a continuous ordinal variable and a binary categorical variable. Initial lesion size was measured based upon the largest diameter of the pre-operative lesion. A p value of < 0.05 was considered statistically significant. Statistical analysis was performed using SAS Statistical Software.

Surgical technique

Using a surgical marking pen, the clinical tumor was outlined with a dotted line and the margin was outlined with a solid line. A photograph was taken prior to removal. A staged excision under local anesthesia was subsequently performed with the steps outlined below. Using a 15-blade scalpel, the clinical lesions with associated surgical margins were excised, with a depth to subcutaneous or fascia. All initial margins were ≥ 0.5 cm. A non-absorbable suture was placed at the 12 o'clock location to allow for exact orientation. Hemostasis was achieved through electrocoagulation unless otherwise contraindicated. The defect was covered with a moist occlusive dressing, and the patient was instructed to return to the clinic within 48 h. A pathology order was placed, notating that the specimen is for 'RUSH' processing by dermatopathology, allowing the final pathologic diagnosis to be available within 24–48 h. The specimen was placed in formalin and sent to dermatopathology for permanents, using serial sectioning, also known as the "bread loafing" technique. Upon release of the final pathologic margins, the surgeon then communicated with the patient to inform them of the need for re-excision (if tumor remained) or reconstruction. Subsequent re-excisions of positive margins were performed using the same technique until the dermatopathologist confirmed tumor clearance. All defects were repaired by the surgeon within 48 h of confirmed negative margins. Patients were seen 1 week following the procedure for suture removal and then scheduled for interval follow-up (Figs. 1, 2).

Results

Melanoma in situ

Patient and tumor characteristics

Staged excision was performed on 130 patients with MIS (Table 1). The majority of tumors were primary tumors (97%), with only four cases (3%) representing recurrent tumors.

Staged excision was performed on 78.5% of cases located on the head and neck, as compared to 21.5% of cases located on the torso and extremities. The most common sites of

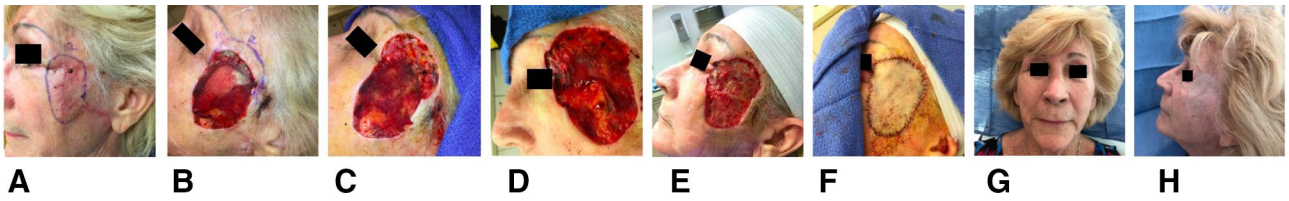

Fig. 1 Staged excision technique. An 80-year-old female with MIS on the left cheek. Four excisions were required for tumor clearance, and the final surgical margin was 2 cm. The defect was repaired with a full-thickness skin graft. **A** Initial margins are marked circumferentially along the periphery of the clinical lesion. **B** Visible lesion and margins are excised. **C**–**E** Re-excision is performed in cases of positive margins. **F** Repair is performed following histopathologic tumor clearance. Columns **G**, **H** Follow-up 4-months post-operatively

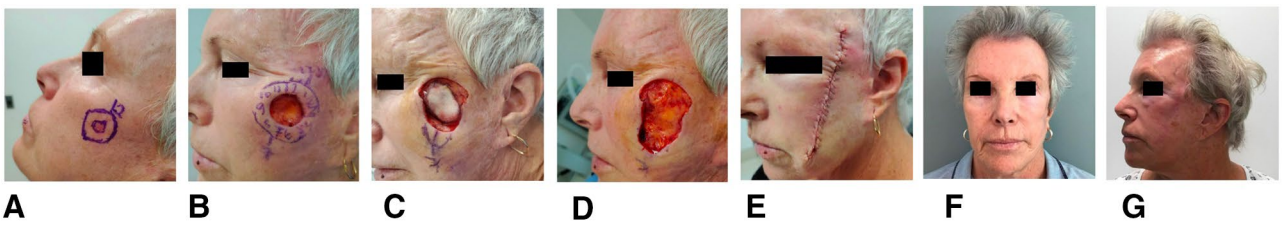

Fig. 2 Staged excision technique. A 77-year-old female with MIS of the left cheek. Three excisions were required for tumor clearance, and the final surgical margin was 2.3 cm. The defect was repaired was a complex linear closure. **A** Initial margins are marked circumferentially along the periphery of the clinical lesion. **B** Visible lesion and margins are excised. **C**, **D** Re-excision is performed in cases of positive margins. **E** Repair is performed following histopathologic tumor clearance. **F**, **G** Follow-up 1 year post-operatively

lesions were the cheek (29.2%), followed by the nose (10.8%) and scalp (9.2%).

Treatment

The mean pre-operative lesion size was 1.5 cm × 1.1 cm (Table 1). The mean final surgical margin to clearance was 0.79 cm. Tumor clearance was obtained with final surgical margins of 0.5 cm in 47% cases and 0.6–1 cm in 45% cases. In 9% cases, > 1 cm margins were excised to obtain tumor clearance.

Positive surgical margins were identified in 18% of cases following initial excision with margins ≥ 0.5 cm. The mean number of excisions to histologically clear the tumor was 1.23 excisions. Upstaging at the time of staged excision occurred in 4% of cases, from atypical intraepidermal melanocytic proliferation (AIMP) to MIS.

The mean follow-up was 19.5 months. There were no reported recurrences.

Reconstruction

The mean post-operative defect size was 3.2 cm × 2.8 cm. Complex repairs, defined as cutaneous flaps, were performed on 64% (82) of cases (Table 1). The most common repair methods were advancement flap (28.5%) followed by rotation flaps (17.7%).

Complex repairs were more commonly performed on the head and neck (75%; 76) as compared to the extremities and torso (21%; 6) (Table 3). The cheek, nose, and scalp were the most common sites of staged excision, and complex repairs were performed on 86.9% of cases located on the cheek, 85.7% of cases on the nose, and 41.7% of cases on the scalp.

Invasive melanoma

Patient and tumor characteristics

Staged excision was performed for 32 patients with IM (Table 2). Two cases (6%) represented recurrent tumors, while 30 (94%) were primary tumors.

The majority of patients who had staged excision for IM had T1a disease (78%, 25), with 6% of patients with stage T1b (2), 13% with T2a (4) and 3% (1) with stage T2b. The mean BD among our patient population was 0.6 mm and the median BD was 0.45 mm.

Staged excision was performed on 72% of cases located on the head and neck, as compared to 28% of cases on the torso and extremities. The most common sites of lesions were the cheek, with 21.8% (7) of total cases, and the scalp at 21.8% (7).

Table 1 Patient demographics and tumor characteristics of melanoma in situ cases

Variable	*n* (SD or %)
Number of cases	130
Sex	
Male	79 (61%)
Female	51 (39%)
Fitzpatrick	
I	33 (25%)
II	73 (56%)
III	15 (12%)
IV	7 (5%)
V	1 (1%)
VI	1 (1%)
Presentation	
Recurrent	4 (3%)
Primary	126 (97%)
Location of tumor	
Head and neck	102 (78.5%)
Cheek	38 (29%)
Chin/jawline	3 (2%)
Ear	8 (6%)
Eyebrow	4 (3%)
Eyelid	2 (2%)
Forehead	9 (7%)
Lip	2 (2%)
Neck	1 (1%)
Nose	14 (11%)
Postauricular	2 (2%)
Preauricular	2 (2%)
Scalp	12 (9%)
Temple	5 (4%)
Torso and extremities	28 (21.5%)
Arm	8 (6%)
Foot	10 (8%)
Hand	2 (2%)
Leg	5 (4%)
Trunk	3 (2%)
Age at excision (years)	Mean 69 (13.4), median 72 (range 30–97)
Mean pre-operative size (cm)	1.5 (1.0) × 1.1 (0.59)
Mean post-operative size (cm)	3.2 (1.4) × 2.8 (1.2)
Positive margins	23 (18%)
Margins to clearance (cm)	
Mean	0.79 (0.4)
0.5	61 (47%)
0.6–1.0	58 (45%)
1.1–2.0	9 (7%)
2.1–3.0	2 (2%)
Excisions to clearance	
Mean	1.23 (0.59)
1	107 (82%)
2	19 (15%)
3	2 (2%)
4	1 (1%)
5	1 (1%)
Upstaging	5 (4%)
Method of repair	
Complex linear	17 (13%)
Xenograft	15 (12%)
Full thickness skin graft	11 (9%)
Secondary Intention	4 (3%)
Transposition flap	5 (4%)
Advancement flap	37 (29%)
Interpolation flap	17 (13%)
Rotation flap	23 (18%)
Follow-up duration (mon)	Mean 19.5 (23.7)
Recurrence	0

Treatment

The mean pre-operative lesion size was 1.7 cm × 1.4 cm (Table 2). The mean surgical margin to clearance was 1.15 cm. Final surgical margins were further assessed based upon BD. Among IM cases with a tumor thickness of 0–1 mm, 22% cases required > 1 cm margins to obtain clearance. Among IM cases with a tumor thickness of 1-2 mm, 100% of cases obtained tumor clearance with margins < 2 cm.

Positive margins were identified in 22% of cases following initial staged excision. The mean number of excisions to tumor clearance was 1.34 excisions and the median number of excisions was 1. Upstaging occurred in 22% of IM cases. Two cases (6%) of IM had increased depth noted following staged excision, but they did not meet criteria for upstaging according to AJCC 8th edition staging system.

The mean follow-up was 18 months. There was 1 case of recurrence that occurred 20 months following staged excision. Both primary and recurrent tumors were stage 1a disease. The patient underwent another staged excision with no evidence of recurrence at 15.4 months. There was 1 (3%) case of metastases in a patient with stage T2a disease. Liver metastases were identified 3 years following staged excision and were treated successfully with pembrolizumab.

Reconstruction

The mean post-operative size was 4.0 cm × 3.3 cm. Complex repairs were performed on 53% (17) of cases (Table 2). The

Table 2 Patient demographics and tumor characteristics of invasive melanoma cases

Variable	*n* (SD or %)
Number of cases	32
Sex	
Male	20 (63%)
Female	12 (38%)
Fitzpatrick	
I	5 (16%)
II	20 (63%)
III	7 (22%)
IV	0 (0%)
V	0 (0%)
VI	0 (0%)
Presentation	
Recurrent	2 (6%)
Primary	30 (94%)
Final stage of IM	
T1a	25 (78%)
T1b	2 (6%)
T2a	4 (13%)
T2b	1 (3%)
Breslow depth (mm)	Mean 0.6 (0.4), median 0.5 (range 0.19–2.0)
Characteristics	
Ulceration	1 (3%)
Mitotic Index > 1	3 (9%)
Tumor regression	4 (13%)
Lymphovascular invasion	0 (0%)
Perineural invasion	1 (3%)
Location of tumor	
Head and neck	23 (72%)
Cheek	7 (22%)
Ear	3 (9%)
Eyelid	2 (6%)
Forehead	3 (9%)
Scalp	7 (22%)
Temple	1 (3%)
Torso and extremities	9 (28%)
Arm	2 (6%)
Leg	4 (13%)
Trunk	3 (9%)
Age at excision (years)	Mean 57 (10.8), median 74 (range 56–96)
Mean pre-operative size (cm)	1.7 (1.1) × 1.4 (1.0)
Mean post-operative size (cm)	4.0 (1.4) × 3.3 (1.1)
Positive margins	7 (22%)
Margins to clearance (cm)	
Mean	1.15
0.5	2 (6%)
0.6–1.0	22 (69%)
1.1–2.0	7 (22%)
2.1–3.0	1 (3%)
Margins to clearance based upon breslow depth	
0–1 mm	
< 1 cm margins	21 (78%)
> 1 cm margins	6 (22%)
1–2 mm	
< 2 cm margins	5 (100%)
> 2 cm margins	0 (0%)
Excisions to clearance	
Mean	1.34 (0.8)
1	25 (78%)
2	5 (16%)
3	1 (3%)
4	0 (0%)
5	1 (3%)
Upstaging	7 (22%)
Increased depth during excision	2 (6%)
Method of repair	
Complex linear	2 (6%)
Xenograft	10 (31%)
Full thickness skin graft	3 (9%)
Secondary intention	0 (0%)
Transposition flap	2 (6%)
Advancement flap	11 (34%)
Interpolation flap	3 (9%)
Rotation flap	1 (3%)
Follow-up duration (mon)	Mean 18 (18.6)
Recurrence	1 (3%)
Metastases	1 (3%)

most common method of repair was advancement flap, with 34% (11) of total cases.

The cheek and scalp were the most common sites of staged excision. Complex repairs were performed on 85.7% of cases located on the cheek. All scalp tumors (7, 100%) were treated with xenograft. Complex repairs were performed on the face and neck in 75% of cases, as compared to the extremities and torso in 56% of cases.

Discussion

Staged excision offers many advantages over wide local excision, including effective margin control, lower recurrence rates, and limiting re-excision of repaired defects. With good communication between surgeons and dermatopathologists, staged excisions offer a relatively simple technique to perform and can be executed in a variety of surgical settings.

Table 3 Tumor characteristics based upon location of tumor for melanoma in situ and invasive melanoma cases

Variable	Head and neck (*n*, SD or %)	Torso and extremities (n, SD or %)
Melanoma in situ		
Number of cases	102 (79%)	28 (22%)
Mean pre-operative lesion size (cm)	1.3 (1.6) × 1.1 (0.5)	2 (1.5) × 1.3 (0.8)
Recurrent tumors	–	4 (14%)
SE performed after standard excision with + margins	3 (3%)	9 (32%)
Positive margins during SE	12 (12%)	11 (29%)
Mean surgical margins to clearance (cm)	0.78 (0.41)	0.86 (0.4)
Cases requiring greater than recommended margins	9 (9%)	2 (7%)
Upstaging	2 (2%)	3 (11%)
Reconstruction		
Complex Linear	11 (11%)	6 (22%)
Xenograft	6 (6%)	9 (32%)
Full thickness skin graft	7 (7%)	4 (14%)
Secondary intent	1 (1%)	3 (11%)
Advancement flap	32 (32%)	5 (18%)
Transposition flap	5 (5%)	–
Interpolation flap	17 (17%)	–
Rotation flap	22 (22%)	1 (4%)
Invasive melanoma		
Number of cases	23 (72%)	9 (28%)
Mean pre-operative lesion size (cm)	1.4 (1.1) × 1.2 (0.81)	2.3 (0.86) × 2 (1.3)
Recurrent tumors	2 (9%)	–
SE performed after standard excision with + margins	1 (4%)	1 (11%)
Positive margins during SE	5 (22%)	2 (22%)
Mean surgical margins to clearance (cm)	1.2 (0.46)	1.1 (0.42)
Cases requiring greater than recommended margins	4 (17%)	2 (22%)
Upstaging during SE	5 (22%)	2 (22%)
Reconstruction		
Complex linear	1 (4%)	1 (11%)
Xenograft	8 (35%)	2 (22%)
Full thickness skin graft	2 (9%)	1 (11%)
Secondary intent	–	–
Advancement flap	7 (30%)	4 (44%)
Transposition flap	1 (4%)	1 (11%)
Interpolation flap	3 (13%)	-
Rotation flap	1 (4%)	-

SE, staged excision; +, positive

Additionally, benefits of the staged excision procedure are that it does not require additional resources, surgical or dermatopathology skills, or personnel when compared to wide local excision or MMS. Moreover, all initial margins were within the recommended guidelines, with full intention of tumor clearance on first excision.

A significant portion of our cases occurred in areas of cosmetically sensitive and chronically photodamaged skin, such as the head, neck (102, 79%). MIS and IM arising in these locations have been associated with higher rates of subclinical extension, leading to positive margins and re-excisions [1, 5, 11]. Staged excision was chosen as an ideal surgical treatment for these challenging cases to ensure histopathological tumor clearance prior to reconstruction. Re-excising positive margins before repair, especially in cosmetically sensitive areas, may also improve cosmetic and functional outcomes.

While previous studies have highlighted using staged excision for cutaneous melanoma on the head and neck, this study uniquely assesses its use among cases located on the torso and extremities [4, 8, 15] (Table 3, Fig. 3). A large subset of our torso and extremity cases were characterized

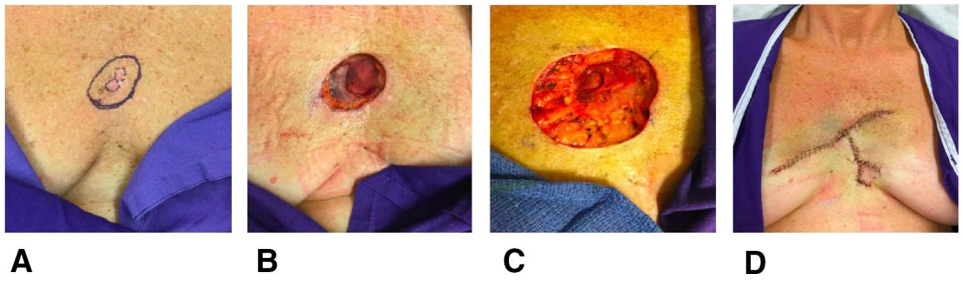

Fig. 3 Staged excision technique. A 56-year-old female with IM (stage T1a) of the right chest. Two excisions were required for tumor clearance, and the final surgical margin was 1.5 cm. The defect was repaired with an advancement flap. **A** Initial margins are marked circumferentially along the periphery of the clinical lesion. **B** Visible lesion and margins are excised. **C** Re-excision is performed in case of positive margins. **D** Repair is performed following histopathologic tumor clearance

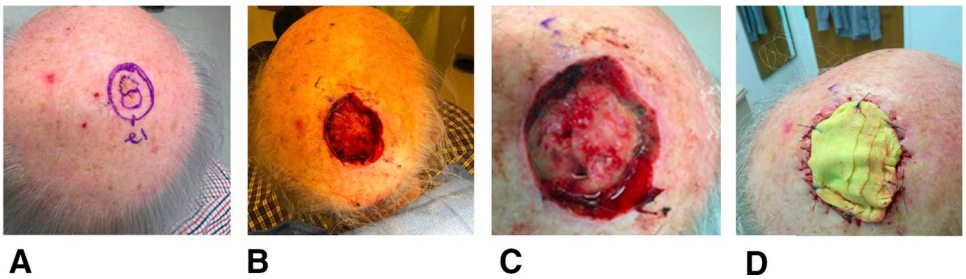

Fig. 4 Staged excision technique. A 76-year-old male with MIS on the right scalp. Two excisions were required for tumor clearance, and the final surgical margin was 1.2 cm. The defect was repaired with a full-thickness skin graft. **A** Initial margins are marked circumferentially along the periphery of the clinical lesion. **B** Visible lesion and margins are excised. **C** Re-excision is performed in case of positive margins. **D** Repair is performed following histopathologic tumor clearance

by large tumor burden defined by greater than 2 cm, recurrent tumors, and tumors requiring re-excision following positive margins with standard excision. Staged excision was also chosen for more complex cases, such as one case in which a MIS occurred within a nevus spilus on the arm. Furthermore, after performing staged excisions we found high rates of positive margins, upstaging, and cases requiring larger margins than currently recommended. There were no cases of recurrence among tumors on the torso and extremities, further signifying the effectiveness of using staged excision to treat challenging cases on the torso and extremities.

Our findings support previous data demonstrating that the currently recommended margins for MIS and superficially IM may be inadequate [3, 6]. Among our MIS cases, 53% required surgical margins > 5 mm to obtain tumor clearance (Fig. 4). This is similar to previous studies showing 22–58% of lesions required > 5 mm for tumor clearance [6, 7, 13]. Moreover, our study revealed that 9% of MIS cases required > 1 cm margins, which is above the NCCN recommended guidelines for wide local excision. These data are also further supported by prior studies in which 21% and 26% of cases required > 1 cm margins for tumor clearance [3, 8].

Among our MIS cases, a larger pre-operative lesion size was associated with larger final surgical margins (Spearman correlation coefficient 0.30, $p = 0.004$), greater number of excisions (Spearman correlation coefficient 0.24, $p = 0.0057$), positive margins (Wald χ^2 $p \leq 0.004$), and upstaging (Wald χ^2 $p \leq 0.0001$) (Table 4, 5). Our study also revealed a mean final surgical margin of 0.8 cm. Therefore, when determining initial surgical margins, it is important to consider pre-operative lesion size and recognize that margins to tumor clearance may be closer to 1 cm as opposed to 5 mm. In cosmetically sensitive areas where initially excised margins are closer to 5 mm, staged excision allows for the opportunity to ensure tumor clearance prior to repair.

Like MIS, previous studies have shown that the recommended margins for IM may be insufficient in a subset of cases. A recent study evaluated 69 IM cases (stage T1a and T1b) with an average BD of 0.41 mm. The average margin size for histopathologic clearance was 19.8 mm, which is almost 1 cm above the recommended guidelines with wide local excision [8]. Our study further supports these findings. In our cases of IM with BD of 0–1 mm, the average margin size of histopathologic clearance was 11.4 mm. Additionally, 22% (6/27) of these cases required > 1 cm margins).

Table 4 Relationship of lesion size and Breslow depth to final surgical margin, number of excisions to clearance, upstaging, and positive margins among melanoma in situ and invasive melanoma cases

Variable	Number of patients (*n*, % of total MIS or IM cases)	Mean surgical margins	Mean number of excisions	Upstaging (*n*, % of lesion size)	Positive Margins (*n*, % of lesion size)
Melainoma in situ					
Largest diameter of lesion (mm)					
≤5	9 (7%)	7.22	1.11	–	1 (11%)
5–10	47 (36%)	6.98	1.09	1 (2%)	3 (6%)
10–20	53 (41%)	7.98	1.25	3 (6%)	10 (19%)
20–30	15 (12%)	9.27	1.27	–	4 (47%)
30–40	3 (2%)	16.67	2.33	–	2 (67%)
40–50	3 (2%)	8.67	2.33	1 (33%)	3 (100%)
Invasive melanoma					
Largest diameter of lesion (mm)					
≤5	3 (10%)	13.33	1.00	1 (33%)	–
5–10	14 (44%)	10.93	1.36	2 (14%)	2 (14%)
10–20	7 (22%)	13.00	1.43	1 (14%)	3 (43%)
20–30	5 (16%)	11.00	1.20	1 (20%)	1 (20%)
>30	3 (9%)	10.00	1.67	2 (67%)	1 (33%)
Breslow depth (mm)					
≤0.5	20 (63%)	1.08	1.20	3 (15%)	3 (15%)
>0.5	12 (38%)	1.28	1.58	4 (33%)	4 (33.3%)

Table 5 Characteristics of patients with negative and positive excision margins for melanoma in situ and invasive melanoma

Variable	Negative margins	Positive margins
Melanoma in situ		
Number of cases	107 (82%)	23 (18%)
Age, years	72 (30–97); 69 (14)	71 (42–91); 69 (12.7)
Largest diameter (cm)	1.2 (0.5–4.0); 1.4 (0.7)	1.6 (0.5–5.7); 2.4 (1.6)
Margins to clearance (cm)	0.65 (0.5–1); 0.69 (0.2)	0.7 (0.5–2.8); 1.3 (0.6)
Number of excisions to clearance	1	1 (2–5); 2.3 (0.8)
Location		
Head and neck	81 (76%)	12 (52%)
Extremities and torso	26 (24%)	11 (48%)
Invasive melanoma		
Number of cases	25 (78%)	7 (22%)
Age, years	74 (56–96); 75 (10.3)	74 (56–88); 75 (13.2)
Largest diameter (cm)	1 (0.4–5); 1.6 (1.1)	2 (1–5); 2.3 (1.4)
Margins to clearance (cm)	1 (0.5–2); 1 (0.25)	1.5 (1–2.8); 1.7 (0.57)
Number of excisions to clearance	1	2 (2–5); 2.6 (1.1)
Location		
Head and neck	18 (72%)	5 (72%)
Extremities and torso	7 (28%)	2 (29%)

*Median (range); mean (SD)

In our IM cases, there was a positive correlation between larger pre-operative lesion size and increased upstaging (Wald χ^2 $p \leq 0.014$) and positive margins (Wald χ^2 $p \leq 0.0083$) (Table 4, 5). There was no statistically significant correlation between pre-operative lesion size and final surgical margins or numbers of excisions. There was no statistically significant correlation between BD and final surgical margins, number of excisions, upstaging, or positive margins.

In our study, there were no recurrences in the MIS cohort and one recurrence in the IM cohort over a mean follow-up duration of 19.2 months. Our low rate of recurrence is comparable to other studies using staged excision for the treatment of cutaneous melanoma. Previously

reported recurrence rates after staged excision ranged from 0 to 12% [1, 4–6, 10–24]. Our mean follow-up duration of 19.2 months is within the mean range of previously reported durations ranging from 4.7 to 96 months [1, 3–7, 10, 12–14, 20]. Furthermore, a systematic review and meta-analysis found that local recurrence rates of MIS and IM were 2.5 times higher after wide local excision when compared to staged excision, further highlighting the benefits of staged excision [9].

Another unique aspect of our study was assessing repair methods commonly performed after staged excision. A large proportion of our cases required local or interpolation flap repairs. This was likely a result of staged excisions being commonly performed on cosmetically sensitive and technically challenging locations. In addition, 7% of patients had upstaging of disease and 10% of patients required larger margins greater than the current recommendations, leading to larger defects and more complex repairs.

Limitations include that this is a retrospective, single-institution chart review study with an average follow-up duration of 19.2 months. Multicenter prospective studies with larger sample sizes comparing staged excision to wide local excision and MMS would be recommended for future studies.

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Declarations

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References

1. Johnson TM et al (1997) Usefulness of the staged excision for lentigo maligna and lentigo maligna melanoma: the "square" procedure. J Am Acad Dermatol 37(5 Pt 1):758–764. https://doi.org/10.1016/s0190-9622(97)70114-2
2. Swetter SM et al (2021) NCCN Guidelines® insights: melanoma: cutaneous, Version 2.2021. J Natl Compr Canc Netw 19(4):364–376. https://doi.org/10.6004/jnccn.2021.0018
3. Ahn GS et al (2022) No Recurrence in primary invasive stage 1a and 1b melanoma and melanoma in situ treated with serial disk staged excision. Dermatol Surg 48(3):276–282. https://doi.org/10.1097/dss.0000000000003357
4. Möller MG et al (2009) Surgical management of melanoma-in-situ using a staged marginal and central excision technique. Ann Surg Oncol 16(6):1526–1536. https://doi.org/10.1245/s10434-008-0239-x
5. Bosbous MW, Dzwierzynski WW, Neuburg M (2009) Staged excision of lentigo maligna and lentigo maligna melanoma: a 10-year experience. Plast Reconstr Surg 124(6):1947–1955. https://doi.org/10.1097/PRS.0b013e3181bcf002
6. Huilgol SC et al (2004) Surgical margins for lentigo maligna and lentigo maligna melanoma: the technique of mapped serial excision. Arch Dermatol 140(9):1087–1092. https://doi.org/10.1001/archderm.140.9.1087
7. Garcia D, Eilers RE, Jiang SB (2017) Recurrence rate of melanoma in situ when treated with serial disk staged excision: a case series. J Clin Investig Dermatol. https://doi.org/10.13188/2373-1044.1000037
8. Moyer JS et al (2017) Efficacy of staged excision with permanent section margin control for cutaneous head and neck melanoma. JAMA Dermatol 153(3):282–288. https://doi.org/10.1001/jamadermatol.2016.4603
9. Pride RLD et al (2022) Local recurrence of melanoma is higher after wide local excision versus Mohs micrographic surgery or staged excision: a systematic review and meta-analysis. Dermatol Surg 48(2):164–170. https://doi.org/10.1097/dss.0000000000003309
10. Walling HW et al (2007) Staged excision versus Mohs micrographic surgery for lentigo maligna and lentigo maligna melanoma. J Am Acad Dermatol 57(4):659–664. https://doi.org/10.1016/j.jaad.2007.02.011
11. Reynolds HH et al (2020) Efficacy of staged excision with permanent section margin control for melanoma in situ. J Am Acad Dermatol 83(4):1163–1164. https://doi.org/10.1016/j.jaad.2020.05.103
12. Bub JL et al (2004) Management of lentigo maligna and lentigo maligna melanoma with staged excision: a 5-year follow-up. Arch Dermatol 140(5):552–558. https://doi.org/10.1001/archderm.140.5.552
13. Agarwal-Antal N, Bowen GM, Gerwels JW (2002) Histologic evaluation of lentigo maligna with permanent sections: implications regarding current guidelines. J Am Acad Dermatol 47(5):743–748. https://doi.org/10.1067/mjd.2002.124085
14. Hill DC, Gramp AA (1999) Surgical treatment of lentigo maligna and lentigo maligna melanoma. Australas J Dermatol 40(1):25–30. https://doi.org/10.1046/j.1440-0960.1999.00311.x
15. Anderson KW et al (2001) Treatment of head and neck melanoma, lentigo maligna subtype: a practical surgical technique. Arch Facial Plast Surg 3(3):202–206. https://doi.org/10.1001/archfaci.3.3.202
16. Malhotra R et al (2003) Mapped serial excision for periocular lentigo maligna and lentigo maligna melanoma. Ophthalmology 110(10):2011–2018. https://doi.org/10.1016/s0161-6420(03)00670-5
17. Mahoney MH, Joseph M, Temple CL (2005) The perimeter technique for lentigo maligna: an alternative to Mohs micrographic surgery. J Surg Oncol 91(2):120–125. https://doi.org/10.1002/jso.20284
18. Albertini JG et al (2002) Mohs micrographic surgery for melanoma: a case series, a comparative study of immunostains, an informative case report, and a unique mapping technique. Dermatol Surg 28(8):656–665. https://doi.org/10.1046/j.1524-4725.2002.02024.x
19. Lee MR, Ryman WJ (2008) Treatment of lentigo maligna with total circumferential margin control using vertical and horizontal

permanent sections: a retrospective study. Australas J Dermatol 49(4):196–201. https://doi.org/10.1111/j.1440-0960.2008.00468.x
20. Joyce KM et al (2015) An assessment of histological margins and recurrence of melanoma in situ. Plast Reconstr Surg Glob Open 3(2):e301. https://doi.org/10.1097/gox.0000000000000272
21. de Vries K et al (2016) Recurrence rate of lentigo maligna after micrographically controlled staged surgical excision. Br J Dermatol 174(3):588–593. https://doi.org/10.1111/bjd.14325
22. Patel AN et al (2014) Johnson square procedure for lentigo maligna and lentigo maligna melanoma. Clin Exp Dermatol 39(5):570–576. https://doi.org/10.1111/ced.12363
23. Lawrence CM et al (2014) Prospective study of formalin-fixed Mohs surgery and haematoxylin and eosin stains with control contralateral biopsies for lentigo maligna: 5-year follow-up results. Br J Dermatol 171(2):298–303. https://doi.org/10.1111/bjd.12841
24. Gaudy-Marqueste C et al (2011) The "spaghetti technique": an alternative to Mohs surgery or staged surgery for problematic lentiginous melanoma (lentigo maligna and acral lentiginous melanoma). J Am Acad Dermatol 64(1):113–118. https://doi.org/10.1016/j.jaad.2010.03.014