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Gabor-domain optical coherence tomography to aid in Mohs resection of basal cell carcinoma

To the Editor: Optical coherence tomography (OCT) has been used as a noninvasive imaging technique to guide initial tumor margin delineation before Mohs microscopic surgery.[1] In this study, we evaluated the ability of Gabor-domain optical coherence microscopy (GD-OCM) to assist Mohs surgeons in predicting and reducing the number of stages required for tumor clearance. GD-OCM is an advanced version of OCT that achieves invariant lateral and depth resolution of 2 μm throughout the imaged volume.[2] Unlike other commercial OCT systems (Table I),[1] GD-OCM provides cellular resolution in cross-sectional and en-face images, helping to delineate subclinical basal cell carcinomas. The ability of GD-OCM to guide diagnosis of nonmelanoma skin cancers as a hand-held device has been previously validated with ex vivo samples.[3,4]

Twenty-eight patients undergoing Mohs microscopic surgery for biopsy-proven basal cell carcinoma were enrolled. For each tumor, the surgeon drew a clinical margin to outline the first stage (Fig 1, *A*). An imaging scientist then placed steristrips on the drawn margin orientations (at 3, 12, 9, and 6 o'clock) to serve as references for image collection. As anatomic location allowed, 6 images were collected along the 4 margin orientations

Table I. OCT systems comparison

System	Light source bandwidth	Imaging depth, mm	Lateral resolution, μm	Axial/ vertical resolution, μm	Field of view, mm	Ascan rate, kHZ	Contact	Handheld	FDA cleared
VivoSight OCT (Michelson Diagnostics, Orpington, UK)	1305 nm	<2	7.5	5	6 × 6	20	No	Yes	Yes
Callisto (Thorlabs, Newton, NJ)	930 nm	1.3	8	5.3	10 × 10	1.2	No	No	No
GD-OCM 4D.R0/R15 (LighTopTechWest Henrietta, NY)	840 nm	1.6	2.85	2.6	1.5 × 1.5	81	Either	Yes	No
Light-CT Scanner (LLTech, Princeton, NJ)	700 nm	1	1.5	1	1.3 × 1.3	FF-OCT NA/en-face	Silicone oil	No	No

Adapted from Cheng et al.[1]

FDA, Food and Drug Administration; *FF-OCT*, full-field optical coherence tomography; *GD-OCM*, Gabor-domain optical coherence microscopy; *NA*, not applicable; *OCT*, optical coherence tomography.

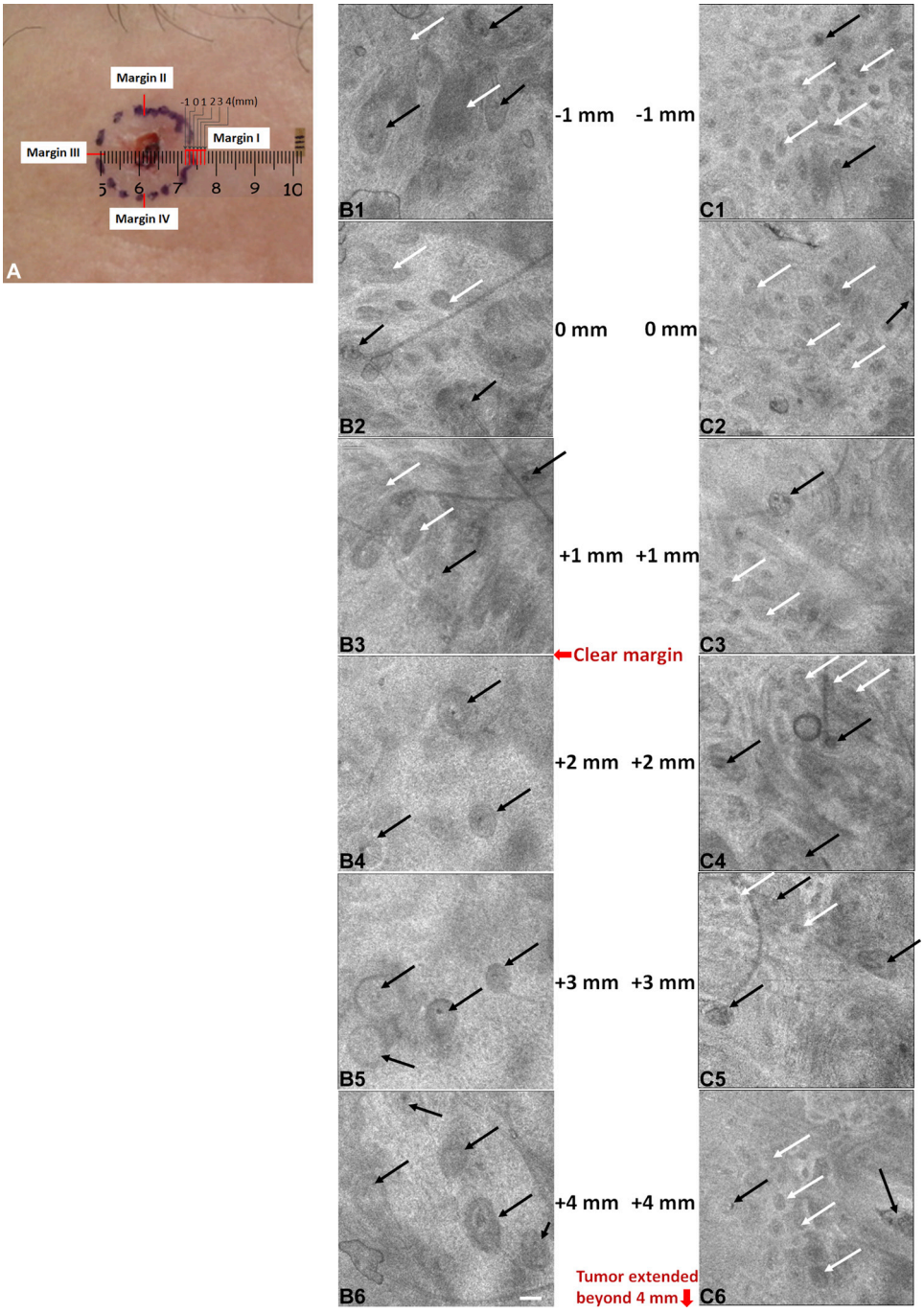

Fig 1. A, Biopsy-proven basal cell carcinoma (BCC) outlined during Mohs procedure. The inked margin surrounding the tumor represents the marked and drawn margin by the surgeon. Margins I-IV are defined at 3, 12, 9, and 6 o'clock, respectively. A ruler straddling the drawn margin provides reference for Gabor-domain optical coherence microscopy (GD-OCM) images. A steri-strip is positioned 27 mm from the ink on margin I to serve as a reference mark for GD-OCM image analysis after the Mohs procedure. 3D images with a field of view of 1 mm^2 were captured every millimeter for 6 mm, starting from 1 mm inside the drawn margin up to 4 mm outside. **B** and **C**, GD-OCM en-face images of 2 biopsy-proven BCCs. **B1-B6** and **C1-C6**, Six different locations collected along 1 margin. The slices represent the cut through the anterior dermis. *White* and *black arrows* represent tumors and hair follicles, respectively. The first case (**B**) is a nodular BCC in which the real tumor margin was identified 1-2 mm from the drawn margin (**B3** and **B4**). The second case (**C**) is a superficial BCC in which the tumor extended beyond 4 mm from the drawn margin. Bar represents 100 μm.

Table II. Patient and tumor characteristics

Category	Value	%
Patients enrolled, n	28	
Patients with incomplete data, n	8	
Total biopsies diagnosed as BCC, n	20	
Male	13	65
Female	7	35
Average patient age, y	69.1	
Tumor location, n		
Forehead	8	40
Cheeks	7	35
Temple	2	10
Lower extremities	3	15
Tumor subtypes, n		
Nodular	15	75
Infiltrative	2	10
Not specified	3	15
Total margins examined, n	38	

BCC, Basal cell carcinoma.

(Fig 1, *B* and *C*). After image collection, the surgeon completed a standard Mohs procedure without any prior knowledge of the imaging outcome. If the surgeon began to curette and felt tumor extending beyond what was initially visible and drawn, he included up to an additional 2 mm of tissue beyond the drawn margin. When surgery was complete, the distance between the final margin and the steri-strip reference marks was measured for comparison with GD-OCM margin images.

Due to motion during image collection, 8 of 28 patients had uninterpretable GD-OCM images. In total, 20 patients with 38 margin orientations ($6 \times 38 = 228$ GD-OCM images) were examined by 2 authors (Drs Tankam and Soh) and compared with frozen-section histology (Table II; Fig 2). In 25 of 38 (65.8%) cases, GD-OCM image review revealed tumor within the final surgical margin. In the remaining 13 (34.2%) cases, the GD-OCM images were interpreted as tumor outside of the final histology margin. In 11 of 11 cases requiring multiple stages, the GD-OCM images revealed tumor beyond 2 mm of the drawn clinical margin; from this, we inferred that an additional Mohs stage would be required. The GD-OCM–determined margin and the final surgical margin were within ±1 mm of agreement in 23 of 38 (60.5%) cases.

In this study, GD-OCM was shown to be able to guide margin delineation while planning initial stages for Mohs surgery. In 100% of cases that required multiple stages; GD-OCM data suggested that a single initial stage (ie, clinical margin +2 mm) would be insufficient. This study is limited by the interpretation and acquisition of the images; in ~34% of cases GD-OCM images revealed tumor outside of the final histologic margin. In these cases, benign structures were misinterpreted as malignant. With standardized training, user interpretation skills can be honed. Another challenge was the motion artifact leading to unreadable images. Last, our inability to collect images on all 4 margin orientations due to the complexity of the anatomic location of the tumor can be addressed with a noncontact probe, which will come at the expense of increased motion artifacts.

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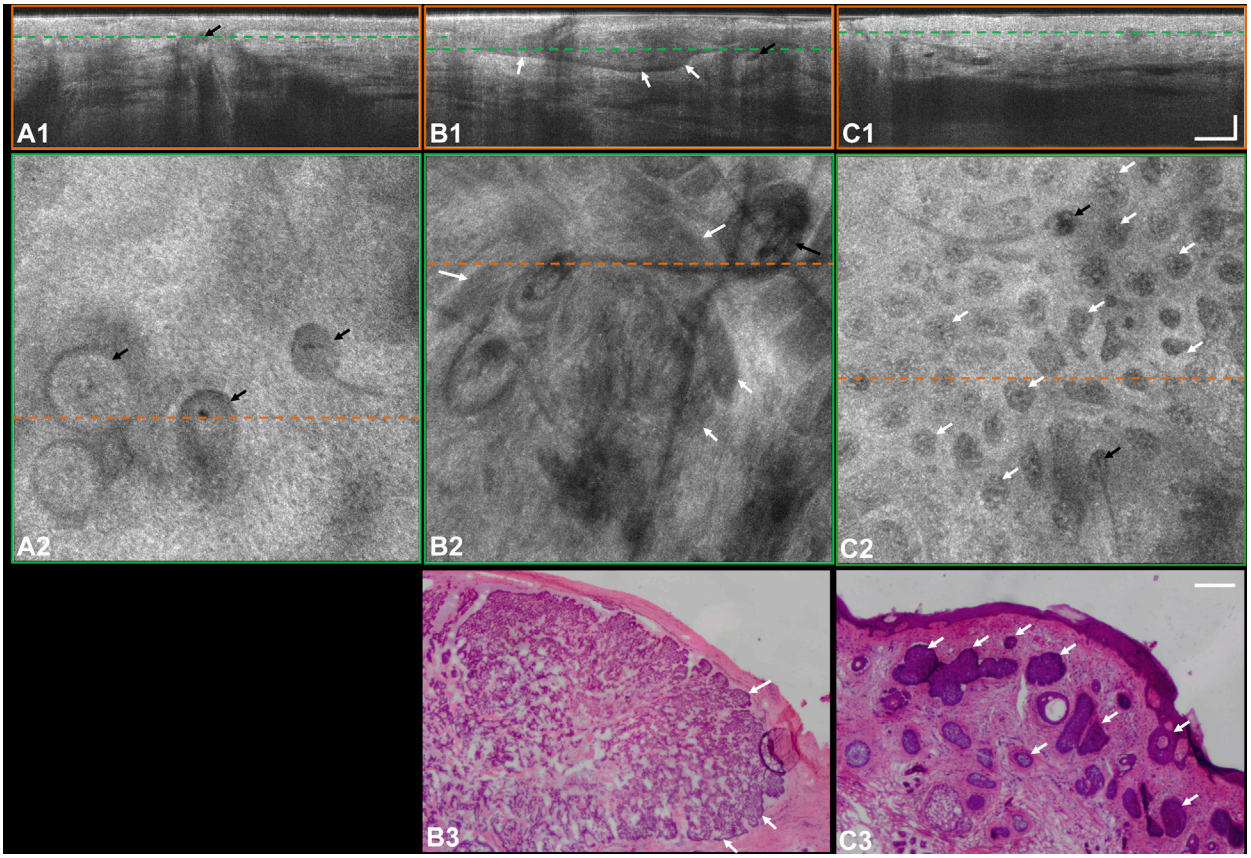

Fig 2. Gabor-domain optical coherence microscopy (GD-OCM) cross-section (parallel to optical axis) and en-face image (perpendicular to optical axis) comparison of healthy skin (**A**), nodular basal cell carcinoma (BCC) (**B**), and superficial BCC (**C**). The superficial BCC case was reported as not specified on the original biopsy (Table I).[1] *White* and *black arrows* represent tumors and hair follicles, respectively. *Green dashed lines* on the cross-section images (**A1**, **B1**, and **C1**) represent the cut-through locations of the en-face images (**A2**, **B2**, and **C2**, respectively). *Orange dashed lines* on the en-face images (**A2**, **B2**, and **C2**) represent the cut-through locations of the cross-section images (**A1**, **B1**, and **C1**, respectively). Unlike the nodular BCC, where the cross-section image clearly shows a nodule of tumor (**B1**), tumor can be barely identified in the cross-section image of the superficial BCC (**C1**). In this case, viewing the en-face image was critical to confirming the presence of tumor (**C2**). **B3** and **C3**, Histologic staining of slices from the corresponding patients. Video-nodular-BCC and Video-superficial-BCC show the 3D images of cases B and C. Bar represents 100 μm.

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Trends in the incidence and survival of eccrine malignancies in the United States: A SEER population-based study

To the Editor: Eccrine malignancies are rare cutaneous tumors that are incompletely described on a population level.[1] In addition, little information exists regarding differences in the clinical characteristics of eccrine malignancies among different demographic groups.[2] The objective of this study is to elucidate trends in the incidence, clinical characteristics, and mortality of primary eccrine malignancies using the National Cancer Institute's Surveillance,