

Optical Coherence Tomography in Dermatology



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PRACTICE POINTS

- Optical coherence tomography (OCT) technology has considerable utility in research and clinical settings given its high resolution, wide field of view, moderate penetration depth, straightforward image acquisition, and accessibility to anatomically challenging areas.
- Potential benefits of OCT include its ability to non-invasively diagnose and monitor nonmelanoma skin cancers as well as to delineate presurgical margins and elucidate the course and mechanism of action of skin conditions at the bedside.
- Limitations of OCT include device cost, lack of reimbursement, and training, as well as restricted ability to image advanced deep tumors and differentiate melanocytic lesions.
- Optical coherence tomography recently received 2 category III *Current Procedural Terminology (CPT)* codes to track its utilization in clinical practice and will hopefully receive category I *CPT* codes within the next 5 years.

Optical coherence tomography (OCT), an emerging noninvasive imaging modality, recently received category III *Current Procedural Terminology (CPT)* codes from the American Medical Association, enabling tracking of its use in the medical community. In this article, we review OCT imaging and its variant systems, discussing its applications and limitations for clinical use. Future directions of OCT technology and goals for obtaining category I *CPT* codes and reimbursement also are discussed.

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Optical coherence tomography (OCT) is a noninvasive imaging technique that is cleared by the US Food and Drug Administration as a 510(k) class II regulatory device to visualize biological tissues

in vivo and in real time.¹⁻³ In July 2017, OCT received 2 category III *Current Procedural Terminology (CPT)* codes from the American Medical Association—0470T and 0471T—enabling physicians to report and track the usage of this emerging imaging method.⁴ Category III *CPT* codes remain investigational and therefore are not easily reimbursed by insurance.⁵ The goal of OCT manufacturers and providers within the next 5 years is to upgrade to category I coding before the present codes are archived. Although documented advantages of OCT include its unique ability to effectively differentiate and monitor skin lesions throughout nonsurgical treatment as well as to efficiently delineate presurgical margins, additional research reporting its efficacy may facilitate the coding conversion and encourage greater usage of OCT technology. We present a brief review of OCT imaging in dermatology, including its indications and limitations.

Types of OCT

Optical coherence tomography, based on the principle of low-coherence interferometry, uses infrared light to extract fine details from within highly scattering turbid media to visualize the subsurface of the skin.² Since its introduction for use in dermatology, OCT has been used to study skin in both the research and clinical settings.^{2,3} Current OCT devices on the market are mobile and easy

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to use in a busy dermatology practice. The Table reviews the most commonly used noninvasive imaging tools for the skin, depicting the inverse relationship between penetration depth and cellular resolution as well as field of view discrepancies.^{2,6-8} Optical coherence tomography technology collects cross-sectional (vertical) images similar to histology and en face (horizontal) images similar to reflective confocal microscopy (RCM) of skin areas with adequate cellular resolution and without compromising penetration depth as well as a field of view comparable to the probe aperture contacting the skin.

Conventional OCT—Due to multiple simultaneous beams, conventional frequency-domain OCT (FD-OCT) provides enhanced lateral resolution of 7.5 to 15 μm and axial resolution of 5 to 10 μm with a field of view of 6.0 \times 6.0 mm^2 and depth of 1.5 to 2.0 mm.^{2,6,8} Conventional FD-OCT detects architectural details within tissue with better cellular clarity than high-frequency ultrasound and better depth than RCM, yet FD-OCT is not sufficient to distinguish individual cells.

Dynamic OCT—The recent development of dynamic OCT (D-OCT) software based on speckle-variance has the added ability to visualize the skin microvasculature and therefore detect blood vessels and their distribution within specific lesions. This angiographic variant of FD-OCT detects motion corresponding to blood flow in the images and may enhance diagnostic accuracy, particularly in the differentiation of nevi and malignant melanomas.⁸⁻¹¹

High-Definition OCT—High-definition OCT (HD-OCT), a hybrid of RCM and FD-OCT, provides improved optical resolution of 3 μm for both lateral and axial imaging approaching a resolution similar to RCM making it possible to visualize individual cells, though at the expense of lower penetration depth of 0.5 to 1.0 mm and reduced field of view

of 1.8 \times 1.5 mm^2 to FD-OCT. High-definition OCT combines 2 different views to produce a 3-dimensional image for additional data interpretation (Table).^{7,8,12}

Current CPT Guidelines

Two category III CPT codes—0470T and 0471T—allow the medical community to collect and track the usage of the emerging OCT technology. Code 0470T is used for microstructural and morphological skin imaging, specifically acquisition, interpretation, and reading of the images. Code 0471T is used for each additional skin lesion imaged.⁴ *Current Procedural Terminology* category III codes remain investigational in contrast to the permanent category I codes. Reimbursement for CPT III codes is difficult because it is not generally an accepted service covered by insurance.⁵ The goal within the next 5 years is to convert to category I CPT codes, meanwhile the CPT III codes should encourage increased utilization of OCT technology.

Indications for OCT

Depiction of Healthy Versus Diseased Skin—Optical coherence tomography is a valuable tool in visualizing normal skin morphology including principal skin layers, namely the dermis, epidermis, and dermoepidermal junction, as well as structures such as hair follicles, blood vessels, and glands.^{2,13} The OCT images show architectural changes of the skin layers and can be used to differentiate abnormal from normal tissue in vivo.²

Diagnosis and Treatment Monitoring of Skin Cancers—Optical coherence tomography is well established for use in the diagnosis and management of nonmelanoma skin cancers and to determine clinical end points of nonsurgical treatment without the need for skin biopsy. Promising diagnostic criteria have been developed for

Comparison of Penetration Depth, Cellular Resolution, and Field of View Discrepancies of Noninvasive Imaging Devices Commonly Used in Dermatology^{2,6-8}

Noninvasive Imaging System	Wavelength	Penetration Depth, mm	Lateral Resolution, μm	Axial Resolution, μm	Field of View, mm^2
Frequency-domain OCT, dynamic OCT	930–1300 nm	1.5–2.0	7.5–15	5–10	6.0 \times 6.0
High-definition OCT	1300 nm	0.5–1.0	3.0	3	1.8 \times 1.5
Handheld RCM, wide-probe RCM ^a	445 nm, 658 nm, 785 nm	0.25–0.30	0.5–1.0	3–5	0.5 \times 0.5 (wide-probe RCM mosaic: 8.0 \times 8.0)
High-frequency ultrasound	20 MHz	8.0	350	50	12.0

Abbreviations: OCT, optical coherence tomography; RCM, reflectance confocal microscopy.

^aWide-probe RCM enables improved field of view by stitching smaller images together into a mosaic.

nonmelanoma skin cancers including basal cell carcinoma (BCC) and squamous cell carcinoma, as well as premalignant actinic keratoses using FD-OCT and the newer D-OCT and HD-OCT devices.⁹⁻¹⁷ For example, FD-OCT offers improved diagnosis of lesions suspicious for BCC, the most common type of skin cancer, showing improved sensitivity (79%–96%) and specificity (75%–96%) when compared with clinical assessment and dermoscopy alone.^{12,14} Typical OCT features differentiating BCC from other lesions include hyporeflexive ovoid nests with a dark rim and an alteration of the dermoepidermal junction. In addition to providing a good diagnostic overview of skin, OCT devices show promise in monitoring the effects of treatment on primary and recurrent lesions.¹⁴⁻¹⁶

In Vivo Excision Planning—Additionally, OCT is a helpful tool in delineating tumor margins prior to surgical resection to achieve optimal cosmesis. By detecting subclinical tumor extension, this preoperative technique has been shown to reduce the number of surgical stages. Pomerantz et al¹⁷ showed that mapping BCC tumor margins with OCT prior to Mohs micrographic surgery closely approximated the final surgical defects. Alawi et al¹⁸ showed that the OCT-defined lateral margins correctly indicated complete removal of tumors. These studies illustrate the ability of OCT to minimize the amount of skin excised without compromising the integrity of tumor-free borders. The use of ex vivo OCT to detect residual tumors is not recommended based on current studies.^{6,17,18}

Diagnosis and Treatment Monitoring of Other Diseases—Further applications of OCT include diagnosis of non-cancerous lesions such as nail conditions, scleroderma, psoriatic arthritis, blistering diseases, and vascular lesions, as well as assessment of skin moisture and hydration, burn depth, wound healing, skin atrophy, and UV damage.² For example, Aldahan et al¹⁹ demonstrated the utility of D-OCT to identify structural and vascular features specific to nail psoriasis useful in the diagnosis and treatment monitoring of the condition.

Limitations of OCT

Resolution—Frequency-domain OCT enables the detection of architectural details within tissue, but its image resolution is not sufficient to distinguish individual cells, therefore restricting its use in evaluating pigmented benign and malignant lesions such as dysplastic nevi and melanomas. Higher-resolution RCM is superior for imaging these lesions, as its device can better evaluate microscopic structures. With the advent of D-OCT and HD-OCT, research is being conducted to assess their use in differentiating pigmented lesions.^{8,20} Schuh et al⁹ and Gambichler et al²⁰ reported preliminary results indicating the utility of D-OCT and HD-OCT to differentiate dysplastic nevi from melanomas and melanoma in situ, respectively.

Depth Measurement—Another limitation is associated with measuring lesion depth for advanced tumors. Although the typical imaging depth of OCT is significantly deeper than most other noninvasive imaging

modalities used on skin, imaging deep tumor margins and invasion is restricted.

Image Interpretation—Diagnostic imaging requires image interpretation leading to potential interobserver and intraobserver variation. Experienced observers in OCT more accurately differentiated normal from lesional skin compared to novices, which suggests that training could improve agreement.^{21,22}

Reimbursement and Device Cost—Other practical limitations to widespread OCT utilization at this time include its initial laser device cost and lack of reimbursement. As such, large academic and research centers remain the primary sites to utilize these devices.

Future Directions

Optical coherence tomography complements other established noninvasive imaging tools allowing for real-time visualization of the skin without interfering with the tissue and offering images with a good balance of depth, resolution, and field of view. Although a single histology cut has superior cellular resolution to any imaging modality, OCT provides additional information that is not provided by a physical biopsy, given the multiple vertical sections of data. Optical coherence tomography is a useful diagnostic technique enabling patients to avoid unnecessary biopsies while increasing early lesion diagnosis. Furthermore, OCT helps to decrease repetitive biopsies throughout nonsurgical treatments. With the availability of newer technology such as D-OCT and HD-OCT, OCT will play an increasing role in patient management. Clinicians and researchers should work to convert from category III to category I CPT codes and obtain reimbursement for imaging, with the ultimate goal of increasing its use in clinical practice and improving patient care.

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