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Optical Coherence Tomography using the Niris System in Otolaryngology.

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ABSTRACT

Objectives: To determine the feasibility and accuracy of the Niris Optical Coherence Tomography (OCT) system in imaging of the mucosal abnormalities of the head and neck. The Niris system is the first commercially available OCT device for applications outside ophthalmology.
Methods: We obtained OCT images of benign, premalignant and malignant lesions throughout the head and neck, using the Niris OCT imaging system (Imalux, Cleveland, OH). This imaging system has a tissue penetration depth of approximately 1-2mm, a scanning range of 2mm and a spatial depth resolution of approximately 10-20μm. Imaging was performed in the outpatient setting and in the operating room using a flexible probe.
Results: High-resolution cross-sectional images from the oral cavity, nasal cavity, ears and larynx showed distinct layers and structures such as mucosa layer, basal membrane and lamina propria, were clearly identified. In the pathology images disruption of the basal membrane was clearly shown. Device set-up took approximately 5 minutes and the image acquisition was rapid. The system can be operated by the person performing the exam.

Conclusions: The Niris system is non invasive and easy to incorporate into the operating room and the clinic. It requires minimal set-up and requires only one person to operate. The unique ability of the OCT offers high-resolution images showing the microanatomy of different sites. OCT imaging with the Niris device potentially offers an efficient, quick and reliable imaging modality in guiding surgical biopsies, intra-operative decision

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making, and therapeutic options for different otolaryngologic pathologies and premalignant disease.

Keywords: Optical Coherence Tomography, otolaryngology, upper aerodigestive tract.

INTRODUCTION

Optical Coherence Tomography (OCT) is an emerging noninvasive imaging technique that uses low-coherence with a Michelson interferometry to produce high-resolution images of microstructures in living tissues (1). It uses near infrared light to discern intrinsic differences in tissue structures and uses coherence gating to localize the origin of the reflected optical signal from different tissue depths. Depending on the source wavelength, the imaging depth in turbid media like biological tissue is 1-2 mm, giving the capability to differentiate the microanatomy (2).

OCT has been widely use in different medical fields, especially in ophthalmology were it has the greatest application in the imaging of corneal and retinal damages (3, 4). It has also been used in dermatology (5), cardiology (6), gastroenterology (7), urology (8) and neurology (9). Recently, OCT has been broadly applied in the field of otolaryngology where laryngeal imaging has become a focus of clinical interest (10, 11).

The objective of this study was to present the results from clinical studies done at the University of California Irvine Medical Center (UCIMC), were high-resolution OCT images were obtain using this commercially available device. And to compare the feasibility and accuracy of this device with the previously used devices at the UCIMC.

METHODS

Using a FDA-approved commercially available OCT device (Niris, Imalux, Cleveland, OH), OCT imaging was performed in patients under general anesthesia that underwent different upper aerodigestive tract surgical procedures as well as in patients at the outpatient clinic. Each patient was consent prior to the imaging, and the study was done in accordance and under the guidelines of Institutional Review Board at the University of California, Irvine.

The imaging was performed using a 2.7mm diameter fiberoptic flexible probe, which was place in contact to the tissue. The imaging system has a tissue penetration depth of approximately 1.6mm, a scanning range of 2mm and a spatial depth resolution of approximately 10-20μm; obtaining in 1.5 seconds per frame a 200 pixel lateral picture. Afterward the characteristics of each image were analyzed.

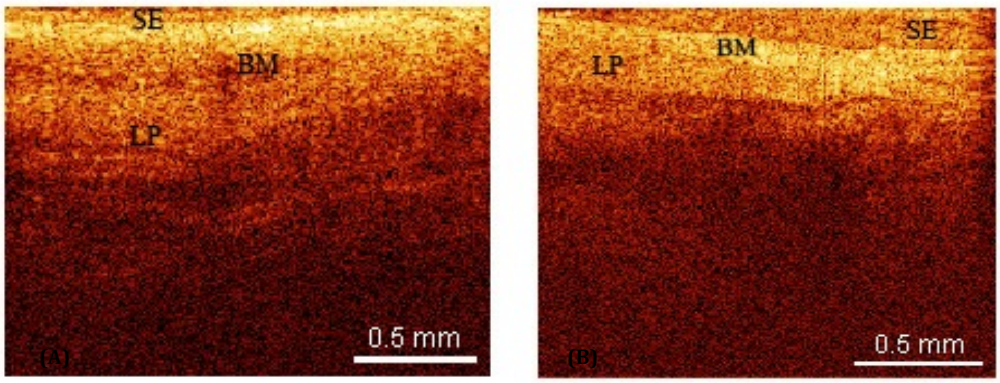
When imaging the larynx, the patient's larynx was complete expose by a laryngoscope with suspension. At that time the probe was gently place in contact with the sites of the larynx to image, and simultaneously endoscopic images were taken.

Imaging the ear occur in two different settings; the first one was in the outpatient clinic, were OCT imaging occur after their regular consult, were under direct vision with an otoscope, the probe was place in the tympanic membrane. The other setting was on patients that underwent mastoidectomy, in this case the probe was previously sterilized and then after the mastoidectomy was performed the probe was placed in the area of interest.

Imaging of the oral cavity and the nose took place in the clinic; where patients were placed on a comfortable position on the exam chair and the probe was place in various locations of the mouth in a systematic fashion, obtaining OCT images of various locations. In the same manner was done for imaging the nose.

RESULTS

We obtained OCT images of the larynx in three different settings: in patients with normal anatomy, in patients with benign disease and in patients with malignant pathologies. Different anatomical areas of the larynx were imaged. The micrstructures were clearly identified in normal anatomy images of the true vocal cord (Fig. 1), false vocal cord (Fig. 2), epiglottis (Fig. 3), arytenoid (Fig. 4), aryepiglottic fold (Fig. 5) and piriform sinus (Fig. 6). In malignant processes we idenfified the infiltration of the tumor and disruption of the basal membrane (Fig. 1 and Fig. 2), as well as the difference between normal and malignant tissue, showing the transition zone (fig. 2).



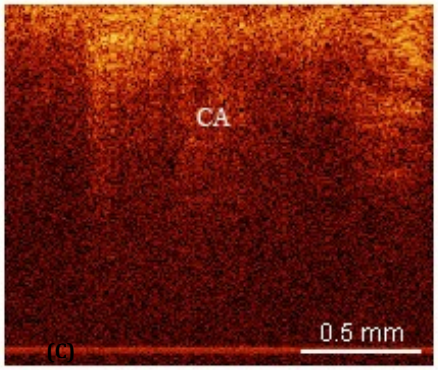


Figure 1. In vivo OCT images of the true vocal cord (TVC). (**A**) Normal TVC, clearly showing the squamous epithelium (SE), lamina propria (LP) and basement membrane (BM). (**B**) TVC with a scar band with thickening of the squamous epithelium and lamina propria with the basal membrane intact. (**C**) TVC with Squamous Cell Carcinoma (CA), where there is infiltration of the tumor causing disruption of the basal membrane.

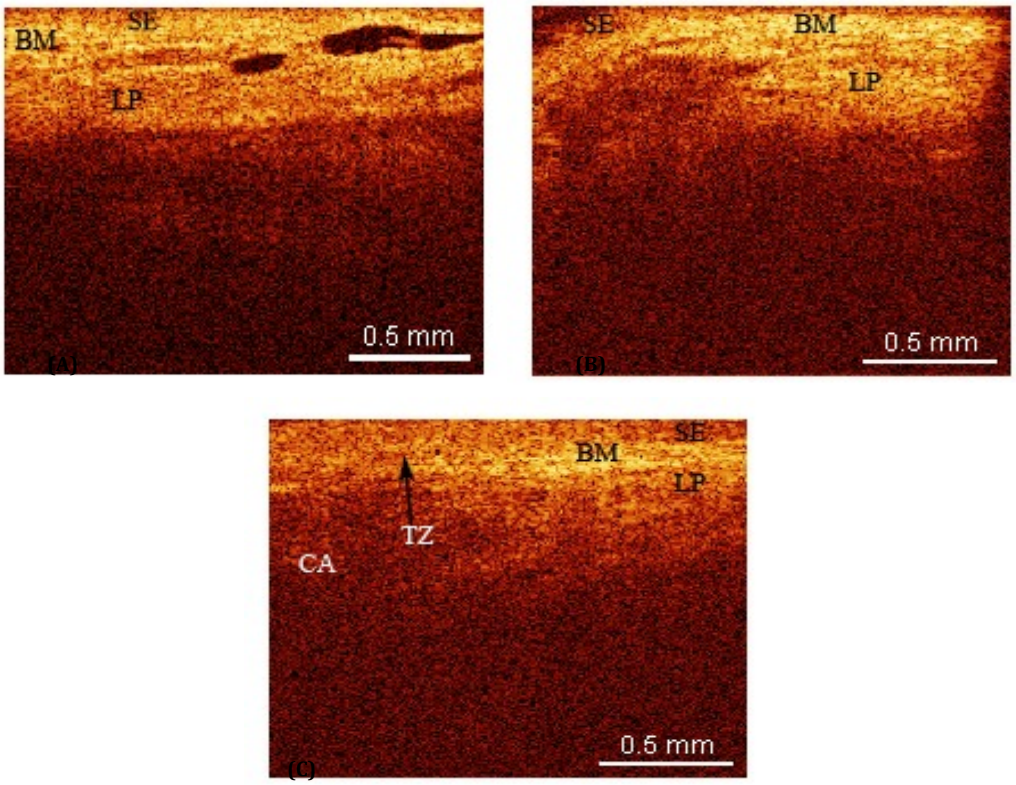


Figure 2. In vivo OCT images of the false vocal cords (FVC). (**A**) Normal FVC, clearly showing the squamous epithelium (SE), lamina propria (LP), basement membrane (BM) and blood vessels (BV). (**B**) FVC with scaring tissue, normal squamous epithelium and basal membrane, with

thickening of the lamina propria. (**C**) FVC tumor in transition zone (TZ), showing intact basal membrane as well as infiltration of the tumor (CA) disrupting the basal membrane.

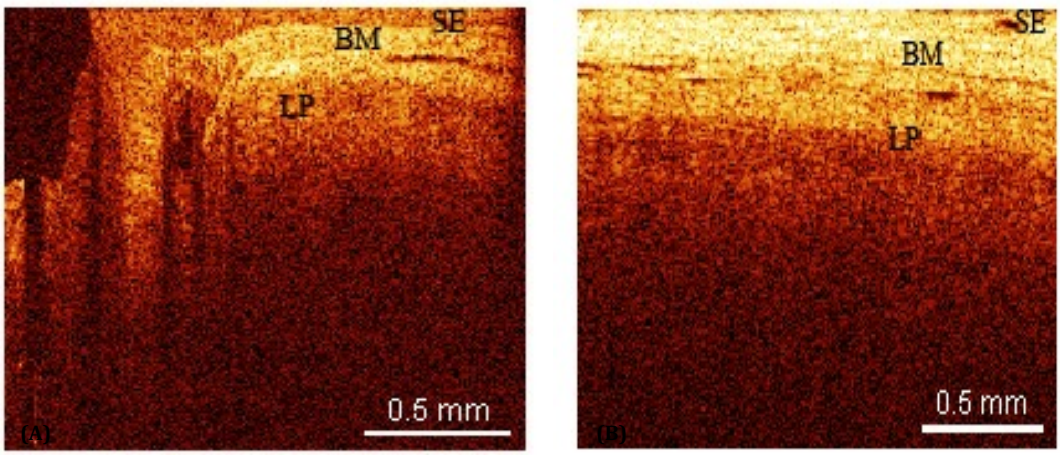


Figure 3. In vivo OCT images of the epiglottis. **(A)** Normal tip of epiglottis; squamous epithelium (SE), lamina propria (LP) and basement membrane (BM). **(B)** Epiglottis with remnant scar with thickening of the lamina propria.

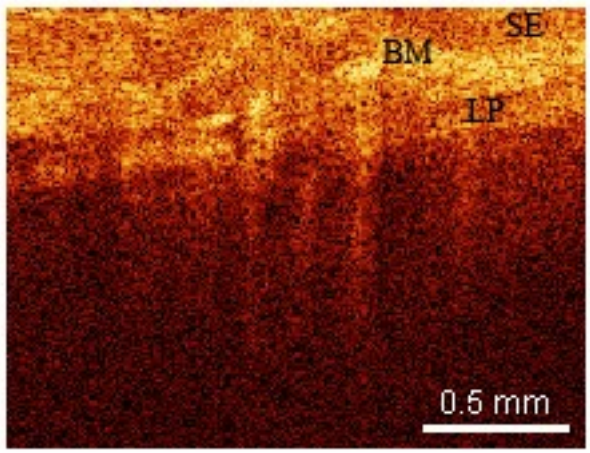


Figure 4. In vivo OCT image of the arytenoid mucosa; squamous epithelium (SE), lamina propria (LP) and basement membrane (BM).

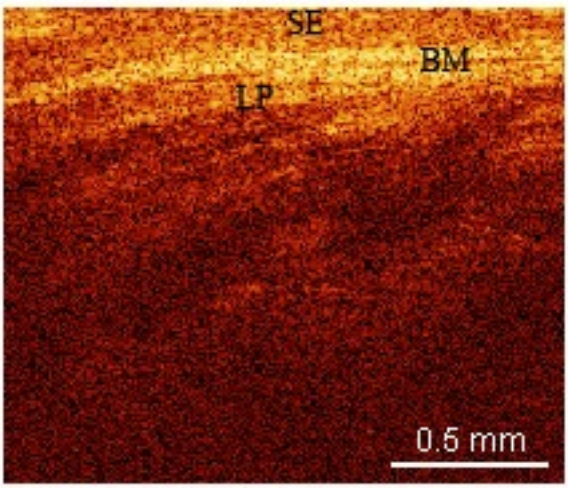


Figure 5. In vivo OCT image of the arypiglottic fold; squamous epithelium (SE), lamina propria (LP) and basement membrane (BM).

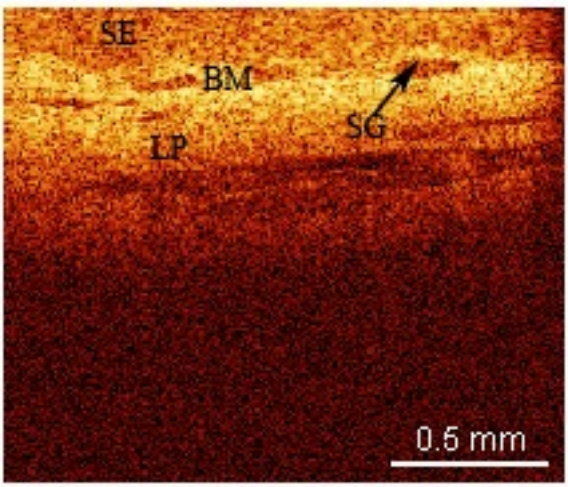


Figure 6. In vivo OCT image of the piriform sinus; squamous epithelium (SE), lamina propria (LP), basement membrane (BM) and seromucinous glands (SG).

OCT images obtained from the ear were from the middle ear, were normal mucosa was seen, as well as middle ear pathologies (Fig. 7). In the tympanic membrane we identified the normal three laminar structures, and also benign pathologies such as tympanosclerosis where there clearly is a thickening of the tympanic membrane (Fig.8).

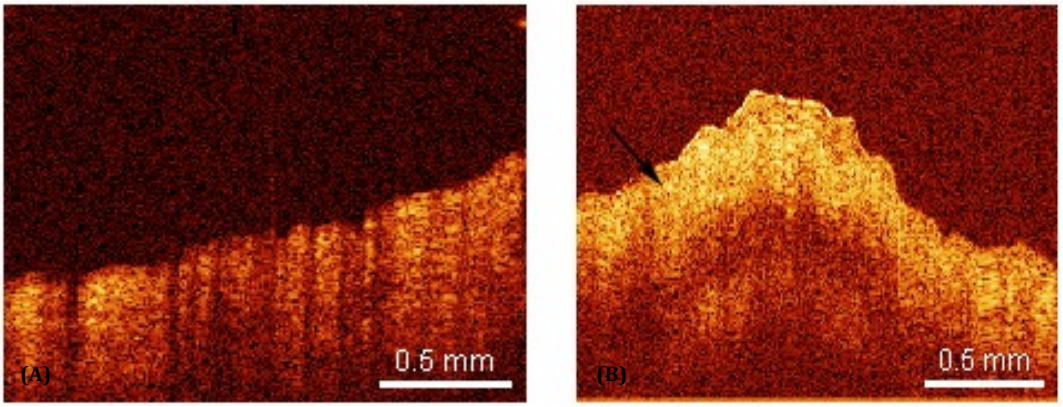


Figure 7. In vivo OCT images of the Middle Ear (ME). **(A)** ME normal mucosa. **(B)** ME keratin plug showing increase scattering (*arrow)*.

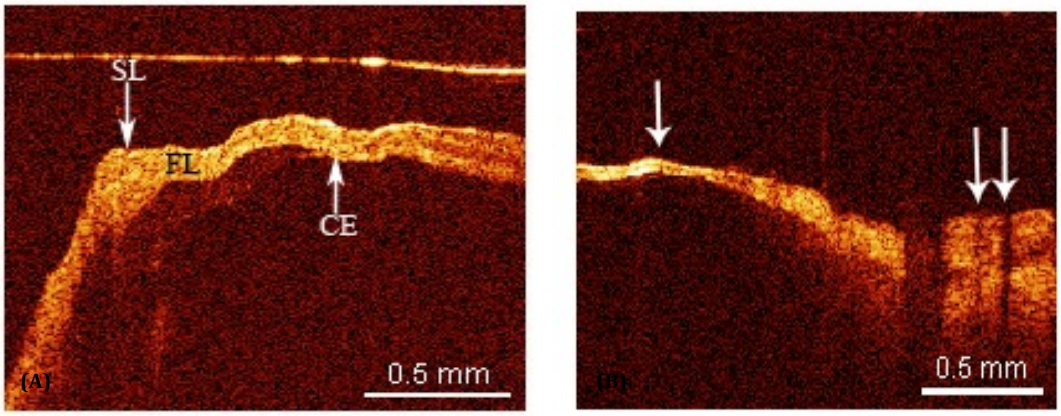


Figure 8. In vivo OCT images of the Tympanic Membrane (TM). **(A)** Normal TM trilaminar structure with the outer squamous layer (SL), middle fibrous layer (FL) and inner medial cuboidal epithelium (CE). **(B)** TM with tympanosclerosis (*double arrow*), and normal TM (*single arrow*).

In the same way we obtained OCT images from different anatomical sites of the normal oral cavity (Fig. 9), and nasal cavity (Fig. 10), were the normal microanatomy and microstructures were clearly identified.

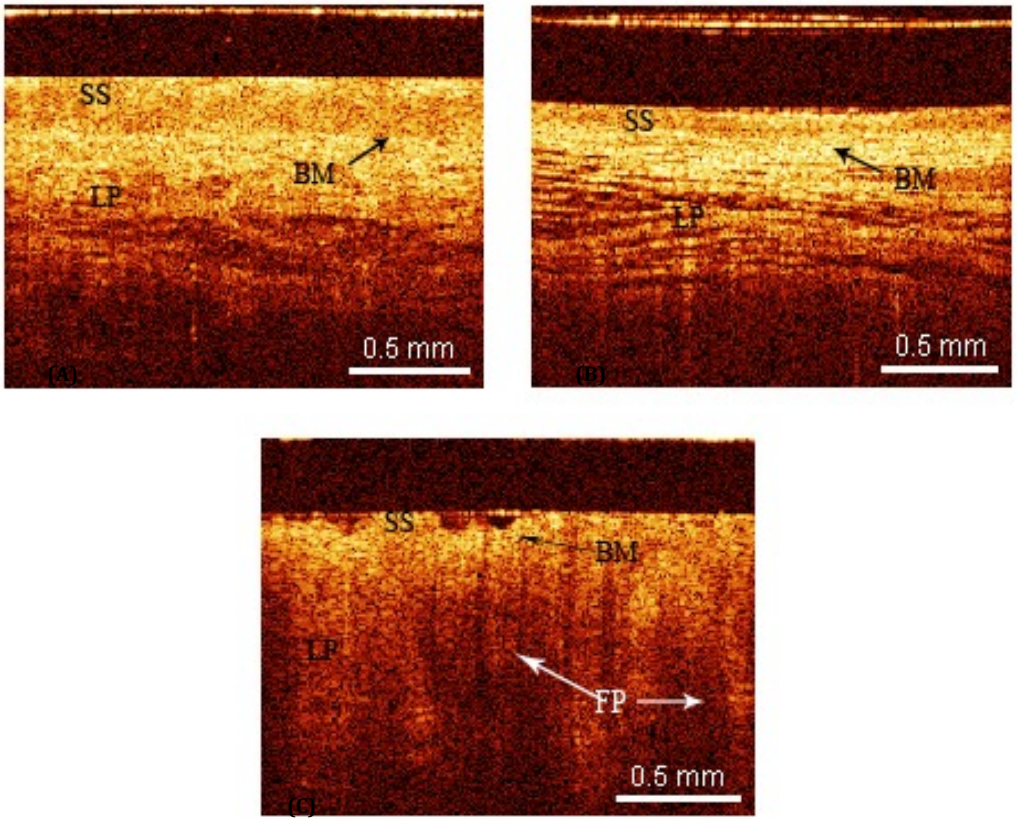


Figure 9. In vivo OCT images of the normal Oral Cavity. **(A)** Buccal mucosa. **(B)** Floor of the mouth. **(C)** Dorsal Tongue. Stratified Squamous epithelium (SS), lamina propria (LP), basement membrane (BM) and filiform papillae (FP).

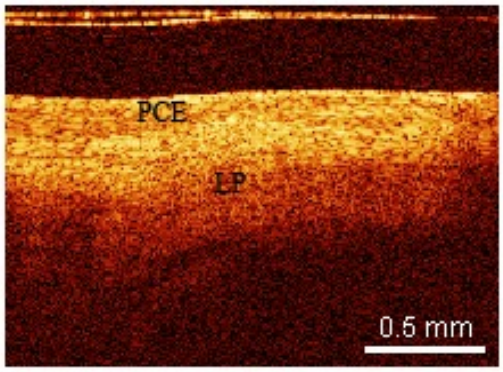


Figure 10. In vivo Oct image of the Nasal Septum; Pseudostratified columnar epithelium (PCE) and lamina propria (LP).

CONCLUSIONS

In this study we present our experience using the Niris system for imaging various anatomical site of the upper aerodiestive tract. The system was easily incorporated into the operating room as well as in the clinic. This system is a very efficient and save device; the setup and acquisition of the OCT images took approximately 5 minutes, and there was not an increase in the morbidity of the patient while they were under general anesthesia for the different surgical procedures.

Using this OCT system we were able to obtain high-resolution cross-sectional images of the microanatomy with an approximately depth resolution of 10-20μm; where we clearly identify different microstructures as well as disruptions of the later ones.

OCT imaging is a noninvasive technology that has a great potential in intra-operative decision-making, guiding surgical biopsies and can provide therapeutic options for different otolaryngologic pathologies especially in premalignant disease.

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