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Emerging Applications for OCT in the Head and Neck

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ABSTRACT

Objectives: To describe the current and promising new applications of Optical Coherence Tomography (OCT) as a helpful tool when imaging the different sites in the head and neck. We used the OCT Niris system, which is the first commercially available OCT device for applications outside the field of ophthalmology.

Methods: OCT images were obtained of normal, benign, premalignant and malignant lesions in different areas of the head and neck. The OCT imaging system has a tissue penetration depth of approximately 1-2mm, a scanning range of 2mm and a spatial depth resolution of approximately 10-20 μ m. Imaging was performed using a flexible probe in two different settings, the outpatient clinic and the operating room.

Results: High-resolution cross-sectional images from the larynx were obtained with the patient awake, without the need for general anesthesia, under direct visualization with a flexible fiberoptic endoscope. The OCT probe was inserted through the nasal cavity and placed in slight contact with the laryngeal tissue. In the ears, cholesteatoma was differentiated from inflamed middle ear mucosa by the different hyperintensity. In the neck, normal as well as different pathologies of the thyroid were identified.

Conclusions: This system is non invasive and easy to incorporate into the operating room setting as well as the outpatient clinic. It requires minimal set-up and only one person is

required to operate the system. OCT has the distinctive capability to obtain high-resolution images, and the microanatomy of different sites can be observed. OCT technology has the potential to offer a quick, efficient and reliable imaging method to help the surgeon not only in the operating room but also in the clinical setting to guide surgical biopsies and aid in clinical decision making of different head and neck pathologies, especially those arising from the larynx.

Keywords: Optical Coherence Tomography, otolaryngology, upper aerodigestive tract, head and neck.

INTRODUCTION

Optical Coherence Tomography (OCT) is a noninvasive imaging technique that uses low-coherence with a Michelson interferometry to produce high-resolution images of living tissue microstructures (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 ranges from 1-2 mm in turbid media such as biological tissue (2). This penetration depth is coupled with a resolution of approximately 10-20 μ m, thus enabling differentiation of tissue microanatomy.

OCT has been widely used in different medical specialties, especially in ophthalmology where it has been used mainly to image corneal and retinal pathology (3, 4). It has also been used in dermatology (5), cardiology (6), gastroenterology (7), urology (8) and neurology (9). OCT has also been broadly used in the field of otolaryngology where laryngeal imaging has become the main focus of interest (10, 11), although OCT has a great potential in other areas of otolaryngology as well.

The objective of this study was to present the promising new application of OCT for imaging the various areas of the head and neck, using a commercially available device and a custom designed system built in our research facility at the University of California, Irvine.

METHODS

OCT imaging of the larynx, ear, and neck was performed using a FDA-approved commercially available OCT device (Niris, Imalux, Cleveland, OH). OCT imaging was performed in two different settings; in the operating room and in the outpatient clinic. All patients in the operating room were under general anesthesia and undergoing different otological and head and neck surgical procedures. In both cases, each patient was consented 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 placed near or in slight contact with the tissues. The imaging system has a central wavelength of 1300 nm with tissue penetration depth of approximately 1.6mm, a lateral scanning range of 2mm, a depth resolution of approximately 15 μ m, acquiring images at a rate of 1.5 frames per second obtaining a 200x200 pixel frame picture.

When imaging the larynx, we used a specially designed “double barrel” sheath (Figure 1), which enable us to guide the OCT probe onto the larynx under visualization of fiberoptic endoscope. Prior to sliding it through the patient’s nose, the sheath was lubricated with surgical lubricant. This allowed us to simultaneously obtain OCT images as well as fiberoptic visualization of the patient’s larynx.

Imaging the ear was performed in the operating room with the patient under general anesthesia, in cases of chronic otitis media with cholesteatoma. Prior to imaging the patient, the probe was sterilized and after the cholesteatoma was exposed and removed, OCT images were obtained by placing the probe in slight contact with the cholesteatoma and the surrounding middle ear mucosa for imaging and comparison of these different areas.

Imaging of the neck structures was done in the operating room with patients undergoing different head and neck surgical procedures under general anesthesia. In these cases the probe was sterilized and after the desired neck structures were exposed, the probe was placed in contact with these structures and OCT images were obtained.

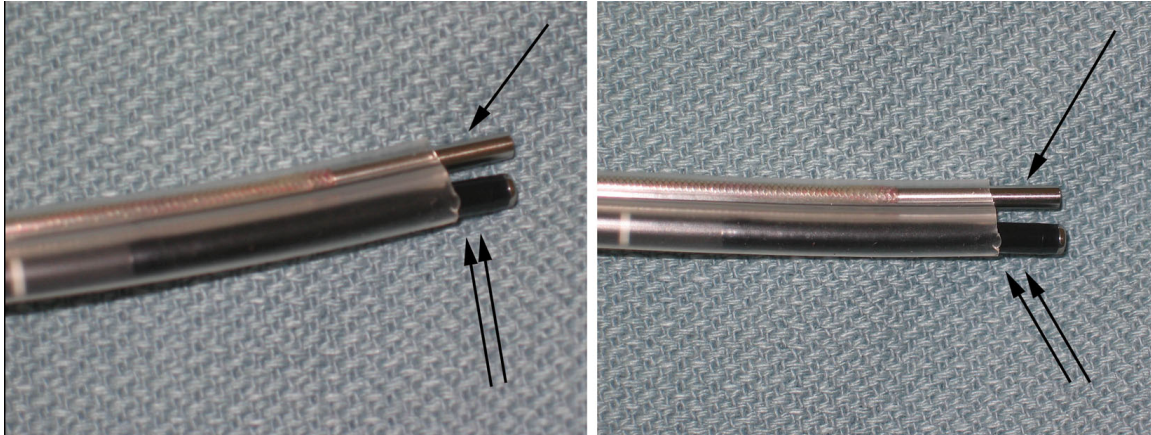


Figure 1. Image showing the “double barrel” sheath with the OCT probe (single arrow) and the fibroscope (double arrow). The sheath is made of a soft material (C-Flex shore 50A), which allows the fibroscope to move freely.

In the nasal cavity and nasopharynx, we used an other OCT system built by our group at the Beckman Laser Institute of University of California, Irvine. This imaging system is a TD-OCT with a scan rate of 250Hz, an axial and lateral resolution of 30 μ m, an imaging

range of 18.5mm and with a probe rotation speed of 0.5 rounds/second. This system was used to gather preliminary data on anatomical OCT (12) of the upper aerodigestive tract.

RESULTS

In the OCT images obtained from the patients undergoing otological surgery, we found that cholesteatoma has distinctive findings that differentiates it from inflamed middle ear mucosa. The middle ear mucosa lack keratin, when compared to the cholesteatoma, which appears as a more hyperintense image in OCT as shown in figure 2. The normal middle ear mucosa, in comparison, lacks hyperintensity (Fig 3).

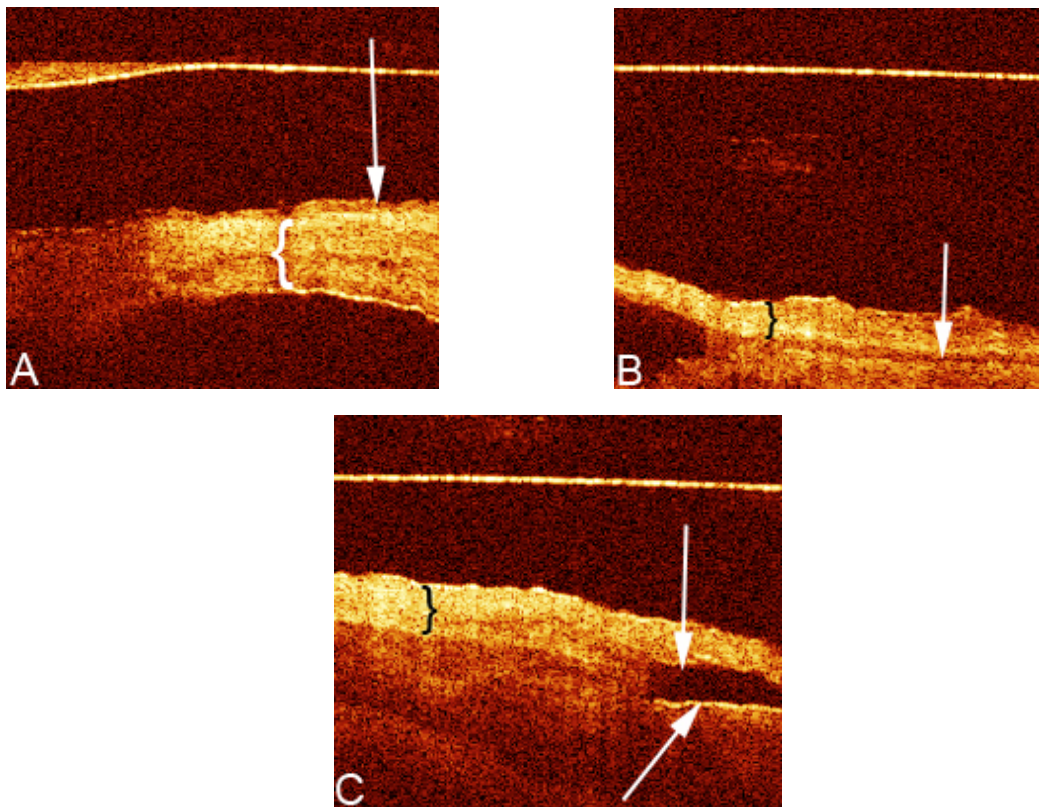


Figure 2. OCT images of cholesteatoma. A) where the cholesteatoma matrix (single arrow) and keratin (bracket) can be observed. Note the hyperintensity of the keratin. B) cholesteatoma matrix from internal surface (arrow) and keratin (bracket). C) cholesteatoma matrix folded over itself (arrows) and keratin (bracket).

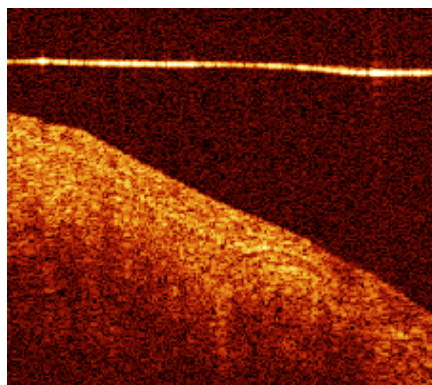


Figure 3. OCT image of middle ear mucosa, were no hyperintensity can be observed.

The intraoperative OCT images obtained from the neck structures clearly demonstrate microstructural characteristics as compared to standard histology. Different structures were imaged including the thyroid (Fig 4.), lymph nodes, parathyroids, fat (Fig 5), parotid and skeletal muscle (Fig 6). When imaging the thyroid, normal, benign and malignant conditions were clearly identified (Fig 4).

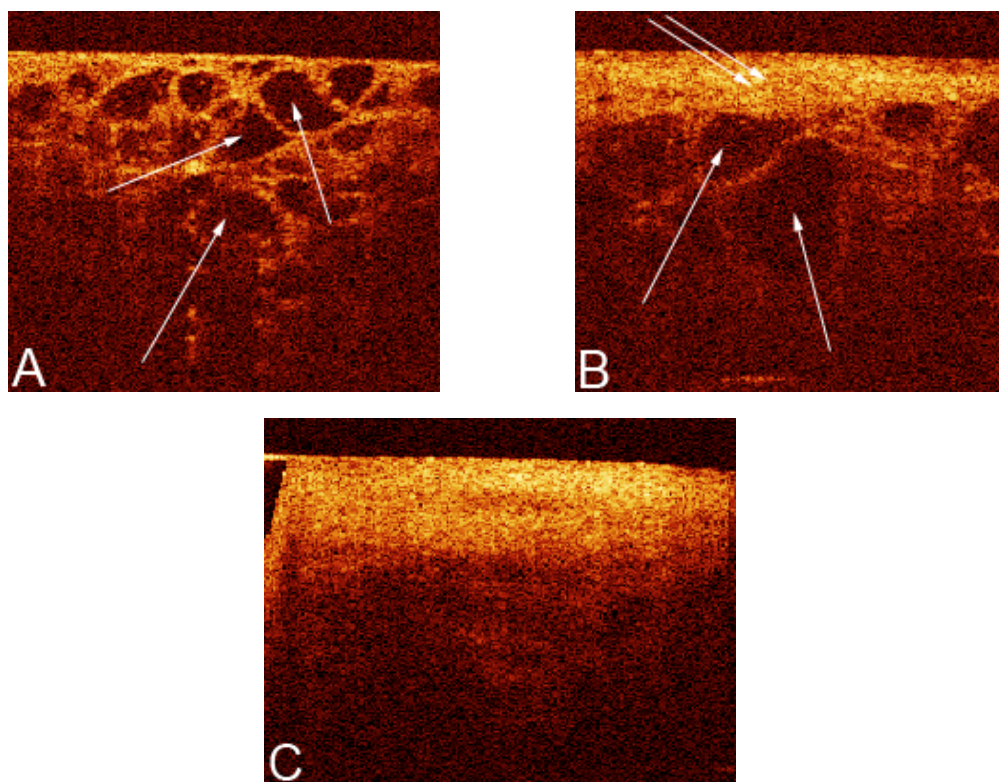


Figure 4. OCT images of the thyroid gland. A) Normal thyroid where the follicles can be observed (arrows). B) Thyroid nodule, where a fibrous capsule (double arrow) as well as the normal follicles (single arrows) can be observed. C) Thyroid cancer, where there is a loss of the thyroid follicle architecture.

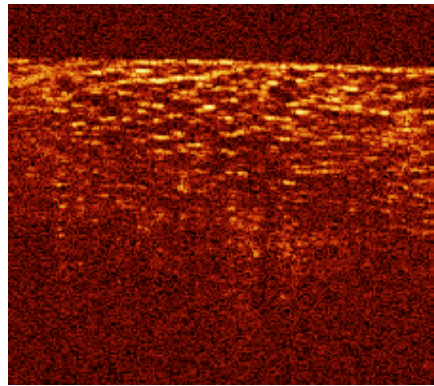


Figure 5. OCT image of fat in the neck.

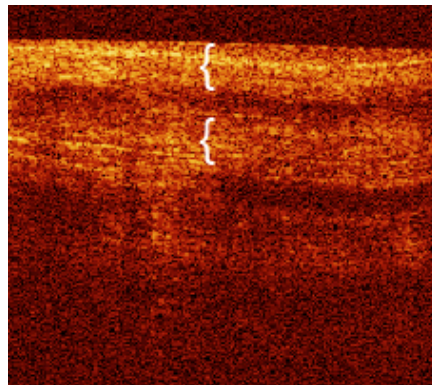


Figure 6. OCT image of skeletal muscle in the neck, where the muscle fibers can be seen (brackets)

We also acquired preliminary anatomical-OCT data using our own OCT system. This was done in healthy volunteers where images of the nasal cavity (Fig. 7) and nasopharynx (Fig. 8) were obtained.

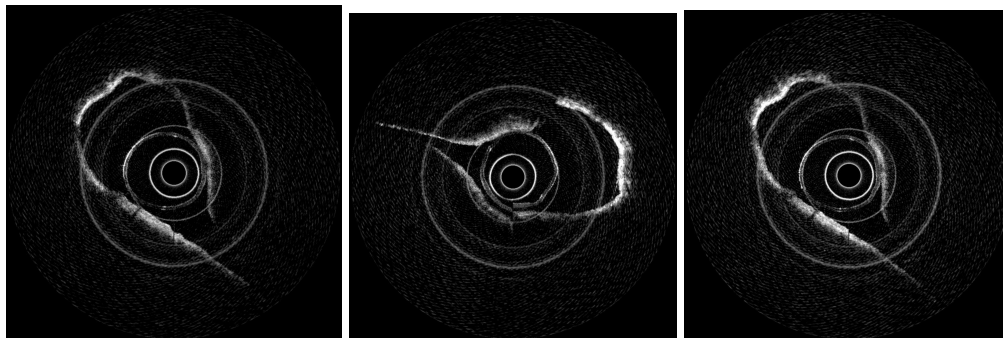


Figure 7. Anatomical-OCT of the nasal cavity

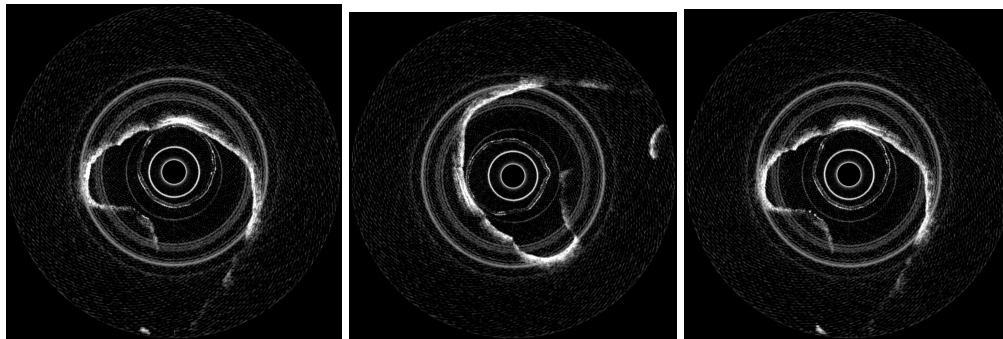


Figure 8. Anatomical-OCT of the nasopharynx

CONCLUSIONS

We presented new applications for OCT in the head and neck. The system was easily incorporated in the operating room as well as in the clinic. This system is a very efficient and safe device; the setup and acquisition of the OCT images took approximately 5 minutes, and there was no 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 of different structures in the head and neck, where we clearly identified microanatomic structures and pathologic changes.

OCT has a great potential in the field of otolaryngology not only for the imaging of the larynx but also for other anatomical areas, providing an efficient non-invasive method to aid the surgeon in the intraoperative decision-making. This system can potentially facilitate therapeutic decisions for different otolaryngologic pathologies, especially in premalignant conditions.

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