Chapter 37
OCT in laryngology

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Abstract

This chapter discusses the history of OCT and the adoption of this technology for laryngology.

Keywords: OCT, intra-operative, office-based

Evolution of laryngeal OCT

In 1991, Huang introduced optical coherence tomography (OCT) as a noninvasive cross-sectional imaging modality of internal structures in biological tissues by measuring their optical reflections [1]. OCT is similar to ultrasound, however it relies on light as opposed to sound in detecting variation in tissue structure and employs coherence gating as opposed to time-of-flight measurements to determine the origin of the reflected optical signal.

Initial applications in ophthalmology expanded to several other fields in medicine, including otolaryngology. In 1997, Sergeev performed the first in vivo endoscopic OCT imaging studies of laryngeal mucosa, a comparative of healthy tissue versus malignant tissue [2]. OCT allows tissue evaluation of up to a depth of 1 mm and permits full thickness visualization of the human laryngeal epithelium, superficial lamina propria, and basement membrane. Much of laryngeal pathology is identified within the first millimeter of mucosa, making OCT an optimal diagnostic imaging modality. Over the last two decades OCT has emerged as a valuable tool to assess the microstructural integrity of the basement membrane in patients at risk for malignancy. While tissue biopsy remains the gold standard for diagnosis, OCT can direct biopsies to areas with higher diagnostic yield and monitor disease progression during surveillance.

Intra-operative and office-based applications of OCT

OCT was first implemented in the operative theatre as an adjuvant to direct laryngoscopy in evaluating vocal cord pathology. The earliest forms of this technology involved handheld probes that required being in contact or in near-contact with the mucosal surface under examination (Figure 1). Such OCT systems obtained excellent images. Shakhov [3] used an OCT probe to delineate the transition from abnormal epithelium to healthy epithelium in the setting of laryngeal cancer surgery. With a spatial resolution of 15 micrometers, the OCT device defined the boundaries of the pathological zone more precisely compared to the surgeon’s visual assessment, therefore facilitating tissue preservation without compromising pathological margins. Burns [4] utilized OCT to perform accurate vocal fold (VF) injections in the superficial lamina propria in an in vivo canine model. OCT locates the depth of injection and may determine whether or not an injectable implant is actually present over time.
Figure 1. Intra-operative OCT. Handheld OCT probe (left) and handheld OCT probe utilized intra-operatively during direct laryngoscopy (right). The OCT handheld probe requires to be in contact or in near-contact with the mucosal surface under examination. Courtesy of Brian J.F. Wong, MD, PhD.

While the handheld probe of the OCT offered impressive imaging, it has its disadvantages in the setting of laryngeal microsurgery. Direct contact with the tissue may result in compression artifacts and image distortion due to hand tremor. Most notably, the presence of an OCT probe in the lumen of a narrow laryngoscope obstructs the use of microlaryngeal instruments and hinders bimanual surgery. Because the probe must be removed in order to treat the larynx, this prolongs operative time and limits the potential benefit of simultaneous OCT imaging during surgery [5].

In response, non-contact OCT systems have been integrated with operative microscopes (Figure 2) that permit high resolution, hands-free OCT imaging of the VF in conjunction with traditional microscopic visualization [6-12]. These systems required the surgeon to manually adjust the OCT focus, which is a major technical challenge. Despite the large imaging distances (240-280 mm), Just and colleagues demonstrated equivalent images compared to its contact probe counterpart [6]. The ultimate goal of these efforts was to precisely identify lesion borders intra-operatively and perform OCT guided resection.

Figure 2. OCT Integrated Operative Microscope. This form of hands-free OCT permits high resolution imaging of the VF in conjunction with traditional microscopic visualization during microlaryngeal surgery. Courtesy of Brian J.F. Wong, MD, PhD.
Similarly, advances have been made in the realm of office-based laryngeal OCT imaging. With their invention of the OCT Laryngoscope in 2006, Luerssen & Lubatschowski ushered in the era of office-based OCT, combining OCT with a rigid transoral laryngoscope [13]. Indirect laryngoscopy and videostroboscopy provide only information on the external surface of the vocal cords while the OCT laryngoscope provides cross sectional imaging of subepithelial tissue up to 1 mm deep. The OCT laryngoscope employs synchronous OCT and video imaging via a single collinear beam path, allowing non-contact evaluation of laryngeal mucosa in awake patients. An integrated focusing unit facilitated adjustment of the working distance (between 40-100 mm) to each patient’s individual anatomy, albeit this still requires immense skill and patience. The main drawback of this approach is the motion artifact due to involuntary movement of the larynx (produced by swallowing, breathing, and reflexes) combined with examiner intention tremor [14]. However, motion artifact may be partially compensated for by using a frame rate of 40 f/s or higher [15]. Guo modified an ophthalmic slit lamp stand as a frame to facilitate patient stability and mounted the OCT laryngoscope on a gooseneck stabilizer to dampen any hand tremor [16]. Images obtained with this approach were comparable to images obtained in anesthetized patients during surgical endoscopy.

OCT probes have also been incorporated into flexible laryngoscopes as well in the office-based setting (Figure 3). Klein et al. reported in 2006 a fiberoptic OCT imaging probe that was incorporated in the working channel of a flexible endoscope [17]. After topical anesthesia, the OCT probe was pressed along the glottic mucosal surface and images were obtained. Sepehr et al. used an interface platform modification that provided for 360° rotational control of the probe tip, allowing for more accurate probe apposition with target tissues and superior imaging in awake patients [18]. Data collected from 17 patients indicated this system may assist in the diagnosis of laryngeal lesions in the office setting.

Figure 3. Office-based flexible OCT. OCT technology integrated into flexible laryngoscope allowing awake, in-office imaging.Courtesy of Brian J.F. Wong, MD, PhD.

References


