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Diagnostic Contribution of Virtual Endoscopy in Diseases of the Upper Airways

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Purpose: Virtual endoscopy (VE) is a new diagnostic tool that generates 3-dimensional (3D) views of a lumen by exploiting cross-sectional images. The purpose of this study was to evaluate the usefulness of VE as a diagnostic tool in the diseases of the larynx and pharynx. _Materials and Methods:_ Twenty-two patients with a mean age of 57 years were included in the study. The patients underwent larynx examination, optical endoscopy (OE), and computed tomography (CT) of the larynx. Later, VE was produced from the CT images. _Results:_ Eight patients had larynx carcinoma, a 5-year-old patient had a laryngeal web, a 43-year-old man had fish bone stuck in his submucosal layer, 10 patients were normal, and the remaining two patients were under follow-up for treated nasopharynx carcinoma and had no evidence for recurrence. VE showed the laryngeal tumor in seven patients and the laryngeal web in one patient, but failed to show a plaquelike tumor and the fishbone within the submucosa. _Conclusions:_ Our findings suggest that VE is a useful and complimentary method of 3D imaging in the diseases compromising the laryngeal lumen. Furthermore, it may be superior to OE in severe stenosis or obstructions where the endoscope cannot be passed through.

KEY WORDS: Virtual endoscopy, larynx, pharynx, CT, imaging, optical endoscopy

INTRODUCTION

The principal diagnostic tools in the evaluation of the pharyngeal and the laryngeal diseases include optical endoscopy (OE), computed tomography (CT), and magnetic resonance (MR) imaging in addition to otorhinolaryngologic examination. Virtual endoscopy (VE) is a new diagnostic tool that generates 3-dimensional (3D) views of a lumen by exploiting cross-sectional images. Because of its recent introduction, not much is known about its utility in the diagnostic work-up of the upper airways and the digestive tract. The purpose of this study was to evaluate the usefulness of VE as a diagnostic tool in the diseases of the larynx and pharynx.

MATERIALS AND METHODS

Because we chose CT images as a source to produce VE, patients who underwent CT examination of the neck as part of the diagnostic work-up of a pharyngeal or laryngeal disease were included in the study in a 6-month period. Radiological assessment included evaluation of both the cross-sectional and the VE images. The patient population comprised 12 males and 10 females. The mean age was 57 (range, 5–75) years. All CT examinations were performed before a biopsy or any other surgical procedure was executed. After CT, the patients underwent OE. The definite diagnosis was established in all patients via a biopsy guided by OE or open surgery. Ethics committee approval was obtained for this study.

CT scanning was performed on a four-detector helical CT scanner (Mx 8000 Multislice CT Imaging Systems; Philips, Best, Netherlands) under the following setting: collimation beam thickness 1.3 mm, increment 0.6 mm, pitch 1.25, rotating

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time 0.75 s, mA s/slice 200, matrix 512, field of view 25 cm. No sedation was necessary for CT examination among patients, except for a 5-year-old pediatric patient. Once the CT exam was completed, the image data stored in DICOM (digital imaging and communication in medicine) format was transferred to a postprocessing unit (Easy Vision Master 5.2; Philips) to create the VE. VE was created via Endo 3D program installed in the postprocessing unit established on a SUN Ultra 60 workstation (Ultra 60 Creator; Sun Microsystems, Mountain View, CA, USA). Actually, VE is a volume rendering while the organ of interest is visualized from interior ("endo") view points.[1] The software assigns transparency to the voxels below a threshold chosen either automatically or manually by the radiologist. Thus the mucosal surfaces are volume rendered. One can also enjoy viewing the rendered structures in color, fused 3D images with 2D grayscale images. The viewing angle is 120° wide, and the virtual lens can be manually projected to any direction. In this study, the threshold value that provided the best mucosa–air interface was always manually chosen. The VE images were always cross-checked with the source CT images so that a false image that would originate from a wrong threshold value was avoided. On a routine basis, the whole airway from the nose to the trachea was scanned with VE in both craniocaudal and caudocranial directions. The pathologic lesions were viewed from below, top, both sides, anterior, posterior, and via many other perspectives. During this viewing process, the most demonstrative images were captured. Furthermore, the images of the whole endoscopic path were produced (at a rate of 1 image/mm), and this image set was converted to a movie in MPEG format.

OE was accepted as the gold standard in viewing an upper airway lesion. OE was performed by two experienced otorhinolaryngologists. For a given lesion, VE was tested for its ability to show its presence, size, relation to other structures, and surface characteristics. The time needed to produce VE was also recorded.

RESULTS

Regarding the final clinical and/or biopsy findings, eight patients had larynx carcinoma, a 5-year-old patient had a laryngeal web, a 43-year-old-man had fish bone stuck in his submucosal layer, 10 patients were normal, and the remaining two patients were under follow-up for treated nasopharynx carcinoma and had no evidence for recurrence (Table 1).

The mean period to produce VE was 10 min per patient. In all patients with larynx carcinoma, the tumor was shown by OE and the histological diagnosis was established by a biopsy under optical endoscopy guidance. The larynx tumor was also shown by both VE and CT in seven patients (patient nos. 1–4 and 6–8 in the table) (Figs. 1 and 2), whereas a plaquelike tumor could not be shown by either VE or CT in one patient (patient no. 5 in the table). The OE showed that this tumor presented with ulceration of the mucosa without any elevation or other contour abnormality of the mucosa. Excluding the mentioned case, VE delineated all contour abnormalities seen on OE and cross-sectional CT images in the tumor patients. Although OE showed the tumor and guided for biopsy in all patients, it could not be advanced beyond the luminal stenosis caused by the tumor in three patients (patient nos. 4, 7, and 8 in the table). VE, on the other hand, was able to show both proximal and distal to the stenosis in all patients. VE failed to give any information about the surface characteristics of the tumor such as ulcers, bleeding, erosions, etc. (patient nos. 3, 5, 7, and 11 in the table). VE also failed to show any functional information such as adduction or abduction of the vocal cords (patient nos. 2 and 3 in the table). OE provided all this information about the surface characteristics. In the patient with the fish bone stuck in the submucosa (patient no. 11 in the table), only the cross-sectional CT images showed the fishbone within the submucosa. Neither OE nor VE was able to show the foreign body; however, OE showed focal hyperemia at the level of the foreign body. One week later, the fishbone was spontaneously discharged through the inflamed tissue and it was extracted under OE guidance. The laryngeal web in the 5-year-old patient was visualized by both OE and VE; however, the subglottic extension of the web was shown by VE and CT images (patient no. 12 in the table).

Five patients with larynx carcinoma underwent surgery, whereas the remaining three received radiotherapy. The surgeons stated that VE images, together with OE, helped in planning of the surgical procedure.

DISCUSSION

Minimally invasive techniques attract more and more attention as the technology advances because these techniques offer less hospitalization time, less expenses, and more tolerability by the patients. Optical endoscopes, as minimally invasive tools, depend on fiber optic technology and provide real-time imaging of various body cavities such as stomach, colon, or the upper aerodigestive tract. OE not only allows for diagnostic imaging, but also biopsy and some therapeutic procedures such as polipectomy and sclerosant therapy of

Table 1. Patient Data

Patient No.	Age (years)	Gender	Diagnosis	OE Findings	VE Findings
1	45	F	Larynx Ca	Small* L VC tumor extending to L aryepiglottic fold.	Small vegetating mass in L VC.
2	64	M	Larynx Ca	Big* mass involving L glottic area and both supraglottic space. L hemilarygeal fixation.	Big mass involving L VC and supraglottic space. Hemilaryngeal fixation not appreciated.
3	75	M	Larynx Ca	Multicetric big* mass involving R glottic, subglottic and supraglottic space and R aryoepiglottic fold. Ulcer (+), R hemilarygeal fixation.	Big mass involving R VC, subglottic and supraglottic space and R aryoepiglottic fold Ulcer not seen. Hemilaryngeal fixation not appreciated.
4	66	M	Larynx Ca	Big* ulcerated mass obliterating larynx lumen totally. Endoscope could not be advanced beyond lesion.	Big mass obliterating larynx lumen totally. Mass extending to subglottic space.
5	60	M	Larynx Ca	Small* flat lesion with shallow ulceration.	Not seen on VE or CT.
6	57	F	Larynx Ca	Small* vegetating mass in L VC.	Small* vegetating mass in L VC.
7	63	M	Larynx Ca	Big* mass obliterating larynx lumen totally. Erosions and ulcers on the tumor surface. Endoscope could not be advanced beyond lesion.	Big mass obliterating lumen totally. Distally mass extends to subglottic space. Furthermore satellite small nodular lesions in the trachea.
8	62	M	Larynx Ca	Big* mass obliterating larynx lumen totally. Endoscope could not be advanced beyond lesion.	Big mass obliterating larynx lumen totally. Distally the mass involves both VC.
9	44	M	Nasopharyx Ca (treated)	Normal	Normal
10	53	M	Nasopharyx Ca (treated)	Normal	Normal
11	43	M	Fish bone stuck in pharynx mucosa	Mild hyperemia and edema in the mucosa.	Normal (fishbone shown on cross-sectional images).
12	5	F	Congenital Laryngeal web	Web severely narrowing laryngeal lumen. Endoscope could not be advanced beyond lesion.	Both web and its distal extension shown.
13–22	32–70	3M, 7F	Normal	Normal	Normal

Small: smaller than 1 cm in diameter; big: bigger than 1 cm; R: right; L: left; Ca: carcinoma; VC: vocal cord.

varices. In spite of these advantages, however, OE is still an invasive procedure, requires anesthesia or sedation, and is unpleasant for the patients. That explains why there is still search for less invasive or noninvasive means of imaging that would provide as much information as the invasive ones would provide. In this regard, VE offers the advantage of being totally noninvasive.[1]

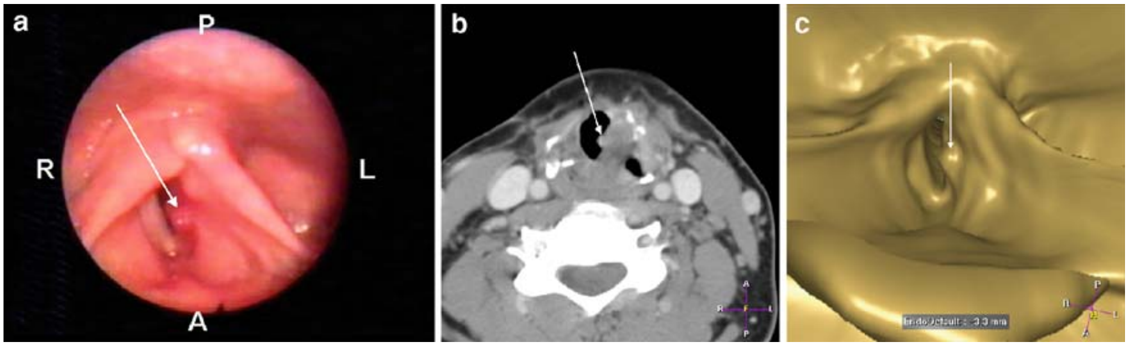

Fig 1. (a) OE image shows a laryngeal tumor (arrow) in a 45-year-old woman involving the left vocal cord with extension into the left supraglottic area and the left aryepiglottic fold. R: right; L: left; A: anterior; P: posterior. (b, c) Transverse CT image through the supraglottic level and VE image showing the tumor (arrow).

VE is a volume-rendered image of a body part or organ. The produced image is a simulation of the view from inside a cavity that borders the region of interest. As evidenced in this study, VE can produce representative images of the luminal masses with fidelity to topographic and dimensional data.[2–4] It has the advantages of viewing beyond a severe stenosis or obstruction by a tumor where an optical endoscope could not be passed. VE may also be useful in showing the congenital causes of airway stenoses in pediatric patients in whom OE may be difficult to use.[5] One can produce hybrid images harboring both 3D and 2D reconstructions in the same image. Thus one takes the advantage of showing the submucosal extension of the mucosal lesion on the same image. In one patient in the present study, a foreign body in the pharyngeal submucosa could not be shown by

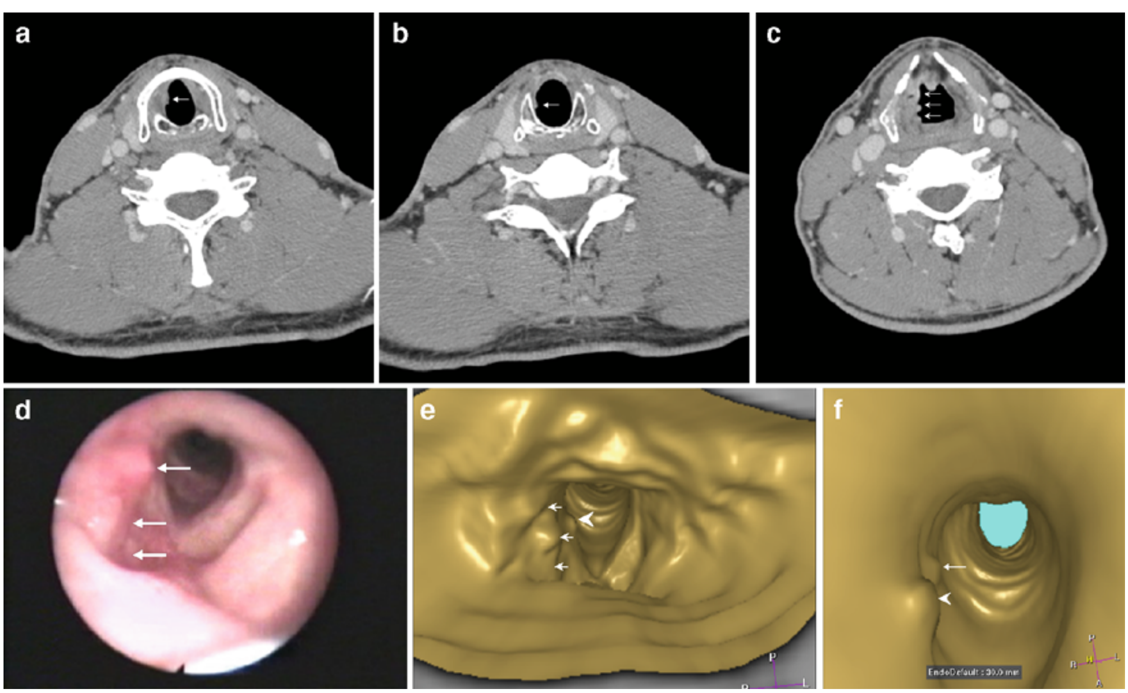

Fig 2. Transverse CT images (a–c) show multifocal carcinoma (arrows) involving the right vocal cord (a), and the right side of the subglottic (b) and supraglottic space (c). OE image (d) showing the right glottic–supraglottic tumor (arrows). VE images showing the right vocal cord lesion (arrowhead in e and f), right supraglottic lesion (e, arrows), and the right subglottic lesion (f, arrow).

OE or VE. The foreign body was seen on CT images. Combining the cross-sectional source images strengthens the diagnostic power of VE.

In all previous VE experience targeted to the head-and-neck region, CT was used to provide the source images. Beam collimation ranged from 1 to 3 mm, and pitch values ranged from 1 to 1.5.[2–7] Although some studies focused on benign lesions of the airways,[5,6] others presented VE findings in various malign and benign lesions including malign neoplasms of the upper airways, vocal cord nodules, laryngeal cysts, Reinke's edema, and leukoplakia.[2–4,7] Common to all these studies, VE provided a good simulation of the OE view of the intraluminal mass when the mass was well projecting into the lumen. Inaccurate delineation of surface contour occurred, however, where there was apposition of normal tissue against tumor. These data show that a clear-cut air–tissue interface is needed for accurate depiction of airway lesions.

Although CT modality was used in this study to serve as the source to produce 3D images, one can use any set of cross-sectional images representing volumetric data such as 3D MR images or rotational angiography images. CT has been the choice of modality in the present study because we use CT as part of work-up of patients with known or suspected larynx or pharynx carcinoma. In this study, however, CT scanning protocol was different from the routine one with the main difference being in the slice thickness. The volumetric data produced with 1.3-mm-thick overlapping slices provided very high quality 3D images in our study. It should be stressed that the quality of 3D images depends highly on the spatial resolution of the source images.[1,8] In a previous experimental study, the authors compared beam collimation (1, 3, and 5 mm) as well as pitch values of 1, 2, and 3 in terms of smoothing artifacts, stair step artifacts, longitudinal blurring, and image distortion.[8] They found that the thin collimation beam combined with smaller pitch was the most resistant to the artifacts noted above. Our VE images were of high quality and free of artifacts. We believe that we mostly owe this success to thin beam collimation and low pitch value used in this study.

In spite of the high spatial resolution it has, VE missed the plaquelike lesion in our study. This results from the fact that VE lacks color resolution; VE cannot detect a lesion if it does not cause a contour abnormality. One of the other drawbacks of VE is that it cannot provide real-time imaging with the present technology. Although with the multidetector CT technology one can acquire nearly real-time data, repeated scans through the same region would cause unnecessary exposure with high dose ionizing radiation. On the other hand, we know that some MR techniques such as echo planar imaging have high temporal resolution, so it can produce nearly real-time images. However, we also know that these real-time images cover a limited area, not a volume. Furthermore, these fast images are of quite poor resolution. However, all of these limitations may be overcome and real-time VE could be produced in the future.

In conclusion, VE is a safe, noninvasive and effective means of 3D visualization of the lumen of the upper airways. Although it fails to show color characteristics of the surface and the dynamic properties such as contraction of the vocal cords, it provides endoscopic views of the lumen distal to a complete obstruction. It can be produced in a short time by exploiting the cross-sectional images appropriately obtained as part of the diagnostic work-up.

REFERENCES

1. Bartz D: Life and medical sciences. Virtual Endosc Res Clin Pract 24(1):1–17, 2005

2. Burke AJ, Vining DJ, McGuirt WF, Postma G, Browne JD: Evaluation of airway obstruction using virtual endoscopy. Laryngoscope 110:23–29, 2000

3. Gallivan RP, Nguyen TH, Armstrong WB: Head and neck computed tomography virtual endoscopy: evaluation of a new imaging technique. Laryngoscope 109:1570–1579, 1999

4. Walshe P, Hamilton S, McShane D, Walsh RM, Walsh MA, Timon MA: The potential of virtual laryngoscopy in the assessment of vocal cord lesions. Clin Otolaryngol 27:98–100, 2002

5. Men S, Ikiz AO, Topcu I, Cakmakci H, Ecevit C: CT and virtual endoscopy findings in congenital laryngeal web. Int J Pediatr Otorhinolaryngol 70:1125–1127, 2006

6. Gluecker T, Lang F, Bessier S, Monnier P, Meuli R, Schnyder P, Duvoisin B: 2D and 3D CT imaging correlated to rigid endoscopy in complex laryngo-tracheal stenoses. Eur Radiol 11:50–54, 2001

7. Byrne AT, Walshe P, McShane D, Hamilton S: Virtual laryngoscopy—preliminary experience. Eur J Radiol 56:38–42, 2005

8. Springer P, Stöhr B, Giacomuzzi SM, Bodner G, Klingler A, Jaschke W, zur Nedden D: Virtual computed tomography colonoscopy: artifacts, image quality and radiation dose load in a cadaver study. Eur Radiol 10:183–187, 2000