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The Role of Virtual Bronchoscopy Compared to That of Fiberoptic Bronchoscopy in Staging of Bronchogenic Carcinoma

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Abstract: Virtual bronchoscopy is a technical development that allows visualization of a dynamic image that resembles what is seen with fiberoptic bronchoscopy. *Objective*: The role of virtual bronchoscopy was compared to that of fiberoptic bronchoscopy in staging of bronchogenic carcinoma. Twenty patients with primary lung cancerwere subjected to Fiberoptic Bronchoscopy and virtual bronchoscopy. Seventeen cases with central tumors were detected by both FOB and VB. Tracheal abnormalities were detected in one case by FOB and in 2 cases by VB. Broadening of the main carina was reported in 5 cases by FOB and in 2 cases by VB. Narrowing of lobar and segmental bronchi was reported in 7 cases by FOB and in 7 cases by VB, 2 cases only were detected by both techniques. FOB reported vocal cords lesions in 4 cases, tracheobronchial mucous membrane lesions in 9 cases, broadening of interlobar and intersegmental carina in 4 cases. Detection of peripheral tumors, lymphadenopathy, the lung parenchyma lesions, pleural effusion, bony deposit were detected by VB supplemented by HRCT. VB can be considered as a valuable tool in the diagnoses, staging of tracheobronchial malignancy. It cannot replace FOB. The two techniques should be considered complementary.

Key words: Computed tomography · Virtualbronchoscopy · Fiberoptic bronchoscopy · Bronchogeniccarcinoma · Tracheobronchial tree · Mediastinal tumors

INTRODUCTION

The staging system for lung cancer has progressed over the years. Staging lung cancer plays several roles pertinent to the care of patients. First, it provides the individual clinician with a road map for evaluation of the disease, incorporating many different factors into an easily understandable system. Second, it provides accurate prognostic information that is necessary to develop an appropriate treatment plan. Third, it provides a standard that is used around the world such that ongoing research is not confused by varying case definitions. As this system continues to undergo evaluation and revision, it is important for all physicians involved in the diagnosis, staging and treatment of Bronchogenic carcinoma to be well versed in its details. In addition, one needs to be aware of new areas of interest such as novel prognostic tools and imaging techniques that may be helpful in patient care and that may be incorporated into future revisions [1].

Bronchoscopy is a valuable tool utilized for the diagnosis, staging and management of lung cancer. There are established techniques such as white light bronchoscopy and its ancillary procedures (forceps biopsy, brush biopsy, bronchoalveolar lavage, bronchial washings and transbronchial needle aspiration) that help assessing tumor location, size and type. Newer technologies such as autofluorescence bronchoscopy, narrow band imaging, endobronchial ultrasound, electromagnetic navigation, optical coherence tomography and confocal fluorescent laser microscopy are introduced and put into perspective [2].

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Multidetector computed tomography generated virtual bronchoscopy (VB) is a technical development that allows visualization of the lumen and wall of the trachea and proximal part of the bronchial tree. A dynamic image is produced that resembles what is seen with fiberoptic bronchoscopy (FOB) [3].

Virtual bronchoscopy (VB) is a computed tomography (CT) based imaging technique that allows a noninvasive intraluminal evaluation of the tracheobronchial tree. Several studies have shown that VB can accurately show the lumen and the diameter of the trachea, the left and right main stem bronchi and the bronchial tree down to the fourth order of bronchial orifices and branches. The morphology of the carinas can be evaluated accurately and the images look very similar to that seen with FOB [4].

In most cases, VB is able to depict direct tumor signs, such as a tumoral mass, a wall irregularity or a loss of cartilages. Indirect signs, such as stenosis or obstruction, compression or swelling, can often be visualized. However, mucosal infiltration, vascular dilatation and necrosis are usually missed [5, 6].

Aim of the Work: The aim of this work is to compare between the role of virtual bronchoscopy to that of fiberoptic bronchoscopy in staging of bronchogenic carcinoma.

Subjects and Methods: This study was a collaboration between the chest and the radiodiagnosis departments of the Cairo University Hospital and the National Research Center. It included 20 patients diagnosed pathologically as primary lung cancer. All subjects gave written informed consent. The study was approved by the ethical committee of the National Research Center. Exclusion criteria were patients receiving any anti-cancer treatment before enrollment.

All subjects included in the study were interviewed to fulfill personal and medical questionnaire, thorough clinical examination and chest radiography, Fiberoptic Bronchoscopy (Bronchial washing and Bronchoalveolar lavage, Bronchial and Transbronchial biopsies or Transbronchial needle aspiration procedures were done as needed),Transthoracic C.T. guided biopsy for peripheral tumors and virtual bronchoscopy.

Virtual Bronchoscopy:Computerized tomography scan examinations of the chest in supine position was performed without intravenous contrast media using GE Light Speed Multislice 4 channels. A scout is taken with Kv 120 and mA 20, then helical scanning was done in caudocranial direction to minimize respiration artifacts, using detector row 4, helical thickness 1.25, pitch 1.5:1, speed (mm/rot) 7.5, Detector configuration 4 X 1.25, beam collimation 5.00 mm, interval 1.00, gantry tilt 0.0, FOV depends on the patients' body build, but is about 35cm, Kv 120-140, mA 120-160, total exposure time 16-20sec during breath hold in inspiration. The images acquired were manipulated and reconstructed.

Reconstruction Techniques: Several reconstruction techniques were used each aiming for a certain diagnostic achievement as follows:

- *3D Internal Surface Rendering:* also termed virtual bronchoscopy (VB), where images simulate those of true bronchoscopy. The cursor of the virtual camera was guided manually to cover all regions from the trachea till the segmental bronchi, taking pertinent images and naming each.
- *3D Volume Reentering:* images show the out features of the bronchial tree and lungs where any external deformity could be detected.
- *2D Minimum Intensity Processing (min IP):*images only detect the lowest Hounsfield attenuation values available thus only detecting air column within the bronchial tree, this technique enhances the detection of internal deformities or caliber changes and shows distal air beyond an obstructed area.
- *2D Multiplanar Images Reconstruction (MPR):* images were reconstructed in axial and coronal showing the airway, the surrounding lesion(s), their extent, effects and relations. It could also clarify other possible lesions such as pleural effusions, mediastinal extension and lymphadenopathy, pericardial changes.
- *High Resolution CT images of the lungs*was done as a supplementary study to evaluate the lungs for possible lymphangitiscarcinomatosus, this was not a part of the virtual bronchographic study but we found it helpful in patient's staging and management without significant extra effort.

Statistical Analysis: Data were analyzed using the SPSS version 15. Quantitative data were presented in mean and standard deviation. Qualitative data were presented using the frequency and percentage. Kappa agreement was calculated between the two diagnostic techniques. The K value can be interpreted as Poor < 0.20, Fair 0.21-0.40, Moderate 0.41-0.60, Good 0.61-0.80 and Very Good 0.81-1.00 [7].

RESULTS

The study included 20 patients (16 males, 4 females) diagnosed pathologically as primary lung cancer. None of the patients was exposed to an industrial hazard related to lung cancer.The mean of age was 57.6± 14.2 years. The female patients included in the study were nonsmokers, while 11 of the males were smokers (83.1±55.2 pack/year) (Table 1).

Out of 20 cases diagnosed as bronchogenic carcinoma 17 cases of central tumors could be detected by both FOB and VB. In defining the exact location of the tumors in the tracheobronchial tree VB Could detect all 17 cases (100 percent) reported by FOB. There was a very good agreement between the two techniques (Kappa =1.0, P <0.001). Tracheal abnormalities were detect in one case as a bulge at its lower end by FOB. VB detected 2 of the abnormalities, as a deformed trachea and as saber sheath trachea, showing a poor agreement between FOB and VB (Kappa = 0.07, P=0.732). Broadening of the main carina was reported in five cases by FOB and in 2 cases by VB, showing a poor agreement between FOB and VB in detecting broadening of the main carina (Kappa = 0.167, P =0.389). Narrowing of lobar and segmental bronchi due to external compression was reported in 7 cases by FOB, VB also reported this abnormality in 7 cases, 2 cases only were detected by both techniques denoting a poor agreement between FOB and VB reports concerning narrowing of lobar or segmental bronchi (external compression) (Kappa = 0.09, P =0.658) (Table 2). FOB reported vocal cords lesions in 4 cases, tracheobronchial mucous membrane lesions in 9 cases, broadening of interlobar and intersegmental carina in 4 cases; VB did not detect these lesions (Table 3). Detection of peripheral tumors (2cases), lymph-adenopathy (11 cases), lesions in the lung parenchyma (18 cases), pleural effusion (7 cases) and bony deposit (1 case) were detected by VB supplemented by HRCT which is done as a supplementary study to evaluate the lungs for possible lesions. FOB did not detect these lesions (Table 4).

Table 1: Characteristics and smoking history of the study sample

Total No.		20
Age (years) (Mean±SD)		57.6±14.2
Sex	Male	16
	Female	4
Smoking history	Non-smokers No.	5
	Smokers No.	15
	Total pack/year	83.1±55.2
	(Mean± SD)	(Min30 – Max215)

Table 2: Comparison between Fiberoptic Bronchoscopy & Virtual Bronchoscopy in detection of central tumors, tracheal compression or distortion, broadening of main carina and narrowing of lobar bronchi.

		Virtual Bronchoscopy			
		Fiberoptic Bronchoscopy			
Lesions		positive	Negative	Kappa	P
Central tumors	positive	17 (85%)	0	1.0	0.001
	Negative	0	3 (15%)		
Tracheal compression or distortion	positive	0 (0%)	2 (10%)	0.07	0.732
	Negative	1 (5%)	17 (85%)		
Broadening of main carina	positive	1 (5%)	1 (5%)	0.167	0.389
	Negative	4 (20%)	14 (70%)		
Narrowing of lobar bronchi	positive	2 (10%)	5 (25%)	0.09	0.658
	Negative	5 (25%)	8 (40%)		

Table 3: Findings detected only by Fiberoptic Bronchoscopy

	Study Sample No. =20	
	No.	%
Vocal cord affection	4	20%
Bronchial mucosal affection	9	45%
Broadening of interlobar carina	4	20%

Table 4: Findings detected only by Virtual Bronchoscopy

	Study Sample No. =20	
	No.	%
Detection of peripheral tumors	2	10%
Lymphadenopathy detection	11	55%
Parenchymatous affection	18	90%
Pleural affection	7	35%
Bony affection	1	5%

DISCUSSION

Computed tomography (CT) can be used for detailed noninvasive imaging of the airways and surrounding structures. Virtual bronchoscopy combines multidetector helical CT with computer-assisted image processing to generate high quality intra- and extra-luminal views of the airways. The use of novel, automated reconstruction algorithms can help assess the craniocaudal extent of an airway abnormality, detect subtle areas of stenosis and define complex anatomical relationship. In addition, this technology improves the ability of radiologists to assess airway disease noninvasively. Helical (or spiral) CT allows uninterrupted acquisition of volumetric near-isotropic source data, from which multiplanar or three-dimensional images can be generated. Multidetector helical CT scanners with sub-second gantry rotation time permit collection of a volumetric data set, extending from the vocal cords through the segmental bronchi, during a single breath-hold of less than 10 seconds. Images are typically obtained at end-inspiration; if dynamic airway collapse is suspected, these are supplemented with end-expiratory imaging. Intravenous contrast may be desirable if vascular rings, slings, or neoplastic airway involvement is suspected [8].

Comparing FOB and VB in the detection and accurate localization of central tumors, 17 out of the 20 cases of bronchogenic carcinoma were detected by both techniques. This result showed the very good agreement of FOB and VB in this concern (Kappa = 1.0, $p < 0.001$) (table 2). Moreover, there was a good agreement between FOB and VB in locating the site of these tumors in the different bronchial radicles.

Out of the 20 cases of bronchogenic carcinoma included in this study, 2 of the cases were reported as negative for central tumors by both FOB and VB, they proved to be peripheral tumors by VB and complementary HRCT (Table 4).

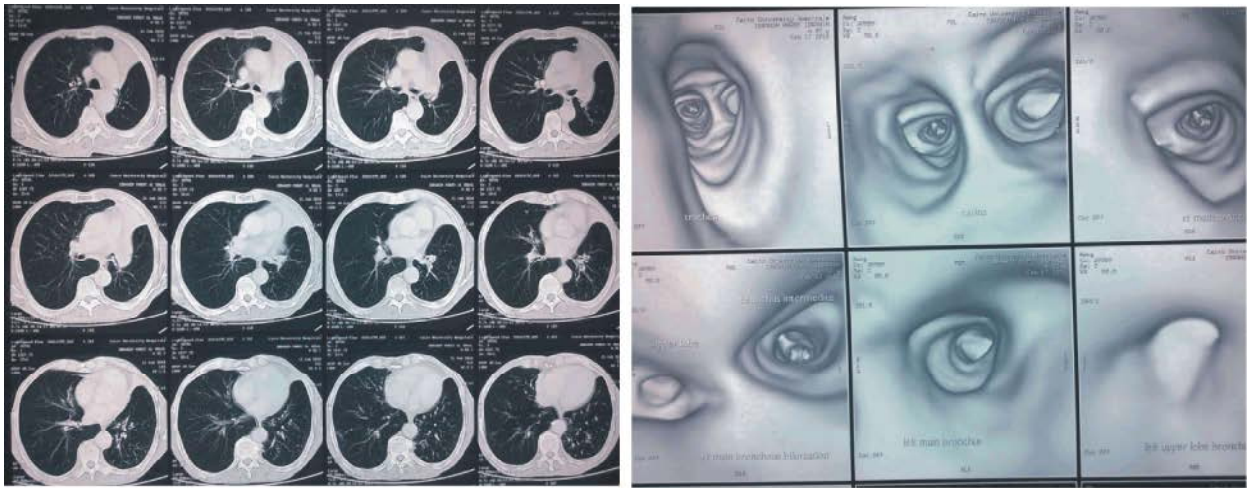
Abnormalities of the bronchial mucosa, bleeding, ulceration, infection or infiltration were not detected by VB. However, these mucosal abnormalities were reported by FOB in 9 of the cases (45%). As well vocal cords affection was reported by FOB in 4 cases but not by VB. The study started at the trachea, the larynx was not included (Table 3).

Broadening of the main carina was reported, in one case by both FOB and VB. In 4 of the cases, broadening of the main carina was reported by FOB but not VB. In one case the abnormality was reported by VB alone (Kappa = 0.167, $p = 0.389$) (table 2) denoting a poor agreement between the two techniques in detecting these lesions.

Although FOB and VB reported the narrowing of lobar or segmental bronchi due to external compression abnormality in 7 of the cases, only 2 cases were detected by both techniques (kappa = 0.09, $p = 0.658$) (Table 2).

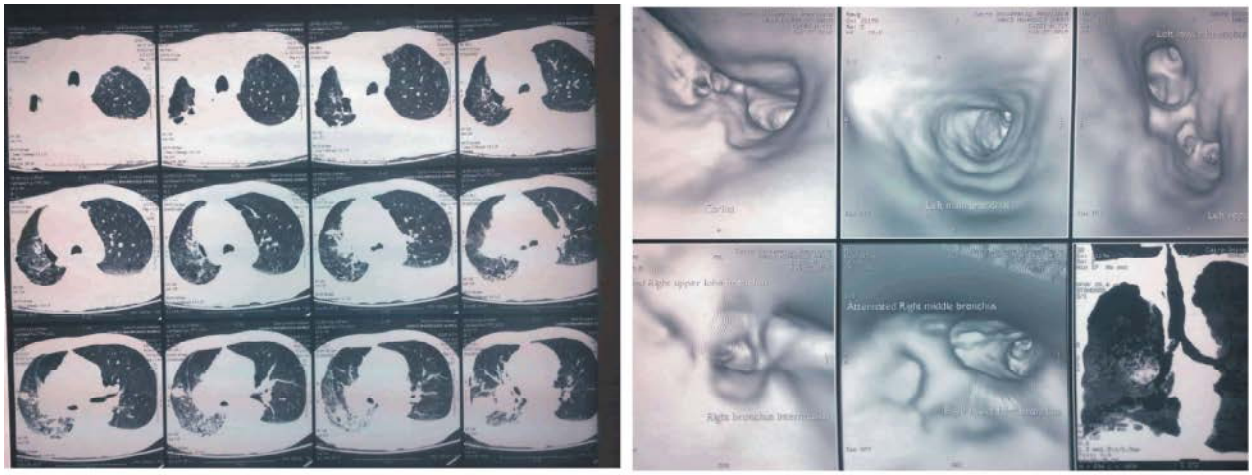
Virtual bronchoscopy provides images that simulate those of true bronchoscopy (Figures 1 and 2). The images show the out features of the bronchial tree and lungs where any external deformity can be detected. It can also clarify other possible lesions such as pleural effusion, mediastinal extensions, lymphadenopathy, pericardial changes. High resolution CT images of the lung are done as a supplementary study to evaluate the lungs for possible lesions. This is not a part of VB. study but it was found helpful in patient staging and management without extra-effort. Accordingly, the following findings were exclusively observed on the VB report; parenchymatous changes in 18 of the cases (90%), lymphadenopathy in 11 of the cases (55 percent), pleural effusion in 7 of the cases (35%) and rib erosion in one cases (Table 4).

Several studies evaluated the role of VB compared to that of FOB in diagnosing and staging of lung cancer. *Fleiter et al.* [9] studied 20 cases with lung and mediastinal tumors by both FOB and VB.; staging these tumors for therapeutic decision making. VB of diagnostic quality was achieved in 19 out of the 20 cases. They concluded that VB is a noninvasive technique equally well as FB. In this respect our findings agreed with their result, in case of central tumors. In their series VB allowed for accurate anatomical visualization beyond stenosis.



(a) (b)

Fig. 1: (a) CT chest shows left hilar mass lesion. (b) VB shows obstructed left upper lobe bronchus.



(a) (b)

Fig. 2: (a) CT chest shows right hilar mass (b) VB shows attenuated right middle lobe bronchus.

Discrete malignant infiltration and extra luminal compression were not visualized by means of VB in 5 of their cases. In our series there was no agreement between FB and VB concerning extra-bronchial compression. The workers found that the major disadvantage of VB is its inability to evaluate the mucosal surface, viscid secretion could be mistaken for stenosis or occlusion, this can be obviated in our opinion, by good preparation of the patients before diagnostic studies. They considered VB particularly promising for patients in whom conventional procedures are not feasible, particularly children, a view we actually support. *Liewald et al.* [10] evaluated 30 patients with lung cancer using FOB and VB. Thirteen obstructive lesions were seen equally well using FOB and VB. However, mucosal lesions were not visualized by VB which is a major disadvantage of the VB compared to FB. These findings match well with ours, VB could detect all central lesions reported by FB (Tables 2 and 3).

Seeman and Claussen[11] studied 14 patients; 11 with lung cancer and 3 post lung transplant. The clinical findings and classification of the stenosis by VB were in agreement with the results of FB, sensitivity 93.8 percent and specificity 99.7 percent.

Finkelsteon *et al*. [12] studied 32 patients with thoracic malignant tumors to evaluate the diagnostic potential of VB by comparing VB images with FOB findings in patients with thoracic malignancy. VB detected 18 out of 22 abnormal FB findings, 13 out of 13

obstructive, 5 of 6 endoluminal lesions, none out of 3 mucosal lesions and 82 percent for all abnormalities. In our series the findings match well with his study, VB detected 17 cases with endobronchial central lesions detected by FOB and none of the 9 cases with mucosal lesions reported by FOB were detected by VB. They concluded that VB provided accurate information regarding the length of the obstructive lesion and the anatomy distal to the obstruction, it had proved useful for assessing the feasibility of anatomic segmentectomy, as well as that of endobronchial laser or photodynamic therapy, in thoracic oncology patients. On the other hand, they found that the limitation of VB is its inability to evaluate the mucosal surface of the tracheo-bronchial tree and acquisition of tissue samples for histologic or microbiologic analysis.

Lacasse *et al*. [13], reported that there was a good agreement between FOB and VB regarding the location of endobronchial lesions but VB is not accurate enough to detect these lesions beyond the main stem bronchi, looking forwards that the following multidetection, helical CT scanners will improve the accuracy of VB to detect endobronchial lesions, findings which matched well with our study.

Adali*et al.* [14] evaluated 22 patients with FOB and VB. The VB results were evaluated blindly, independent of the FOB data. Tracheo-bronchial abnormalities were reported by FOB in 19 cases and 3 cases were normal. VB detected 17 abnormalities out of the 19 reported by the FOB. In their series FB detected endoluminal lesions, VB detected six. In evaluating external compression FOB detected 2 lesions and VB detected 15. They concluded that FOB was difficult to use in evaluating external compression, these findings are in concordance with ours, where no agreement was found between FOB and VB in this concern.

Allah *et al*, [15] found that the data obtained by VB and FOB (signs of tumor infiltration including endobronchial mass, stenosis, obstruction and external indentations) were comparable. However, FOB had the advantage of giving direct cues to color, vascularity and motility. It also detected early tumor infiltration by picking up subtle mucosal changes. Alternatively, VB was superior in bypassing any obstruction and therefore provided an excellent view distal to the obstructive lesions or stenotic segments. VB provided an excellent overview of the trachea, main stem and lobar bronchi up to the fourth order. It also defined the optimum pathway for passing instruments into lesions beyond the field of view.

Hussein, [6] concluded that VB allows a noninvasive intraluminal evaluation of the tracheobronchial tree. In addition to its direct roles in patient care, VB has great potential in education, bronchoscopy training and procedure planning. VB can be performed when FOB is contraindicated or considered risky, as in cases with airway narrowing. Also, it can be done as a preliminary evaluation before FOB. VB is not effective for the detection of subtle mucosal abnormalities, such as erythema or early sessile lesions.

In conclusion, VB can be considered as a valuable tool in the diagnoses, staging and treatment planning for cases of tracheobronchial malignancy. VB provides accurate information regarding the length of the obstructive lesion and its anatomy. Additional information provided by VB. and the complimentary HRCT. allow a more precise staging of bronchogenic carcinoma, yet for lack of pathologic diagnosis it cannot completely replace FOB. The two techniques should not be considered as competing tools but rather complementary to each other.

Abbreviations: Computed tomography (CT), High Resolution CT images (HRCT) Fiberoptic bronchoscopy (FOB), Minimum Intensity Processing (min IP), Multiplanar Images Reconstruction (MPR), Virtual bronchoscopy (VB)

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