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Comparative evaluation of 64- slice multidetector CT virtual bronchoscopy with fiberoptic bronchoscopy in the evaluation of tracheobronchial neoplasms

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Abstract
Introduction: Lung tumours represent a true epidemic of the twentieth century. Lung cancer has become the leading cause of cancer-related mortality worldwide. Multidetector CT has revolutionized anatomic and functional imaging of the central airways and enhanced the ability to diagnose airway pathology especially using three- dimensional reconstruction techniques. These images aid both radiologists and referring clinicians by demonstrating anatomic relationships and the extent of disease
Aim: To evaluate the diagnostic accuracy of MDCT virtual bronchoscopy (VB) compared to fiberoptic bronchoscopy (FOB) in detecting tracheobronchial neoplasms. To find ways in which MDCT VB could be additive to FOB.
Materials and methods: Fifty-eight patients with suspected tracheobronchial malignancies were selected for a comparative analysis analysis between VB and FOB. Lesions were evaluated in terms of site of lesion, type of lesion, degree of stenosis and visualization of airway distal to the lesion. Additional findings were also sought in each modality.
Results: The study comprised 38 men and 21 women. VB detected 110 lesions and FOB identified 84 lesions. Concordant findings for tumour detection and localization were noted in 69 airways. Sensitivity of VB was therefore 82.1% and specificity was 97.2%. The accuracy was 96.4%. There was a substantial agreement (κ: 0.69; C.I. 0.64 to 0.74) between VB and FOB regarding the site of tumour detection. In assessing the type of lesion, the study showed sensitivities and specificities of 60% and 99.6% respectively for endoluminal lesions (moderate agreement, κ=0.50), 87.2% and 98.3% respectively for lesions causing extrinsic compression (substantial agreement, κ=0.67). Overall, the agreement between VB and FOB regarding the grade of stenosis detected in corresponding areas/ levels was moderate to substantial (κ: 0.63; C.I. 0.56 to 0.71). VB offered the advantage of being able to visualize areas beyond even high grade stenoses. VB was able to explore the airways beyond stenosis in 33 patients, whereas, FOB was able to explore the airways beyond stenosis in 6 patients. Thus, virtual bronchoscopy had a sensitivity of 100% and a NPV of 100 %.
Conclusion: The results of the study indicate that VB is an excellent non-invasive modality that can be used efficiently as a first-line investigative tool and complementary tool to FOB in the diagnosis, treatment and management of patients with tracheobronchial neoplasms. It can guide the referring clinician in further management of the patient. It can also replace FOB in selected cases.

Keywords: airway, bronchoscopy, computed tomography, endoluminal, extrinsic compression, obstructive, three-dimensional

Introduction
Lung tumours represent a true epidemic of the twentieth century. Once rare, there are now 1.61 million new cases of lung cancer per year, with 1.38 million deaths, making lung cancer the leading cause of cancer-related mortality worldwide. In India, approximately 63,000 new lung cancer cases are reported each year. The global trend of rise in adenocarcinoma is paralleled in India [1, 2, 3, 4, 5]. The presented epidemiological data emphasizes the need for earlier detection, better treatment and prevention of lung cancer and points to the importance of better diagnostic methods.
Multidetector CT (MDCT) due to its higher spatial resolution, faster speed, greater anatomic coverage, and higher quality multiplanar reformation and 3-dimensional (3D) reconstruction images has revolutionized anatomic and functional imaging of the central airways [6]. The 3D images enable visualization of all the structures within the thorax (i.e. airways, mediastinal blood vessels, and the mediastinal lymph nodes) display their complex 3D relationships, detect subtle airway stenosis and estimate cranio-caudal extent of the disease [7].
Virtual Bronchoscopy (VB) is a novel computer generated 3D post processing technique that employs reconstruction of high- resolution helical CT images for non- invasive evaluation of the tracheobronchial tree [8, 9], VB assists navigation in bronchoscopy, and the volume-rendering technique is effective in finding congenital anomalies of the vessels during preoperative assessment [10]. In their patients with lung cancer Cicero *et al* observed that neither the staging nor diagnosis was modified substantially, but virtual bronchoscopy contributed to enhanced understanding of the pathology of `the neoplastic process [11]. However, its limitations include poor sensitivity for evaluating mucosal lesions; secondly retained mucus or blood can create false positive findings. Histological/ cytological analysis of tissue is not possible and dynamic airway lesions such as immobile vocal cords etc. cannot be identified [12, 13].

Aim

The aim of this study was to evaluate the diagnostic accuracy of MDCT virtual bronchoscopy compared to fiberoptic bronchoscopy in detecting tracheobronchial neoplasms and to investigate if virtual bronchoscopy could prove to be a non-invasive investigative novel technique for evaluating obstructions, endoluminal masses, and post-stenotic areas within the tracheobronchial tree.

Materials and Methods

This prospective study was conducted on 58 patients with suspected tracheobronchial malignancies who reported to our hospital between July 2011 to June 2012. The approval of the local ethical committee was sought and informed consent was obtained from patients before the examinations. All patients were subjected to prior clinical history, examination and chest X rays. Patients with contraindications for FOB, history of significant allergic reaction to contrast media, pregnant patients, those unable to hold breath for sufficient time and patient unwilling to undergo diagnostic imaging of the chest were excluded from the study. All these patients underwent FOB first followed by MDCT Virtual Bronchoscopy or vice versa. The average time interval between FOB and VB was 14 days. FOB was considered as "gold (reference) standard". VB results were evaluated blindly and independently from those of FOB.

Bronchoscopy technique: Fibreoptic Bronchoscopy was performed by an experienced Pulmonologist via the oral or nasal route with a bronchoscope (Pentax EPK- i) under anaesthesia and /or light sedation (Midazolam 1-3 mg/kg body weight). The bronchial tree was explored systematically (trachea, mainstem bronchi, lobar and segmental bronchi) and samples were obtained wherever possible using endobronchial biopsy, transbronchial needle aspiration, brushing, bronchoalveolar lavage or a combination of them. Final diagnosis was approved by cytology and/or histopathology of these specimens.

MDCT and Virtual Bronchoscopy technique: The study was conducted using 64-MDCT (Lightspeed VCT-XTe, GE medical systems) scanner. Scans were acquired cranio-caudally from the soft palate upto the lower costal margin. For the CT scans, the kVp was 100-120 kV, the pitch was 0.948:1 and the effective collimation was 64× 0.625 mm. Images with thickness of 0.625 mm with 0.625 mm increment were reconstructed using a standard kernel. The data was transferred to a real-time interactive 3D Workstation: Advantage Window version 4.5, GE Healthcare. Intravenous contrast agent was administered in all patients except those in whom renal function tests were deranged. Virtual bronchoscopy images were generated using endoscopic shaded surface display (SSD) views. The system used ASiR (Adaptive Statistical Iterative Reconstruction) an advanced image reconstruction technique that reduces image noise and improves low contrast detectability by up to 30%, and reduces radiation dose by up to 40% without sacrificing image quality.

Image Analysis: In a normal person, having no developmental anomalies, the bronchial tree consists of the trachea and 26 bronchi (15 bronchial branches on the right and 11 on the left side). Hence, in 58 patients, 1,566 different levels of the bronchial tree altogether were analysed. The airways were further divided into central airways (trachea, RMB, RUL, BI, RML, RLL, LMB, LUL, LLL) and segmental airways (all segmental bronchi).

Two- dimensional views were evaluated at the standard lung parenchymal window (level -600 HU, width 1200 HU) and mediastinal window (level -40 HU, width 400 HU). A threshold value of –250 to –500 HU was used for visualization of the central bronchial tree, whereas a threshold of –750 to -900 HU was used for evaluation of the distal airway branches.

The following features were assessed on both FOB and MDCT Virtual bronchoscopy:

1. Number and site of lesions: The tracheobronchial tree was investigated after dividing it into segments for an objective comparison between FOB and VB.
2. Type of lesions: These were described as obstructive lesions (defined as a bronchial narrowing of > 50%), endoluminal lesions (defined as a mass protruding into the lumen with < 50% occlusion), or mucosal lesions (defined as haemorrhage, erythema, or tissue friability) as described by Finkelstein *et al*[8]. In addition, extrinsic compressions detected on VB and MPR findings were recorded.
3. Grade of stenosis: We used a semi-quantitative grading where bronchial stenosis was graded as follows: grade I- no stenosis, grade II- <30% stenosis, grade III- 30% to 59% stenosis, grade IV- 60% to 79% stenosis, grade V- ≥80% stenosis and grade VI- complete occlusion.
4. Distal patency beyond the lesions.
5. Additional findings.

Statistical analysis

Statistical analysis was performed using Epi Info™ 7 AND Open Epi version 2.3 for Windows 7. The results of VB were compared directly with actual FOB findings considering FOB as gold (reference) standard and the sensitivity, specificity, positive and negative predictive values for VB was calculated (using Wilson score). The sensitivity, specificity, and accuracy were calculated from 2 × 2 contingency tables, with confidence intervals being derived from binomial distribution. A method developed by Dr. Alex Mitchell called the clinical utility index (CUI) was also used wherever possible in our study (with kind permission of the author). The scores were converted into qualitative grades as follows: excellent utility ≥ 0.81, good utility ≥0.64 and satisfactory utility ≥0.49 and poor utility < 0.49 [14, 15].

We determined the concordance between FOB and VB for i) type of lesion and ii) grade of stenosis detected at different airway levels. Kappa (κ) statistics were calculated to compare the results of FOB and VB to evaluate the level of agreement between these investigations. Based on criteria originally proposed by Landis and Koch in 1977, a kappa ranging from 0.81 to 1.0 would denote an almost perfect agreement; 0.61 to 0.80, a substantial agreement; 0.41 to 0.60, a moderate agreement; 0.21 to 0.40, a fair agreement; 0 to 0.20, a slight agreement and less than 0, a poor agreement. The p value for κ was calculated [16].

Results

The study population consisted of 38 men (64.4%) and 21 women (35.6%) with an age range of 26-83 years (mean age, 58.5 years; median age, 60.5 years; SD, ±10.5 years Maximum number of patients were in the age group of 60-69

years (n=23; 81.8%). Most patients in the study group were smokers (48 persons, 81.4%), while 11 were non- smokers (18.6%). The most common histopathological/ cytological diagnoses included: adenocarcinoma in 23 patients (39%), squamous cell carcinoma (SCC) in 20 patients (33.9%), small cell lung cancer (SCLC) in 13 patients (22%). Of the 11 non-smokers, six (54.6%) were diagnosed with adenocarcinoma.

Table 1: Comparison of number of lesions detected with FOB and VB on a per-airway analysis

	Fibreoptic bronchoscopy		
	Positive	Negative	Total
Virtual bronchoscopy			
Positive	69	41	110
Negative	15	1441	1456
Total	84	1482	1566

VB had a sensitivity of 82.1% (C.I. 76.2% to 88.9%) and a specificity of 97.2% (C.I. 96.3% to 98%) in the detection of tumour lesions. The PPV and NPV of VB were 62.7% (C.I. 53.4% to 71.2%) and 99% (C.I. 98.3% to 99.3%) respectively. The diagnostic accuracy was calculated to be 96.4% (C.I. 95.4% to 97.2%). The clinical utility of the test for case-finding (confirmation) i.e. positive clinical utility index was 0.52 (fair). The clinical utility of the test for screening (ruling out) i.e. negative clinical utility index was 0.96 (excellent). The overall value of this single test for combined screening and case-finding was good with a score of 96.4 on 100. Overall, the agreement between VB and FOB regarding the site of tumour detection was substantial (κ: 0.69; C.I. 0.64 to 0.74). The p value of κ (kappa) was < 0.001.

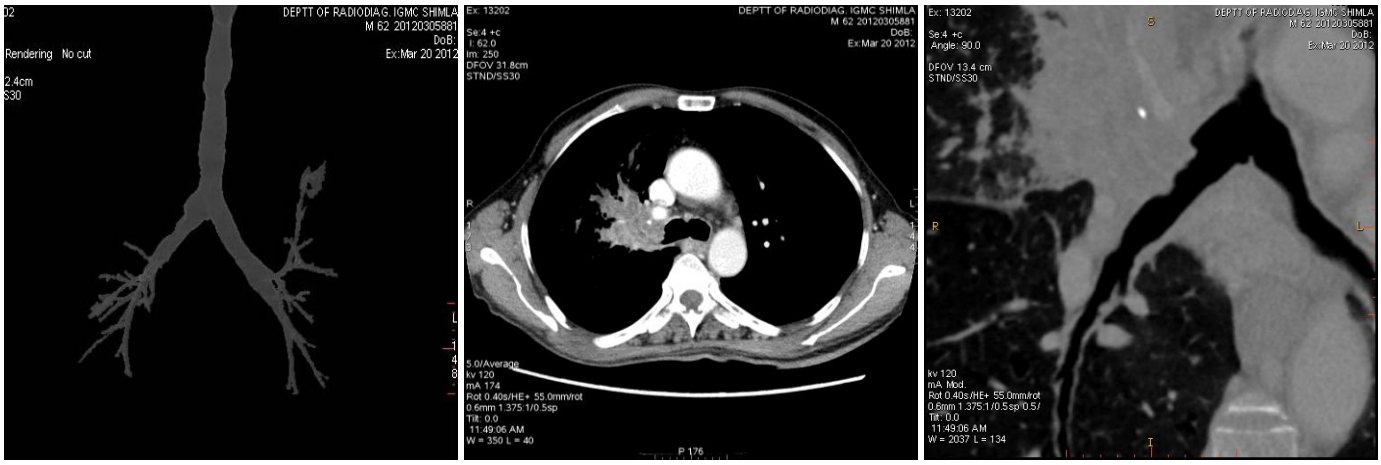
NUMBER AND SITE OF LESIONS: FOB revealed lesions in 73 central airways, whereas VB showed lesions in 86 central airways. VB had a sensitivity of 78.1% (C.I. 68.6% to 87.6%) and a specificity of 93.5% (C.I. 91.3% to 95.8%) in the detection of tumour lesions in central airways. The PPV and NPV of VB were 66.3% (C.I. 56.3% to 76.3%) and 96.3% (C.I. 94.6% to 98.1%) respectively. The diagnostic accuracy was calculated to be 91.4% (C.I. 88.7% to 93.5%). The positive clinical utility index was 0.52 (fair). The negative clinical utility index was 0.90 (excellent). There was a moderate to substantial agreement between VB and FOB regarding the site of tumour detection (κ: 0.67; C.I. 0.58 to 0.75). The p value of κ was < 0.001.

Table 2: Comparison of number of lesions detected with FOB and VB on a per-airway analysis in Central and Segmental airways

		Group 1 (Central airways)	**Group 2 (Segmental airways)**
VB +	FOB +	57	7
VB -	FOB +	16	5
VB +	FOB -	29	16
VB -	FOB -	420	1016
TOTAL		522	1044

TYPE OF LESIONS: Type of lesion assessed on FOB and MDCT Virtual bronchoscopy is shown in table 3. Virtual bronchoscopy detected obstructive lesions as effectively as FOB with a sensitivity of 88% and a specificity of 99.2% (*Figures 1*). There was substantial agreement between the two modalities (κ=0.74). In addition, in one case, it detected obstructive lesion of a sub-segmental bronchus (RB10) where FOB could not reach. Additional obstructive lesions were also detected by VB in segmental bronchi in 11 cases where FOB could not negotiate through high grade stenosis in the corresponding obstructed proximal airway. Virtual bronchoscopy could detect 6 of the 10 endoluminal lesions. It missed lesions in 4 locations. There was moderate agreement between the two modalities (κ=0.50). In addition, VB detected 7 extra endoluminal lesions (false positive) not picked up by FOB. In our study, VB detected only 2 of the 11 mucosal lesions detected on FOB (*Figure 2*). These lesions were in the central airways in the same patient. The mucosal lesions were seen as irregularities of the inner surface of the bronchi. Most subtle mucosal lesions identified by FOB were either not identified or misinterpreted as lesions causing mere extrinsic compression.

On an analysis of the overall concordance between VB and FOB regarding the type of lesion, VB missed 3 of the 25 obstructive lesions, 5 of the 39 lesions causing extrinsic compression and 2 of the 9 endoluminal lesions. Overall, the agreement between VB and FOB regarding the type of lesion detected in corresponding areas/ levels was substantial (κ: 0.67; C.I. 0.60 to 0.75). The p value of κ was < 0.001.



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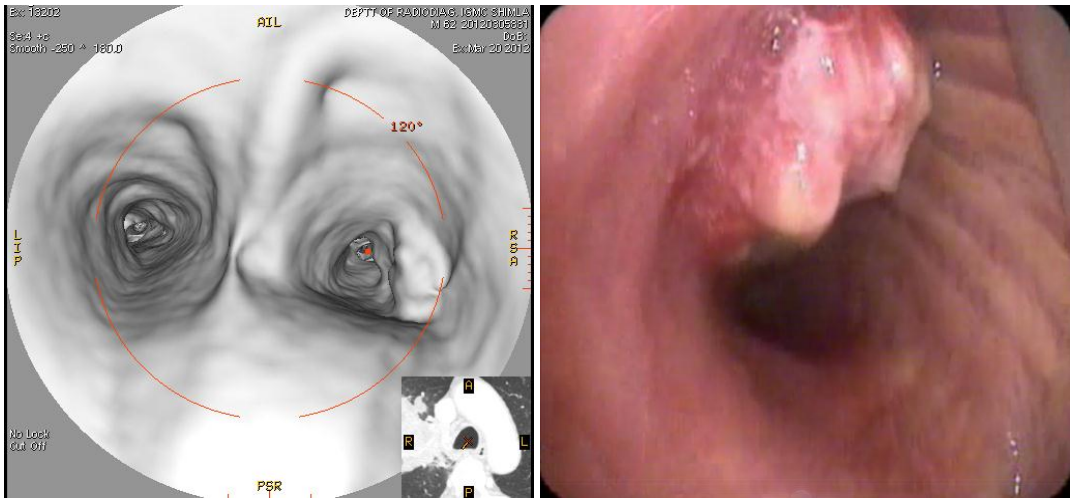
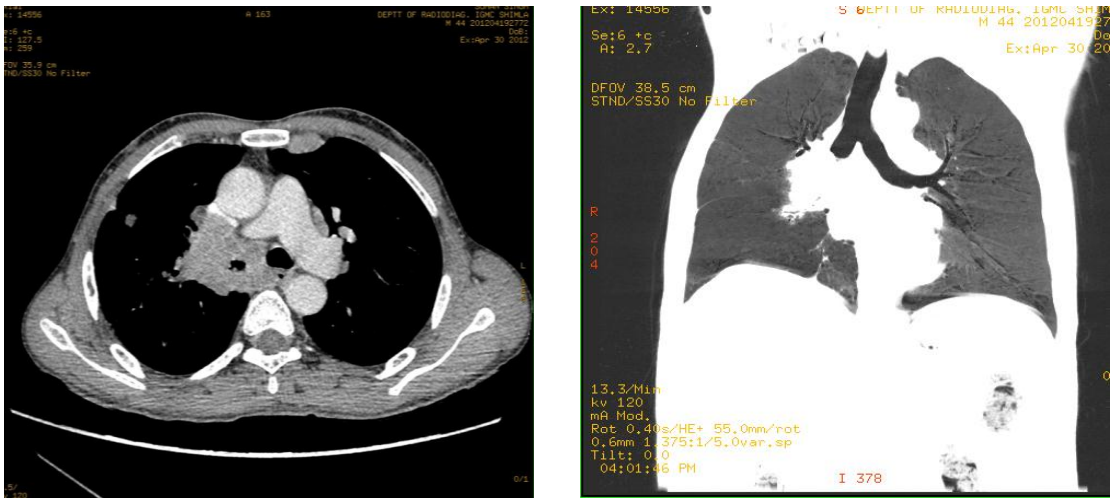


d **e**

Fig 1: 62 year old man who presented with cough, chest pain, dyspnoea and haemoptysis.
a: Virtual 3D reconstruction of airways when viewed externally shows cut off at the level of the RUL bronchus with an irregularity at this area. **b:** Contrast enhanced axial CT image shows a heterogeneously enhancing spiculated mass in relation to the RUL bronchus. **c & d:** MPR in lung window and VB images show an endobronchial growth causing complete occlusion of the RUL bronchus and <50% stenosis of the bronchus intermedius. **e:** FOB confirmed the findings of VB
Biopsy revealed keratinizing squamous cell carcinoma.



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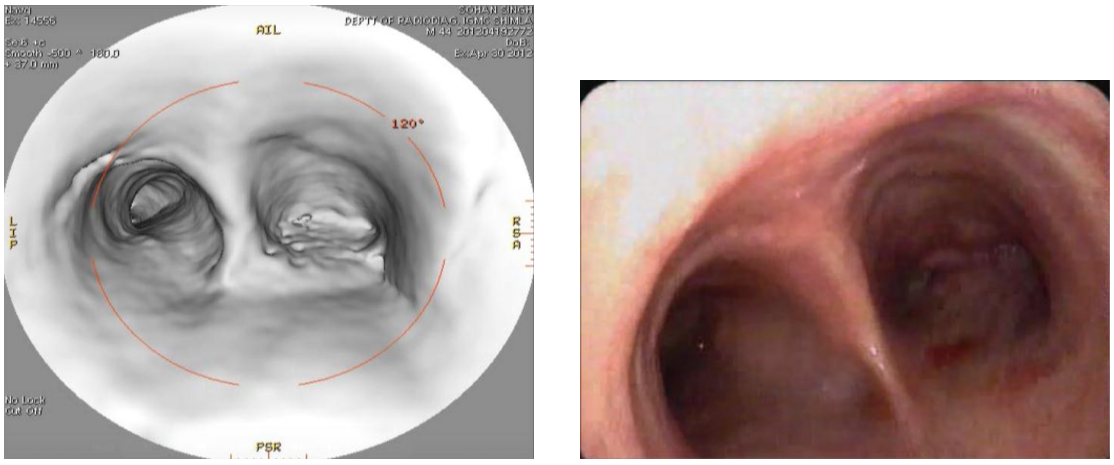


c **d**

Fig 2: 44 year old man, smoker, who presented with chest pain and dyspnoea. **a & b:** Contrast enhanced axial CT (mediastinal window) and minIP images show a mass in relation to the RMB, RUL and BI. **c & d:** VB showed surface irregularities at the RMB and RUL with extrinsic compression at BI. FOB confirmed these findings. HPE revealed small cell lung cancer. **Comment:** VB was able to identify surface irregularities. This case illustrates that VB when combined with MDCT axial images helps in staging lung cancer for further management of patients.

Table 3: Analysis of overall concordance between FOB and VB regarding type of lesion on a per-airway reading

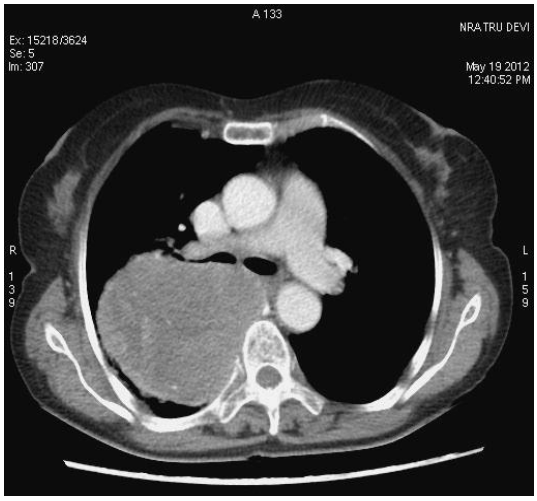
Types of lesions at VB	Types of lesions at FOB					Total
	Obstructive	Endoluminal	Mucosal	Extrinsic compression	No lesion	
Obstructive	22	0	0	0	12	34
Endoluminal	0	6	0	0	7	13
Mucosal	0	0	2	0	0	2
Extrinsic compression	0	1	4	34	21	60
No lesion	3	3	5	5	1441	1456
Total	25	10	11	39	1481	1566

BRONCHIAL STENOSIS: The grade of stenosis as detected on FOB and MDCT Virtual bronchoscopy is shown in table 4. In our study, the gold standard FOB revealed 84 stenoses, whereas VB showed 110 stenotic lesions. In 69 airways, stenoses were identified in both VB and FOB. The overall sensitivity was 82.1% and specificity was 97.2%. The diagnostic accuracy was calculated to be 96.4%. Most stenoses were detected in central airways with a sensitivity of 85.9% and a specificity of 93.8%. In segmental airways, the sensitivity was 66.7% and specificity was 98.6%. The agreement between VB and FOB regarding the site of detection of stenosis was substantial (κ=0.69).

On an analysis of the overall concordance between VB and FOB regarding the grade of stenosis, VB missed 3 of the 22 complete occlusions (100% stenosis), 6 of the 16 grade I (<30%) stenosis, 5 of the 35 grade II (30%- 59%) stenosis. Only 4 of the 8 grade IV (≥80%) stenosis described at FOB were described as such at VB. Overall, the agreement between VB and FOB regarding the grade of stenosis detected in corresponding areas/ levels was moderate to substantial (κ: 0.63; C.I. 0.56 to 0.71). The best concordance in the detection of grade of stenosis in corresponding areas in both modalities was seen in the central airways, in particular, upper lobe bronchi (right and left lungs). The maximum numbers of stenoses detected in both modalities were also found in the upper lobe bronchi.

Table 4: Analysis of concordance between FOB and VB regarding grade of stenosis

Grade of stenosis at VB	Grade of stenosis at FOB						Total
	0%	< 30%	30%-59%	60%-79%	≥80%	100%	
0%	1441	6	5	0	1	3	1456
< 30%	11	6	3	0	1	0	21
30%-59%	21	4	27	1	0	0	53
60%-79%	0	0	0	3	0	0	3
≥80%	5	0	0	0	4	3	12
100%	3	0	0	0	2	16	21
Total	1481	16	35	4	8	22	1566



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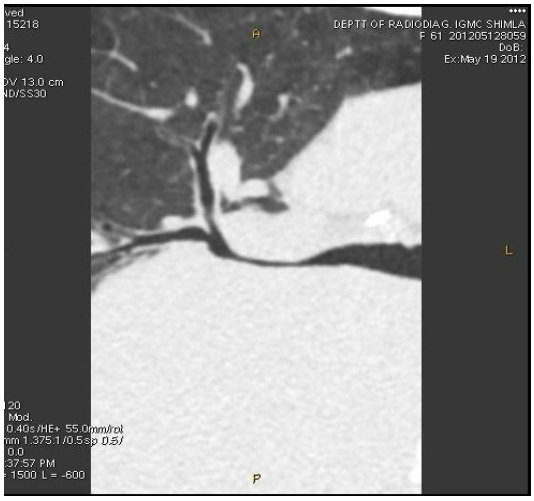

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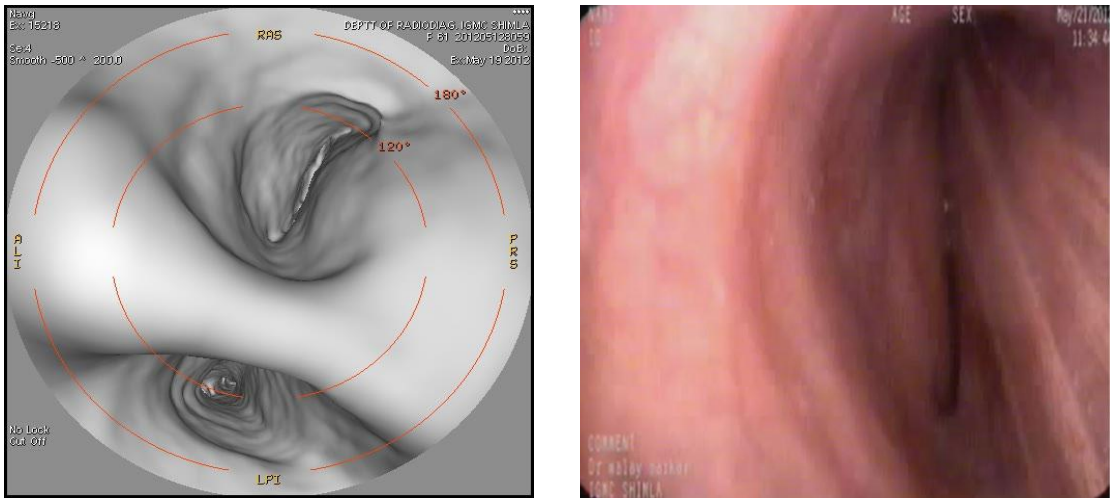
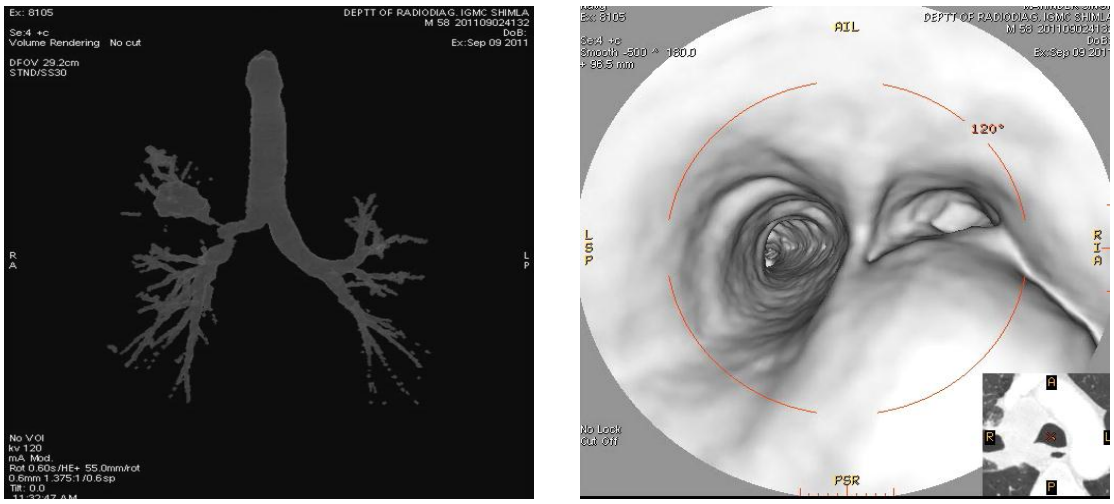


c d

Fig 3: 60 year old woman, non-smoker, who presented with cough and chest pain. **a:** Contrast enhanced axial CT image (mediastinal window) shows a large heterogeneous mass compressing the RUL bronchus causing severe stenosis. **b:** MPR in lung window shows extrinsic compression of the RUL bronchus and its segmental branches. However, they are patent. **c:** VB shows extrinsic compression at RUL bronchus. This caused severe stenosis. However, VB could pass this stenosis and explore airways beyond the lesion. **d:** FOB also showed extrinsic compression at RUL bronchus. However, distal patency could not be assessed. Bronchial brushings revealed adenocarcinoma.



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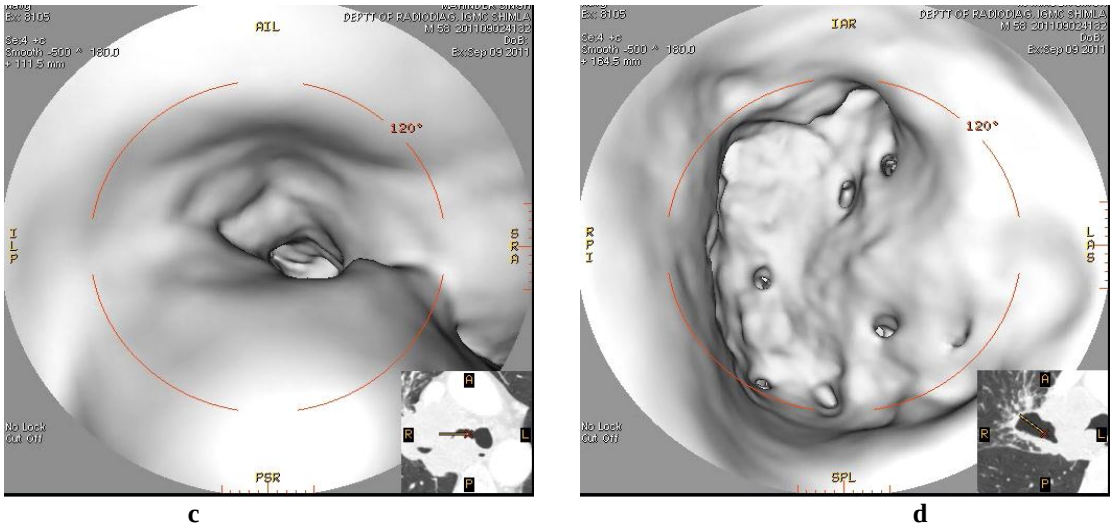

c d

Fig 4: 58 year old man, smoker, presented with haemoptysis and chest pain. **a:** 3D virtual reconstruction of the airways shows distortion and ectasia of the RMB, RUL and BI bronchi. In addition, the RUL bronchus is seen communicating with a cavity which is further communicating with segmental and subsegmental branches. **b, c & d:** VB showed an endoluminal lesion at the RMB (which was also detected on FOB). There was extrinsic compression at the RUL bronchus. FOB was not able to navigate through this region. However, VB passed the stenosis (d) and revealed that a cavity was communicating with the RUL bronchus (e). Bronchial brushings revealed squamous cell carcinoma.

DISTAL PATENCY: Of the 58 patients, distal airways were not evaluated in 9 patients (on FOB, VB or both) and these were excluded from the comparative analysis for distal patency. Only 49 patients were considered. VB offered the advantage of being able to visualize areas beyond even high grade stenoses *(Figure 3).* VB was able to explore the airways beyond stenosis in 33 patients, whereas, FOB was able to explore the airways beyond stenosis in 6 patients. Thus, virtual bronchoscopy had a sensitivity of 100% and a NPV of 100 %.

ADDITIONAL FINDINGS: In our study, FOB detected impaired true vocal cord mobility (unilateral/ bilateral) in 5 patients, which were not detected by VB.

Virtual bronchoscopy detected sabre-sheath and lunate configuration of trachea in 2 patients. Tracheal diverticulum was seen in one patient. VB also showed a cavity communicating with a distorted RUL bronchus in one patient *(Figure 4).*

Discussion

In the present study, virtual bronchoscopy showed a modest sensitivity in detecting endoluminal lesions. It could detect 6 of the 10 endoluminal lesions. It missed lesions in 4 locations. The difference was thought to be due to the size of the lesions. Seven extra endoluminal lesions (false positive) which were picked up by VB were not picked up by FOB. In the retrospective assessment of these cases, it was found that VB had wrongly interpreted mucus plugs as endoluminal lesions. Also, it could be possible that bronchial wall thickening could have been misinterpreted as endoluminal lesion. False negative results were noted for lesions situated in much smaller bronchi, which are probably related to the technical principles of VB, which is not reliable enough for visualization of lesions in small calibre bronchi.

Virtual bronchoscopy detected lesions causing extrinsic compression as effectively as FOB with a sensitivity of 87.2% and a specificity of 98.3%. There was substantial agreement between the two modalities (κ=0.67). Additional lesions causing extrinsic compression were also detected by VB in segmental bronchi in 25 airways and in a subsegmental bronchus (RB2) where FOB could not negotiate through high grade stenosis. FOB could have also misinterpreted few high grade stenoses causing extrinsic compression as obstructive lesions.

The false positive cases of obstructive lesions and lesions causing extrinsic compression detected by VB in our study could be attributed to clotted blood or secretions inside the bronchial lumen, which has also been described by Finkelstein *et al* (2002) [8]] in his study.

Previous published data [17, 18, 19] have shown that mucosal lesions are hardly or never detected on VB. The mucosal descriptions of these lesions are most of the time, described only by FOB. In our study, VB detected only 2 of the 11 mucosal lesions.

As a whole, the best concordances in detection of type of lesion in corresponding areas in both modalities as revealed in our study were seen in the upper lobe bronchi (right and left lungs), particularly the right upper lobe bronchus (75%) in central airways and the left superior lingular followed by left apicoposterior bronchi in segmental airways. This data indicates that a better concordance is seen in the central airways which have a wider diameter and better aeration. Also, minor changes in the isosurface threshold do not affect the nature of the lesion. Lesions in segmental airways of the upper lobes can be defined well on VB as they are more aerated and less bronchial secretions tend to accumulate. Our observations are in agreement with the data published by Finkelstein *et al* (2003) [20] and Lacasse Y *et al* (2004) [12] where maximum concordances were seen in the central airways.

Patients with incurable bronchial carcinoma often have severe bronchial stenosis and post- tumoral atelectasis. In these patients, palliative treatment such as laser therapy, irradiation therapy, or stent implantation may become necessary; it is important that referring physicians know the exact grade of tracheobronchial narrowing. In VB, the perspective of the endoluminal view, unlike that in orthoplanar images, stays within the axis of the airway which allows reliable semi-quantitative assessment of tracheobronchial stenosis. It produces more realistic images of the narrowed bronchial lumen.

Findings of virtual bronchoscopy correlated closely with findings of flexible bronchoscopy in allowing accurate grading of tracheobronchial stenosis. Twenty eight false positive bronchial stenoses were noted in central airways and 14 in segmental bronchi. False positive VB results could have been caused by the threshold attenuation level being set too low or by the presence of secretion in bronchial lumen resulting in appearance of pseudo-tumours. Another reason might be a human error resulting in wrong interpretation which applies to all radiological diagnostic modalities.

In our study, VB offered the advantage of being able to visualize airways beyond even high grade stenoses. It registered a sensitivity of 100% and a NPV of 100 %. In 6 patients, FOB was able to explore the airways beyond stenosis, whereas, VB was able to explore the airways beyond stenosis in 33 patients

The etiology of various extrinsic compressions could not be clarified on FOB, whereas VB with the help of MPR provided comprehensive information. In most cases the cause of extrinsic compression over airways was either a huge tumour mass or lymphadenopathy. Also, the extent and sizes of the lesions were better identified on axial source images and MPRs. Airway anatomy was better delineated on minIP images. The three-dimensional external view of the bronchial tree (also referred to as CT bronchography in some studies) permitted 'at a glance' visualization of the airways and anatomical localization of the pathologies. These observations have been substantiated by authors like Adali F *et al* (2010) [21]. Virtual bronchoscopy allows quantitative measurements like the size of a lesion, its relationship with neighbouring structures, length of a stenosis and the diameter of a bronchus, via axial and multiplanar images. Therefore, in the evaluation of patients for surgery and other interventional procedures, in contrast to FOB, VB, axial images and MPR should be considered together.

Based on the concepts and data depicted above, it is our belief that VB can be used as an effective first-line investigative tool in patients with known or suspected tracheobronchial neoplasms. It can also help in guiding the referring clinician in further investigation/ management of the patient.

The limitations of this study were 1) a small study group 2) selection bias 3) high number of false positives 4)

categorizing non-evaluable airways in both FOB and VB as no lesions.

A number of technical improvements and enhancements have taken place over the years that have broadened the horizon of virtual bronchoscopy. Of interest is a recent development, wherein a team of researchers has patented an improved virtual bronchoscopy system designed to enhance endoscopic examination of peripheral lung lesions. The system has specific software and also adapts automated movement planning techniques to map paths from the trachea to peripheral lung lesions. The novelty of the system is that, unlike current virtual bronchoscopy systems, it takes bronchoscope geometry and kinematic constraints into account. The system guides physicians by describing the best bronchoscope route from the trachea to a peripheral lung lesion. It avoids futile examinations and minimises potential risk for the patient [22].

Conclusion:

Virtual bronchoscopy is reliable and non-invasive. It can be used as a pre-bronchoscopy planning strategy to reduce the time of subsequent FOB procedures. It could also be used as an educational and learning tool. Most important of all, it could be a potentially useful tool in early detection and further management of cancer in patients with known or suspected tracheobronchial neoplasms. It could be used in planning biopsies and other interventional procedures.

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