Research Article

Estimation of the Accuracy of CT Virtual Bronchoscopy in the Diagnosis of Tracheo-Bronchial Lesions in Comparison to Fiberoptic Endoscopic Examination

Hoda Abdel Kareem*, Moustafa Abdel Kader and Mohamed Shahat*****

* Department of Radiodiagnosis, South Valley Faculty of medicine,

** Department of Radiodiagnosis, El-Minia Faculty of medicine

*** Department of Chest Disease, South Valley Faculty of medicine,

Abstract

Objective: The purpose of this work was to assess the accuracy of ٦٤ MDCT and virtual bronchoscopy in patients with tracheo-bronchial obstruction in comparison with the fiberoptic bronchoscopy. **Subjects and Methods:** Twenty five patients presented to the Radiology Departments at South Valley University Hospital and El-Minia University Hospital, with clinical diagnosis of tracheo-bronchial lesions during the period from December ٢٠١٢ to December ٢٠١٣, their ages ranged from ٣٢ to ٦٧ years. All patients subjected to plain chest radiography, ٦٤ MDCT with virtual bronchoscopy and fiberoptic bronchoscopy. **Results:** A total of ٢٥ patients were included in this study, their mean age was ±٥٥ years. ١١ lesions were diagnosed as inflammatory in nature, ٩ neoplastic"bronchogenic Ca", ٤ lesions were diagnosed as post-traumatic sequel & one patient showed mild stenosis due to external compression by mediastinal masses. MDCT with ٣D reconstruction and VB was near equal to FO broncoscopy in diagnosis of the tracheo-bronchial stenosis as well as in defining the degree and etiology of stenosis. **Conclusion:** Virtual bronchoscopy is a novel technique for noninvasive evaluation of the tracheo-bronchial tree. It is used not only for the diagnosis of bronchial obstructions and endoluminal lesions, but also for the assessment of the tracheo-bronchial tree beyond stenosis level. It can assist and direct the fibreoptical bronchoscopy and add some diagnostic information.

Key words: MDCT Virtual bronchoscopy, Fiberoptic bronchoscopy and Tracheo-bronchial obstruction.

Introduction

Tracheo-bronchial stenosis is defined as focal or diffuse narrowing of the tracheal and bronchial lumen. It may arise secondary to a wide variety of benign and malignant lesions[١].

Typically, patients who have suspected airway disease undergo diagnostic evaluation consisting of chest radiographs and conventional CT scans followed by fiberoptic bronchoscopy[٢].

MDCT-generated Virtual bronchoscopy (VB) represents one of the most recent developments in three dimensional (٣D) visualization techniques[٣]. VB is a reformatted ٣-D CT image that generates intraluminal views of the airway to the sixth and seventh generation bronchi[٤].

VB represents a technical development that allows visualization of a dynamic image that resembles what is seen with fiberoptic bronchoscopy[٥].

VB has become available for noninvasive evaluation of the tracheo-bronchial tree. VB also enables imaging of endo-luminal and extra-luminal anatomy, which is not possible with FB. The virtual airway can be manipulated in space and evaluated from multiple angles[٦].

VB allows CT reconstruction of the bronchial tree allowing "virtual" bronchoscopic animation enabling more accurate procedure planning[٧].

Patient and Methods

This study included ٢٥ patients presented to the Radiology Departments at South Valley and El-Minia University Hospitals, with clinical

diagnosis of tracheo-bronchial lesions. They presented during the period from December ٢٠١٢ to December ٢٠١٣. Their ages range from ٣٢ to ٦٧ years (mean age + ٥٥ years). ١٦ patients were males and ٩ patients were females. All patients were subjected to:

١) Full history taking.
٢) Through clinical examination.
٣) X-ray chest examination, PA & Lateral views.
٤) Multi-detector computed tomography: The MDCT examinations were performed using ٦٤ detectors CT scanner (GE bright speed),
٥) Fiberoptic broncoscopy.

Mdct Technique For The Chest:

By using MDCT and VB, the imaging of the trachea and bronchus is very sufficient down to the subsegmental level [٨].

MDCT Examination:

After proper positioning of the patient, AP scannogram was taken and the reference line starts from the lower neck till the upper abdomen. Multiple contiguous axial cuts ٨ mm in thickness were taken using the following parameters: ١٢٠ kV and ٢٠٠ mA.

Contrast*:* IV non-ionic water soluble contrast medium was given to all patients, in dose of ٢ml/kg body weight.

Post-processing:- External ٣-D rendering of the airways depicts the external surface of the airway and its relationship to adjacent structures; this can improve the detection of subtle airway stenosis and help to illustrate complex airway abnormalities.

- Internal rendering of the airways allowed the viewer to navigate through the internal lumen of the airways in a fashion similar to that of conventional bronchoscopy that is called virtual bronchoscopy.

Fiberoptic Bronchoscopy technique:

The bronchoscopic procedures were performed in the Endoscopic unites for chest diseases of Qena and El Minia University Hospitals. Written consent was obtained from each patient prior to the procedure. The Pentax fiberoptic bronchoscopes were used: The broncho-fiberoscopes were done under local anesthesia through the nose. The larynx, vocal cord and the entire bronchial tree, including the trachea, both main bronchi, lobar and segmental bronchi, as well as carina were evaluated. Routine sampling included bronchial wash for cytological and bacteriological assessment as well as ٢–٤ tumor samples, were taken using biopsy forceps. Tissue samples were assessed by a histo-pathologist on a routine basis.

Findings from VB and FOB from each patient were compared in correlation with the histo-pathological results.

Results

This study included ٢٥ patients presented to the Radiology Departments at South Valley and El-Minia University Hospitals with clinical diagnosis of tracheobronchial lesions. Their ages ranged from ٣٢ to ٦٧ years (mean$\pm$ ٥٥ years). ١٦ patients were males and ٩ were females.

The clinical picture of the affected patients were ranged from, wheezing, dyspnea on exertion, and stridor. Patients with mild stenosis were initially asymptomatic, however, some of these patients were seen complaining from signs of tracheal and bronchial obstruction when the endo-luminal narrowing is worsened by airway edema and secretions from a coexistent respiratory infection.

Table I: Clinical presentation(C/O) of all patients (no.=٢٥)

Pt.'s number	C/O	Onset of C/O
٩	asymptomatic	-
٧	wheezing	Gradual
٥	dyspnea on exertion	Gradual
٤	Stridor	Sudden

In the studied patient group (a total of ٢٥ patients), the tracheobronchial stenosis was assessed by virtual bronchoscopy and the results were compared with fibreoptic bronchoscopy findings. (Tables II-V & figures ١- ٤).

- The ١st group (١١ patients): MDCT & VB showed: Stenotic segment affecting the trachea/ bronchi(٨/٤), which was long segment in ٩ patients & short segment in ٣ patients with circumferential wall thickening noted in all patients ranged from mild to moderate degree. No focal mass lesions detected and features collectively diagnosed as benign stricture.

By FO broncoscopy: ١١ patients showed friable mucosa which is congested and bleed on touch with narrow lumen, no masses detected with primary diagnosis as inflammatory benign stricture while one patient showed findings suspicious of neoplasm (irregular wall thickening & broad subcarinal bronchus); Bronchial wash was taken for cytological and bacteriological examination. Final diagnosis: ١٠ inflammatory & ١ malignant strictures.

- The ٢nd group (٨ patients): MDCT & VB showed: Stenotic segment affecting the bronchi Rt./Lt. (٦/٢), which was short in ٦ patients & long segment in ٢ patients, with Irregular soft tissue density wall thickening noted in all patients ranged from partial to complete luminal obstruction. Lobar/segmental console-dation collapse with enlarged hilar and mediastinal lymph nodes as well as the pleural involvement were accurately evaluated by MDCT and the suggested diagnosis was malignant neopalstic stricture likely bronchogenic carcinoma.

By FO broncoscopy: Friable mucosa with partial/complete obstruction of the affected bronchial lumen by soft tissue mass lesion. Biopsy & bronchial wash was taken for pathological examination. Final diagnosis: Malignant stricture "bronchogenic carcinoma".

- The ٣rd group (٤ patients): Who's finally diagnosed as post- trumatic sequel: MDCT & VB showed: Stenotic segment affecting the trachea with short stenotic segment and eccentric wall thickening in all the ٤ patients; Extra-luminal hematomas were seen in ٢ patients. No soft tissue masses. The history, clinical picture and the imaging findings are collectively made the diagnosis of post-traumatic sequel.

- The ٤th group (two patient): Who's diagnosed metastatic breast cancer & lymphoma making external compression of the trachea and bronchus by the lymph node masses: MDCT & VB showed irregular stenotic segment affecting the trachea & Rt. main stem bronchus; extraluminal mediastinal masses were also clearly seen. The history, clinical picture and the imaging findings are collectively made the diagnosis.
By FO broncoscopy: Congested mucosa with irregular segment stricture of the affected tracheal & Rt. main bronchus segments. It could not seen the mediastinal masses. Bronchial wash was taken for cytological examination.

Table II: Analysis of the affected stenotic segment of tracheo-bronchial lesions in all patients (no.= ٢٥)

Group	etiology	location	Length	wall thickness
Gr. I ١٠ Pt.	inflammatory	Trachea/bronchi ٧/٥	Long/short ٧/٥	circumferential
Gr. II٢ ٩ Pt.	Neoplastic	Trachea/bronchi (٠/٩)	Long/short ٣/٦	Irregular soft tissue density
Gr. III ٤ Pt.	Post-traumatic	Trachea/bronchi ٣/١	Long/short ١/٣	Symmetrical, hour glass deformity
Gr. IV, ٢pt.	Tumoral external invasion	Tracheal & Rt. bronchus	Skip lesions	Irregular

Table III: Findings detected by MDCT & VB in all patients (no.=٢٥):

Findings	Pt. number	Percent %
No mass	١٤	٥٦
Central mass	٦	٢٤
Peripheral mass	٣	١٢
External mass	٢	٨
Lymph node	٦	٢٤
Pleural fluid	٢	٨

Table IV: Findings detected by Fiberoptic Bronchoscopy in all patients (no.=٢٥):

Findings	Pt. number	Percent %
Mucosal affection	٢٥	١٠٠
Soft tissue mass	٩	٣٦
broad interlobar carina	٣	١٢
Vocal cord affection	١	٤

Table V: Comparison of MDCT with VB and the F.O. bronchoscopic findings in all patients (no.=٢٥)

Findings	MDCT & VB (%)	F.O. broncoscopy(%)
Mucosal affection	١٢(٤٨%)	٢٥(١٠٠٪)
Soft tissue mass	١٠(٤٠٪)	٩ (٣٦٪)
Vocal cord affection	٠(٠٪)	١(٤٪)
Lymph nodes	٦(٢٤٪)	٠(٠٪)
Pleural fluid	٢(٨٪)	٠(٠٪)

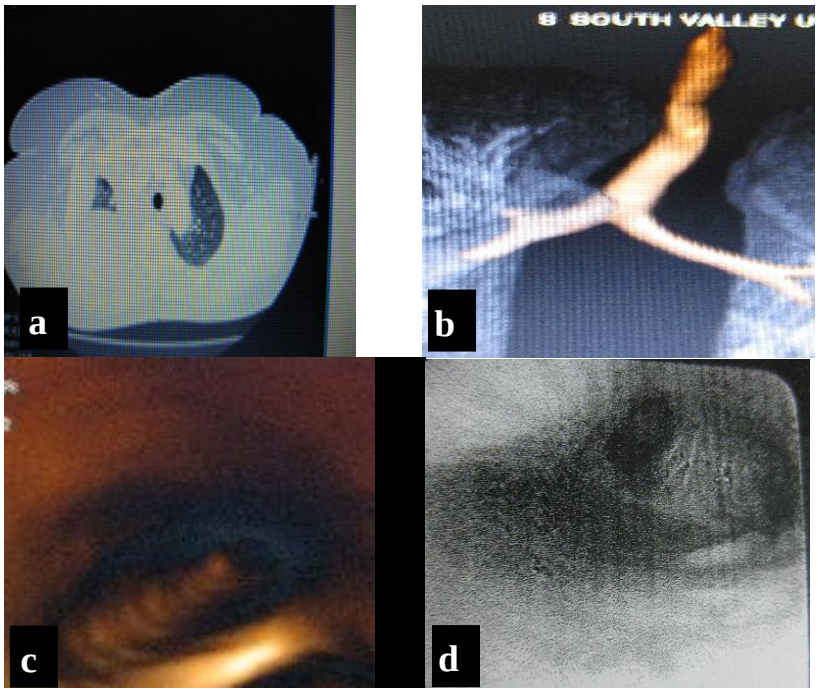

Fig.١: Post-traumatic tracheal stenosis. (a) axial CT image shows elongated trachea with reduced diameter & Rt. Pleural effusion. (b) ٣D reconstructed image showed short stenotic segment at the upper trachea. (c) VB CT showed the stenotic segment with reduced caliber. (d) FO broncoscopy showed congested inflamed mucosa, no masses.

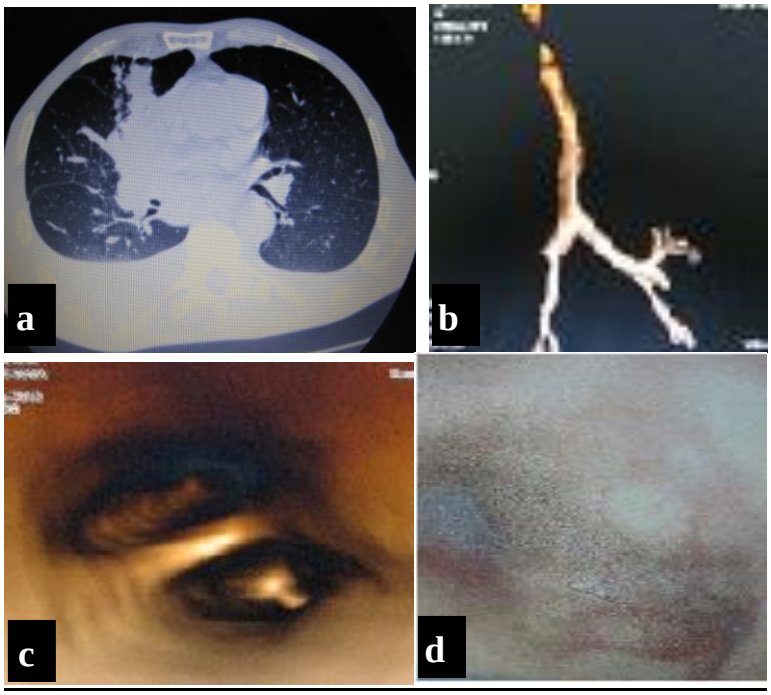

Fig.٢: Central bronchogenic Ca. (a) axial CT image shows mass obliterating Rt. main bronchus. (b) ٣D reconstructed image showed amputated Rt. main bronchus (c) VB CT showed a mass bulging from the orifice of Rt. main bronchus (d) FO broncoscopy showed soft tissue mass & take biopsy.

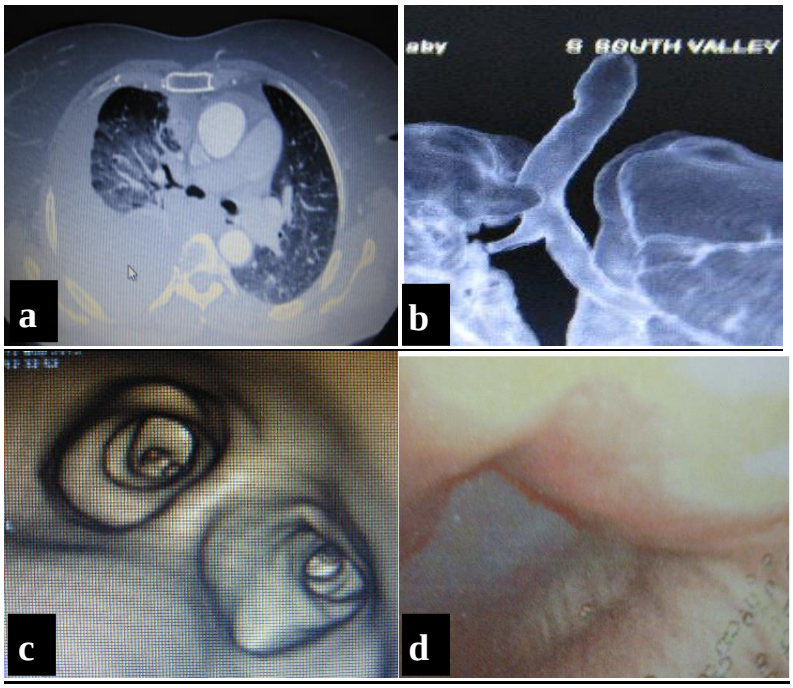

Fig.٣: Inflammatory Rt. bronchial stenosis. (a) Axial CT image shows attenuated Rt. main bronchus. (b) ٣D reconstructed image showed reduced caliber of Rt. main bronchus (c) VB CT showed mildly narrowed Rt. main bronchus (d) FO broncoscopy showed inflammatory changes with congested mucosa, no masses.

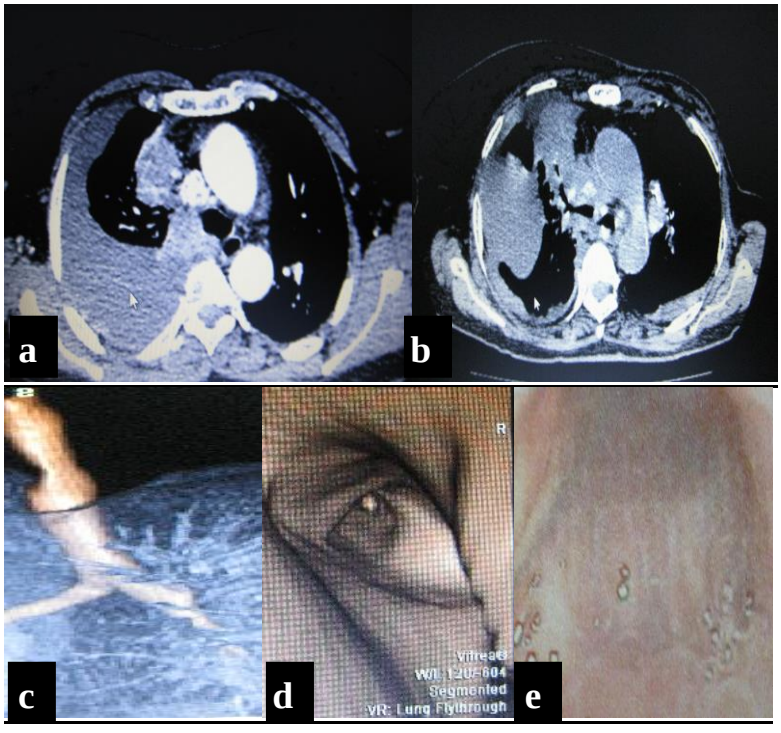

Fig.٤: Metastatic Br. Ca tracheo-bron. invasion & external compression (a&b) Axial CT images shows multiple medias. Soft tissue masses encroaching upon & invading the trachea and Rt. Main bronchus. (c) ٣D image showed circumferential tracheal narrowing due to mass effect & attenuated Rt. main bronchus (d) VB CT showed mildly narrowed trachea (e) FO broncoscopy showed congested mucosa, no masses.

Discussion

The severity of an airway stricture affects airflow, symptoms, functional status and management decisions[٩]. Computed tomography can be used for detailed noninvasive imaging of the airways and surrounding structures[١٠].

In our study of ٢٥ patients with tracheo-bronchial obstructions, ١٠ patients had stenosis that's finally diagnosed as inflammatory process. Nine patients had malignant bronchial mass and ٤ patients showed post-traumatic sequel in the form of tracheobronchial stenosis with extra-luminal hematomas while only two patients showed trachea-bronchial invasion by mediastinal masses from metastatic breast cancer & lymphoma. ٦٤ MDCT & VB were nearly sensitive to FO broncoscopy in evaluation of the stenotic segment as well as in suggesting the correct final diagnosis. In addition, MDCT &VB were superior in showing the extension and relation of the malignant masses as well as the associated enlarged lymph node, pulmonary & pleural affection. While FO broncoscopy was superior in evaluation of the mucosa as well as it has the advantage of taken biopsy & bronchial wash.

Septimiu Murgua, and Henri Coltb, ٢٠١٣[٩] concluded that: MDCT with or without ٣D reconstruction, can be used to quantify the degree of airway narrowing. MDCT airway measurements correlate with results of objective bronchoscopic assessments[١١&١٢]. VB offers ٣D with high-resolution endo-luminal images, reveals inaccessible areas, evaluates bronchial stenosis and obstruction caused by both endo-luminal pathology (tumour, mucus, foreign bodies) and extra-luminal airways compression (anatomical structures, tumour, lymph nodes)[١٣]. VB helps guiding biopsy and endo-bronchial treatment planning: However it cannot clearly depict the mucosal surface and distinguish between infiltrating and vegetative lesions[١٤]. VB estimation of the grade of trachea-bronchial stenosis resulting from either endo-bronchial pathology or external compression was found to be correlated with findings on flexible bronchoscopy[١٥].

Virtual bronchoscopy permits visualization of the respiratory tract and with the aid of VB, the area of bronchial stenosis can be accessed and passed through, extra-bronchial lesions such as tumours or enlarged lymph nodes can be evaluated. Its noninvasiveness is the main advantage of this technique, permitting evaluation of patients in poor general condition or having advanced cardio-respiratory failure. There are, however, several limitations to the virtual bronchoscopy technique, of which no possibility of tissue sampling or mucosa evaluation are the most serious ones[١٦,١٧]. VB can determine the level of involvement in the trachea-bronchial system with similar specificity and sensitivity to those of FOB, particularly in patients in whom FOB is contraindicated and who cannot tolerate or refuse the procedure. VB can nevertheless be applied for assessment of both central and peripheral lung tumors[١٨]. Published data show that sensitivity of VB for lung tumour detection ranges between ٨٣ and ٩٠.٩٪, and for bronchial stenosis detection between ٩٢.٨ and ٩٥٪ [١٩,٢٠].

D. Yildirim et al., ٢٠١٢[٢١] stated that: Findings determined during CT/VB such as stenosis of the relevant bronchial lumen, endo-luminal irregularity and vegetation, scalloping and extensions were considered positive and all data were recorded. The lumen of the airways up to the segmental bronchi can be evaluated by these non-invasive procedures[٢٢]. By using VB as a guide during bronchoscopic biopsy, the chance for obtaining appropriate sample is increased while the risk for vascular damage is significantly decreased[٢٣]. Fiberoptic broncho-scopy, rather than virtual bronchoscopy, is being used in the Pulmonary Diseases and Thoracic Surgery Departments for diagnostic or therapeutic purposes[٢٤]. During FOB, it is possible to obtain samples (brush cytology, punch biopsy,etc.), aspiration, washing, and detection of color changes in the mucosa[٢٥].

CT is the imaging modality of choice for detecting and characterizing tracheal post-intubation stenosis. On axial images, CT demonstrates eccentric or concentric soft-tissue thickening with associated luminal narrowwing[٢٦]. The sensitivity of CTVB in detecting bronchial masses was higher than that of Fiberoptic bronchoscopy, and when combined with multiplanar reconstruction (MPR) and VB can demonstrate the extra-luminal extension of

tumors, however, CTVB is limited to observe mucosal abnormalities and to obtain histologic samples[٢١].

The meta-analysis confirms good accuracy of VB in the overall diagnosis in patients with suspected airways lesions. The accuracy of VB in the diagnosis of obstructive lesions or endoluminal disease in the face of malignancy is excellent. However, VB is not reliable in diagnosis of dynamic airway or mucosal lesions[٢٨]. The correlation of stenotic shape and contour between VB and conventional bronchoscopy was excellent. The stenosis-to-lumen ratios determined with VB and conventional bronchoscopy were found to be within ١٠٪ of each other. [٢٩]

In a study of Hoppe et al., ٢٠٠٢[١٨] CT was highly accurate in revealing airway stenosis (accuracy of VB, ٩٨٪; axial images, ٩٦٪; coronal MPR, ٩٦٪; sagittal MPR, ٩٦.٥٪). The VB images correlated closely with the findings at flexible bronchoscopy (r = ٠.٩١) for grading of stenosis. In that study, the VB images were better than the other CT display methods for semiquan-titative assessment of stenosis. In a more recent study, Hoppe et al., ٢٠٠٤,[٣٠], found that VB had an accuracy of ٩٥.٥٪ in detection of central airway stenosis (trachea, main bronchi, lobar bronchi). VB also had an accuracy of ٩٥.٥٪ in the detection of stenosis in the segmental airways.

Hui J. et al., ٢٠١٣.,[٣١] concluded that: MDCT with improved spatial and temporal resolution, larger anatomic coverage and high quality reconstructions has become an important examination tool in the detection of the tracheobronchial anomalies and stenoses. Fariba R. et al., ٢٠١٢[٣٢] stated that: Multiplanar reconstructed thoracic bronchoscopy may avoid the inherent risks of invasive procedures such as conventional bronchoscopy in critically ill patients. Thus, we nominate that the results of Fiberoptic bronchoscopy were nearly similar to multiplanar reconstructed thoracic CT bronchoscopy. M. Shweel, et al., ٢٠١٣[٣٣] concluded that: MDCT is a well-tolerated procedure, and permits rapid data acquisition during a single breath hold. The acquired images provide detailed information regarding the trachea-bronchial tree and its pathology.

Conclusion

VB is a novel technique for noninvasive evaluation of the tracheobronchial tree. In comparison with real FO.bronchoscopy, VB has the advantage of being a noninvasive procedure that can visualize areas inaccessible to the flexible bronchoscopy beyond the level of stenosis. VB will never replace actual bronchoscopy, but it can assist, direct it and give additional information as regarding the associated lymph node enlargements, pleural effusion & extraluminal lesions.

References

١. Boiselle PM, Lee KS and Ernst A. Multidetector CT of the central airways. J Thorac Imaging ٢٠٠٥;٢٠:١٨٦–١٩٥.

٢. Dawn SK, Gotway MB and Webb WR. Multidetector-row spiral computed tomography in the diagnosis of thoracic diseases. Respir Care ٢٠٠١; ٤٦:٩١٢–٩٢١.

٣. Wever W. D., Bogaert J., and Verschakelen J.A. Virtual Bronchoscopy: Accuracy and Usefulness An Overview. Seminars in Ultrasound, CT and MRI, ٢٠٠٥; ٢٦: ٣٦٤-٣٧٣.

٤. Christina W. Fidkowski, Hui Zheng, and Paul G. Firth The Anesthetic Considerations of Tracheobronchial Foreign Bodies in Children: A Literature Review of ١٢,٩٧٩ Cases Anesth Analg ٢٠١٠;١١١:١٠١٦–٢٥).

٥. Maysa Sharaf El Din, Nada Ezzeldin Gomaa, Youssriah Yahia Sabri, Hossam Hosni Massoud and Ali Hussein. The Role of Virtual Bronchoscopy Compared to That of Fiberoptic Bronchoscopy in Staging of Bronchogenic Carcinoma; World Applied Sciences Journal ٢٠١٣: ٢٦ (٥): ٦٢٣-٦٢٩.

٦. McWilliams A, MacAulay C, Gazdar AF, et al.,. Innovative molecular and imaging approaches for the detection of lung cancer and its precursor lesions. Oncogene ٢٠٠٢; ٢١:٦٩٤٩–٦٩٥٩.

٧. Steven Leong, Tawimas Shaipanich, Stephen Lam and Kazuhiro Yasufuku¨ Diagnostic bronchoscopy--current and future perspective. journal of Thoracic Disease (Lung cancer) ;Vol ٥, Supplement ٥ (October ٢٠١٣):

٨. K Vassiou, F Kotrogianni, E Lavdas, M Vlychou, M Fanariotis, DL Arvanitis and IV Fezoulidis. Tracheobronchial variations

evaluated by multidetector computed tomography and virtual bronchoscopy. Radiology: ٢٠١٣ Mar ٠١;٢(٣):٢٣.

٩. Septimiu Murgua, and Henri Coltb. Subjective assessment using still bronchoscopic images misclassifies airway narrowing in laryngotracheal stenosis, Interactive Cardiovascular and Thoracic Surgery ١٦ (٢٠١٣) ٦٥٥–٦٦٠.

١٠. Horton, K.M., M.R. Horton and E.K. Fishman. Advanced visualization of airways with ٦٤-MDCT. ٣D mapping and virtual bronchoscopy, AJR. Am J. Roentgenol., ٢٠٠٧;١٨٩: ١٣٨٧.

١١. Lee KS, Sun MR, Ernst A, Feller-Kopman D, Majid A and Boiselle PM. Comparison of dynamic expiratory CT with bronchoscopy for diagnosing airway malacia: a pilot evaluation. Chest ٢٠٠٧;١٣١:٧٥٨–٦٤.

١٢. Czaja P, Soja J, Grzanka P, Cmiel A, Szczeklik A and Sładek K. Assessment of airway caliber in quantitative videobronchoscopy. Respiration ٢٠٠٧;٧٤:٤٣٢–٨.

١٣. Gianluigi Sergiacomi, Amedeo Taglieri, Eleonora Gaspari, Irene Coco and Giovanni Simonetti. Role of computed tomography and virtual tracheo-bronchoscopy in endobronchial tuberculosis {Online} ٢٠١٢, Sep. ١٩)URL: http://www.eurorad.org/ case.php/id=١٠٣٠٤

١٤. Polverosi R, Vigo M, Baron S et al., (٢٠٠١) Evaluation of tracheobronchial lesions with spiral CT: comparison between virtual endoscopy and bronchoscopy. Radiol Med. Nov-Dec; ١٠٢ (٥-٦): ٣١٣-٣١٩.

١٥. Vi{eslav]uk, Stanko Belina, Rajko Fure, Damir Bukovi, Daniel Lovri}٥ and Ivana Seso. Virtual Bronchoscopy and ٣D Spiral CT Reconstructions in the Management of Patient with Bronchial Cancer – Our Experience with Syngo ٣D Postprocessing Software; Coll. Antropol. ٣١ (٢٠٠٧) ١: ٣١٥–٣٢٠.

١٦. Piotr Radwan ٢٠١٢ {Piotr Radwan-Rohrenschef, Barbara Burakowska. Virtual bronchoscopy versus bronchofiberoscopy a comparison of diagnostic value in assessment of central lung tumours; Pneumonol. Alergol. Pol. ٢٠١٢; ٨٠, ٢: ١٢٧–١٣٩.

١٧. De Wever W and Bogaert J., Verschakelen J. Virtual bronchoscopy: Accuracy and usefulness — an overview. Seminars in Ultrasound CT and MRI ٢٠٠٥; ٣٦٤–٣٧٣.

١٨. Hoppe H., Walder B., Sonnenschein M., Vock P and Dinkel H.P. Multidetector CT virtual bronchoscopy to grade tracheabronchial stenosis. AJR ٢٠٠٢;١٧٨:١١٩٥–١٢٠٠.

١٩. Finkelstein SE, Summers RM, Nguyen DM, Stewart JH, Tretler JA and Schrump DS. Virtual bronchoscopy for evaluation of malignant tumors of the thorax. J Thorac Cardiovasc Surg ٢٠٠٢; ١٢٣:٩٦٧–٩٧٢}.

٢٠. Burke A.J., Vining D.J., McGuirt W.F., Postma G. and Browne J.D. Evaluation of airway obstruction using virtual endoscopy. Laryngoscope ٢٠٠٠; ١١٠: ٢٣–٢٩.

٢١. D. Yildirimi, M. Tamam, Y. Sanli, M.A. Ozgul and A. Somay. Virtual bronchoscopy using FDG-PET/CT images for the evaluation of lung cancer European Review for Medical and Pharmacological Sciences. ٢٠١٢; ١٦: ١٩٥١-١٩٦٠.

٢٢. Ovassapian A. Flexible bronchoscope: A tool for anesthesiologists. Clin Chest Med ٢٠٠١; ٢٢: ٢٨١- ٢٩٩(٢٨,٣١,٣٢).

٢٣. Fleiter T, Merkle EM, Aschoff AJ, Lang G, Stein M, Gorich J, Liewald F, Rilinger N and Sokiranski R. Comparison of real-time virtual and Fiberoptic bronchoscopy in patients with bronchial carcinoma: opportunities and limitations. AJR ١٩٩٧; ١٦٩: ١٥٩١-١٥٩٥.).

٢٤. Verhagen AF, Bootsma GP and Tjan-Heijnen VC. FDGPET in staging lung cancer: how does it change the algorithm? Lung Cancer ٢٠٠٤; ٤٤: ١٧٥-١٨١.

٢٥. Poon B. Invasive Diagnostic Procedure. In Shields TW (ed). General Thoracic Surgery. ٧th Edition Philadelphia, Lippincot Williams & Wilkins ٢٠٠٥; pp.٢٩٩-٣١٣.

٢٦. Webb EM, Elicker BM and Webb WR. Using CT to diagnose nonneoplastic tracheal abnormalities: appearance of the tracheal wall. AJR Am J Roentgenol. ٢٠٠٠;١٧٤:١٣١٥-١٣٢١

٢٧. Xiong Minghui, Zhang Wanshi. Wang Dong and XU Jiaxing. CT virtual bronchoscopy: imaging method and clinical application Chinese Medical Journal ٢٠٠٠;١١٣(١١):١٠٢٢-١٠٢٥)

٢٨. Catherine M. Jones &, Thanos Athanasiou. Is Virtual Bronchoscopy an Efficient Diagnostic Tool for the Thoracic Surgeon?

The Annals of Thoracic SurgeryVolume ٧٩, Issue ١ , Pages ٣٦٥-٣٧٤, January ٢٠٠٥

٢٩. Karen M. Horton, Maureen R. Horton and Elliot K. Fishman. Advanced Visualization of Airways with ٦٤-MDCT: ٣D Mapping and Virtual Bronchoscopy AJR: December ٢٠٠٧, Volume ١٨٩, Number

٣٠. Hoppe H, Dinkel HP, Walder B, von Allmen G, Gugger M and Vock P. Grading airway stenosis down to the segmental level using virtual bronchoscopy. Chest ٢٠٠٤; ١٢٥:٧٠٤–٧١١

٣١. Hui Jiao, Zhuodong Xu mail, Lebin Wu, Zhaoping Cheng, Xiaopeng Ji, Hai Zhong and Chen Meng. Detection of Airway Anomalies in Pediatric Patients with Cardiovascular Anomalies with Low Dose Prospective ECG-Gated Dual-Source CT .Published: December ٠٦, ٢٠١٣. DOI: ١٠.١٣٧١/journal.pone.٠٠٨٢٨٢٦

٣٢. Fariba Rezaeetalab, Donya Farrokh and Behrouz Zandiee. Iranian Journal of Radiology. Multiplanar Reconstructed Thoracic CT Bronchoscopy in Endo-bronchial Tuberculosis. Article type: Letter; Received: ١١ Jun ٢٠١١, Revised: ٢٥ Jul ٢٠١٢, Accepted: ٠١ Aug ٢٠١٢; DOI: ١٠.٥٨١٢/iranjradiol.٨٧٢٦

٣٣. Mohamed Shweel and Yasser Shaban. Radiological evaluation of post-traumatic tracheal stenosis using multidetector CT with multiplanar reformatted imaging and virtual bronchoscopy: Comparison with intraoperative findings. The Egyptian Journal of Radiology and Nuclear Medicine Volume ٤٤, Issue ٣ , Pages ٥١٣-٥٢١, September ٢٠١٣.