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In the evaluation of tracheobronchial lesions, MDCT virtual bronchoscopy with fiber optic bronchoscopy comparison

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Abstract

Objective: The aim of this study is compare multislice CT VB and FOB to assess tracheobronchial lesions with multislace CT VB.

Material and Methods: In the period between September 2012 and August 2013 found indications for bronchoscopy and the total of 44 patients underwent FOB and FOB MDCT-SB were included in the study to be evaluated. All patients underwent VB and/or FOB. In both methods, tracheobronchial tree were divided into 18 separate segments. FOB virtual bronchoscopic findings as the gold standard method to assess the results were considered. Accordingly, positive and negative predictive values of MDCT for VB, sensitivity, selectivity and specificity values were calculated.

Results: Patient ages 1 and 79 (mean: 53 ± 16) of the patients ranged from 7 (16%) female and 37 (84%) were men. In FOB 16 narrowing, 9 congestion, four external compression, 11 mucosal abnormalities were found and in the VB 12 narrowing, 16 obstruction, 8 external compression detected. None of the 11 mucosal findings in the FOB could not be determined in VB. Patients detect in FOB 25 cases were detected in VB; two patients with lesions on the FOB, although not detected in the VB (false negative). In 14 cases both FOB and endoluminal lesion was detected in the VB. FOB lesions not seen in the VB lesion in 5 cases (false positive). According to these values, sensitivity 92%, specificity 73%, positive predictive value (PPV) of 82%, negative predictive value (NPV) 87%, Accuracy: 84%, respectively.

Conclusion: Both mucosal biopsies should not be made to give details because of disadvantages such as virtual bronchoscopy fob is not an alternative for the moment. However tracheobronchial tumor research, interventional bronchoscopic procedures and biopsy guidance, foreign body aspiration of the initial assessment, tracheal injury is evaluation and treatment planning, obstructive lesions of the distal show, stenosis evaluation of endobronchial abnormalities characterization and postoperative follow-up issues of virtual bronchoscopy, constantly evolving detector technology and software when placed through the right indications for routine use will take time, we believe that the rightful place.

Keywords: Virtual bronchoscopy, Fiberoptic bronchoscopy, MSCT, Tracheobrochial pathologies

Introduction

The term virtual endoscopy (VE) refers to the use of computer software for the construction of realistic mucosal surface and intraluminal images of hollow organs. The earliest studies in this field date back to 1994 when Vining et al. carried out a virtual colonoscopy [1], while in 1996, the same researchers published the results of their studies into virtual bronchoscopy (VB) [2] and virtual cystoscopy [3]. The term VB refers to the computer-aided construction and examination of endoscopic images of the tracheobronchial tree using volumetric data obtained from scans of the thoracic cavity with a thin-slice spiral or multi-slice computed tomography (MSCT), similar to that used in fiberoptic bronchoscopy (FOB).

Assessments made from multiplanar images and a three-dimensional perception facilitates control over anatomical structures. Images of higher quality have been acquired with the introduction of MSCT, which was first introduced in 2000 and became rapidly widespread due to the avoidance of the disadvantages associated with spiral CT such as motion artifacts and time loss. The present study evaluates the success, limitations, advantages and disadvantages of MSCT-VB in demonstrating tracheobronchial system pathologies, and makes a comparison of fiberoptic bronchoscopy and VB in terms of diagnostic accuracy and success in the evaluation of tracheobronchial lesions.

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Material and Methods

After obtaining the approval of the relevant ethics committee (Gaziantep University Ethics Committee) and written informed consent from all subjects, a total of 44 cases who were scheduled to undergo bronchoscopy and FOB were evaluated using MSCT and VB between September 2012 and August 2013.

For VB, the tracheobronchial system was scanned using a 64-detector (VCT XTe Light Speed, General Electric, Milwaukee, USA) MSCT in the axial plane with a slice thickness of 0.625 mm. The detector was configured with a collimation of 64x0.625 mm, a table rotation speed of 0.65 sec, 120 Kv, 120 mAs, a FOV of 25–50 mm and 1 pitch. Less than 1 cc of a contrast agent per body weight of the patient was injected intravenously as a bolus to the patients using a pump. Volumetric scanning was completed within 10 sec on average in a single breath, although this differed from patient to patient.

All axial images, with a slice thickness of 0.625 mm, were evaluated in the workstation. The virtual bronchoscopic images acquired using thoracic VCAR software in the navigation mode were evaluated by simultaneously displaying the images with axial, coronal, sagittal and curve MPR images on two screens, split into four and five quadrants. In the virtual bronchoscopic evaluation, the intraluminal appearance of the two main bronchi and segmental and subsegmental branches of the bronchi were examined starting from the proximal to the trachea, as in aFOB.

While advancing in the tracheobronchial tree, the images in the two planes were used to evaluate the localization, luminal wall and extraluminal structures. When needed, the three-dimensional external bronchial simulations were used to evaluate any lesions that extended beyond the tracheobronchial wall.

All patients underwent FOB with an Olympus bronchoscope, model LTF, type 160. The interval between the FOB and VB in each patient was a maximum of three days. The biopsy specimens obtained during FOB were evaluated by experienced pathologists (image 1).

Statistical Analysis

FOB examinations are considered the optimum approach for the evaluation of VB results. Accordingly, true positive, true negative, false positive, false negative, specificity, sensitivity and accuracy values were calculated for MSCT-VB, with IBM SPSS software v15.0 used for the statistical analysis.

Results

Included in the study were 44 patients in which FOB and MSCT-VB were performed independently. The mean age of the patients was 53±16 years with a range of 1–79 years;seven patients (16%) were female and 37 patients (84%) were male.

A total of 43 patients underwent bronchoalveolar lavage and a fine needle aspiration biopsy or histopathological sampling using surgical or radiological methods. The histopathological examinations revealed benign lesions in 12 patients (non-specific), squamous cell carcinoma in nine patients, adenocarcinoma in seven patients, small cell lung cancer in four patients, bronchiolitis obliterans with organized pneumonia (BOOP) in one patient, NSCLC-NOS in one patient, inflammatory myofibroblastic tumor in one patient, hydatid cyst in one patient, malignant epithelial tumor in one patient, malignant mesothelioma in one patient, granulomatous lesion (sarcodiosis or tuberculosis) in one patient and tuberculosis in one patient. The histopathological results of the patients are presented in Table 1.

Considering the trachea, two main bronchi and 18 segments in the lungs, a total of 968 areas in 44 patients were evaluated with FOB and VB. The rate of endoluminal lesions detected by VB was 4.4% and the rate of endoluminal lesions detected by FOB was 4.1%.

In terms of endobronchial lesions, FOB identified 16 stenoses, nine obstructions, four external compressions and 11 mucosal findings, whereas VB identified 12 stenoses, 16 obstructions and eight external compressions. None of the 11 mucosal findings on FOB were detected on VB. The distribution of the endobronchial lesions detected by both FOB and VB is presented in Table 2.

The localizations of the endobronchial lesions detected on VB and FOB are presented in Table 3. No significant difference was detected in diagnostic accuracy for the central and segmental branches in the virtual bronchoscopic evaluation ($P<0.05$).

In the comparison of FOB and VB, considering FOB as the optimum approach, 23 cases in which a lesion was detected on FOB were also detected on VB, whereas VB was unable to detect two cases in which FOB identified a lesion (false negative). FOB and VB identified no endoluminal lesions in 14 cases. VB revealed a lesion in five cases in which FOB did not identify any lesions (false positive). The comparison of diagnostic accuracy is shown in Figure 1 and Table 4; accordingly, sensitivity was 92%, specificity was 73%, positive predictive value (PPV) was 82%, negative predictive value (NPV) was 87% and accuracy was 84%.

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Image 1 : A mass lesion that completely obstructs the left lower lobe bronchus by externally compressing it. FOB (A,B), 3D (C) , coronal (D) and VB (E,F) images.

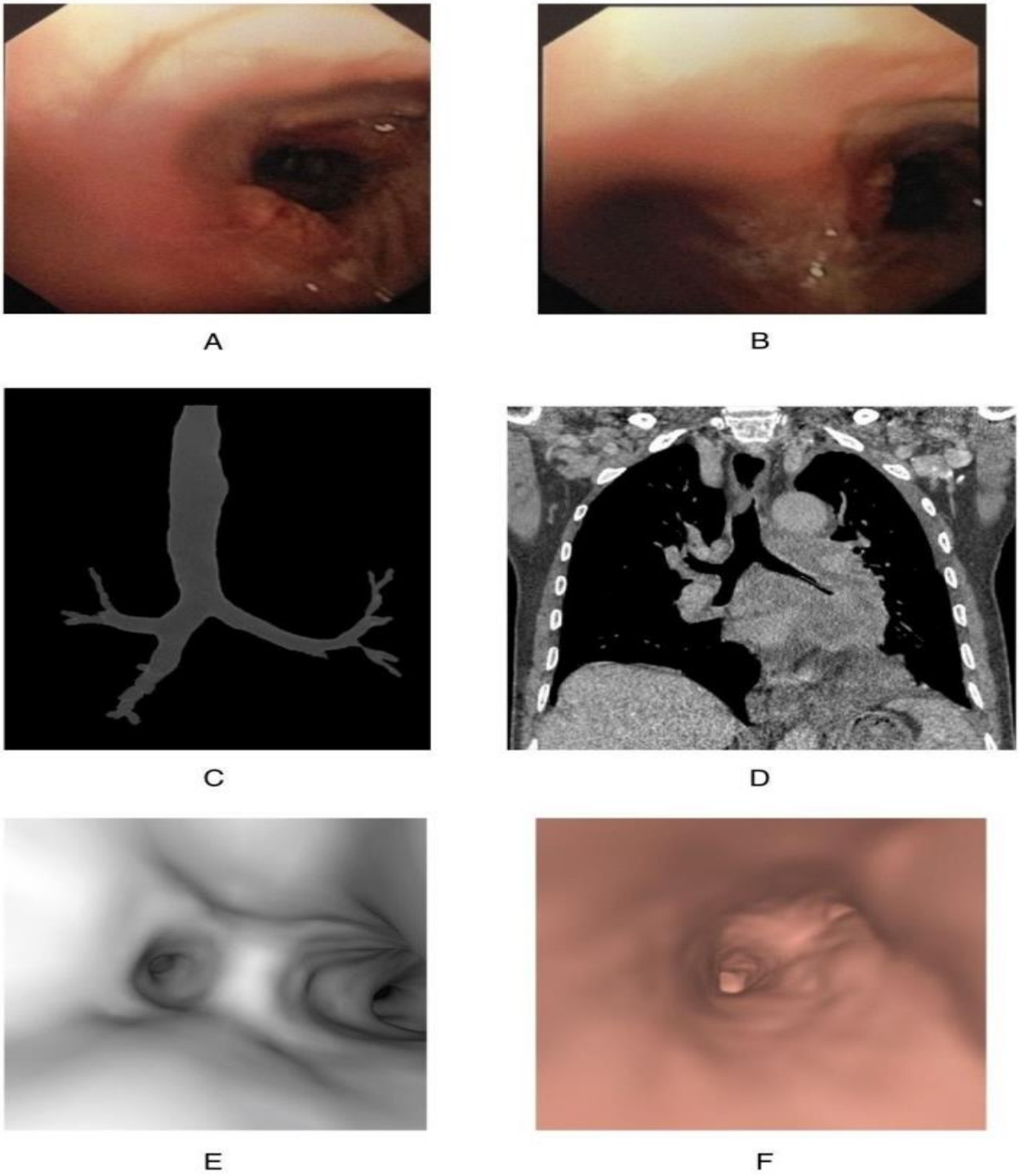

Table 1: Distribution of histopathological results of the cases.

Histopathology	Case Number
Benign (non-specific)	12
Squamous cell carcinoma	9
Adenocarcinoma	7
SCLC	4
Chronic inflammation	4
NSCLC -NOS	1
Malignant epithelial tumor	1
Malignant mesothelioma	1
Granulomatous lesion (sarcoidosis /tbc?)	1
Tuberculosis	1
Hydatid cyst	1
BOOP	1
Inflammatory myofibroblastic tumor	1
No biopsy	1

Table 2: Distribution of endobronchial lesions detected on FOB and VB.

	Stenosis	Occlusion	External Compression	Mucosal Finding
FOB	16	9	4	11
VB	12	16	8	0

Table 3: Distribution of the localization of endobronchial lesions detected on FOB and VB.

		Lesion distribution according to FOB				
Lesion distribution according to VB		Trachea	Main Bronchus	Lober bronchus	Segmental Bronchus	No Lesion
	Trachea	3				
	Main Bronchus		4	1		
	Lober bronchus			5		3
	Segmental Bronchus			1	12	2
	No Lesion		1	1		14

Table 4. Evaluation of the diagnostic accuracy of the findings detected on VB.

	VB (+)	VB (-)	Total
FOB (+)	23 (TP)	2 (YN)	25
FOB (-)	5 (FP)	14 (TN)	19
Total	28	16	44

TP: True Positive, FN: False Negative, FP: False Positive, FN: False Negative

Discussion

prompted the researcher to investigate alternative diagnostic methods. FOB is a similarly invasive diagnostic method, andalthough rare, complications may occur during the procedure. Bronchoscopy using alternative and noninvasive methods has become a popular topic in recent years, and has raised the interest of the imaging industry, resulting in a shift toward the pursuit of methods that take advantage of the advances in the computer, medical engineering and software fields. The emergence and development of the idea of VB, which dates back to the mid-1990s, was a result of technical advances and the pursuit of alternative methods [2, 3, 4]. At that time it became possible to transfer and process volumetric data on conventional axial images of tissue obtained to date through spiral or multi-slice CT systems on a separate computer. This allowed multiplanar reformatted images and virtual endoscopic images to be acquired. The direct visualization of the airways through FOB and the opportunity to obtain a biopsy instantly from the desired localization, however, have preserved the importance of this procedure, with has thus retained its value as the optimum approach. The availability of other diagnostic and therapeutic procedures, such as concurrent bronchial lavage, and obtaining culture material and removing existing foreign bodies can be regarded as other advantages of this method. There has been no change, however, in the invasiveness of the procedure, the need for sedation or the intolerance of some patients, even when performed with more flexible fiber optic catheters than a rigid bronchoscope [5, 6].

Although VB is performed using computer software, the experience of the operator is an important concern, as the region or localization of the lesion cannot be evaluated if orientation to the area is poor. VB should have a place in such evaluations, considering that it can be performed on existing CT images of the lungs, and the fact that it does not require a separate examination or patient preparation. Aside from clinical indications, VB can also be used for training and research purposes, with VB images similar to those of FOB being attained that can be used to teach and learn anatomical details of the tracheobronchial tree. VB allows chest disease specialists to practice, and permits an easier and more effective performance of a more invasive FOB if interpreted earlier [2, 7, 8].

Patients undergo 15–20 minutes of preparation for anesthesia before a conventional bronchoscopy, although the evaluation of more complicated cases may even require general anesthesia.

In terms of complications, VB is more advantageous than FOB. Unnecessary FOB examinations must be avoided, particularly in pediatric cases in whom complication rates can be as high as 7%. Haliloğlu et al. reported that unnecessary FOBs can be avoided through the use of VB [9]. Various retrospective studies have reported mortality rates of 0.008–0.04%, major complication rates of 0.05–3.4% and minor complication rates of a little below 10% [10, 11]. A prospective study, on the other hand, reported a mortality rate of 0.44%, a major complication rate of 1.65% (such as severe hemorrhage, respiratory arrest, pneumonia, pneumothorax and severe airway obstruction) and a minor complication rate of 6.5% [12]. No complication was reported among the cases that underwent FOB in the present study.

Virtual bronchoscopic images can also be obtained using helical CT scans, although such images have a low spatial resolution and a prolonged acquisition time, and the very slow reconstruction also makes their use inconvenient. The introduction of multi-slice CT into practice has reduced the entire examination time to 15–20 seconds and the slice thickness to 0.5–1 mm, and so the resolution of three-dimensional imaging has increased. According to Lacasse et al. [13], an examination with a collimation of 3 mm and a slice interval of 1.5 mm lacks sufficient accuracy for the investigation of endoluminal lesions. The use of MSCT images has also increased diagnostic accuracy, while the use of faster computers with higher processing capacities has allowed the acquisition of virtual bronchoscopic and other reconstructed images in a short period of time [14]. A virtual bronchoscopy is more advantageous than FOB in terms of the total examination time, althougha reduced procedural time can be regarded as a trivial advantage considering the time saved for the patient and physician and the lack of any increase in diagnostic accuracy. The reconstruction of images and virtual examinations after image acquisition depends on the radiologist, and the time spent on these procedures can vary considerably. The printing and saving of images and video images acquired through multidisciplinary works in hospitals lacking PACS, making them available to the clinician and then archiving them all require additional time. The time spent for VB is, on average, 15 minutes according to Wever et al. [15]. The time required for the reconstruction and examination of VB images ranged between 15 and 20 minutes in the present study, although this varied from one patient to another. The procedural time has decreased over time; although it does not seem likely that it will be further reduced in the near future. There have been studies attempting to reduce examination times through the provision of panoramic images or the use of developed automatic lesion detection software. It can currently be argued that VB is among the routine practices considering the time spent by a radiologist on VB.

One of the most significant differences between FOB and VB is that FOB is a dynamic procedure, which comes with its own advantages and disadvantages. Factors such as inspiration and expiration during FOB, cough reflex and continuous secretions that can be challenging for the clinician during the procedure are of no concern during VB. The procedure can be repeated any number of times in a VB, and there are no secretions that impair visibility. The images can be tracked from proximal to distal, and also from distal to proximal, allowing the visualization of endoluminal lesions from multiple perspectives. VB, however, lacks many of the important diagnostic advantages that come with FOB. The first of these is the inability with VB to observe the response of airways to respiratory movements and cough reflexes. A clinician can clearly observe the enlargement and narrowing of airways

during FOB, as well as segmental bronchial openings that open and close and the movements of cartilage and mucosal tissues. Irregular changes in the diameter of the trachea of different types that are diagnostic for tracheomalacia, diverticula and herniation's, and that become visible during inspiration, and movements of pedunculated lesions and their extensions can also be recognized during FOB. There is no opportunity to observe such movements in VB. In a study of 45 cases with a mean age of 4.4 years, Heyer et al. [16] reported an NPV of 54.5%, and attributed this low rate to five patients with tracheomalacia/bronchomalacia in the patient group. They reported in the study that CT images acquired during inspiration would not be diagnostic for tracheomalacia, but that a diagnosis could be established through a biphasic investigation on VB during inspiration and expiration. Secretions and mucous plugs may be misdiagnosed as mass lesions, and such conditions are the most common cause of false positive results in VB [9]. Secretions and coagulum were mistaken for stenosis in five patients in VB, being later identified as secretion and coagulum. The appearance of air-foam in the left bronchus was thought to be associated with secretions. Mucous plugs can be aspirated and the lumen or orifices can be opened during FOB. Furthermore, foreign bodies can be removed upon detection, while invirtual bronchoscopy, it is not possible to recognize such bodies or remove them through aspiration.

Virtual bronchoscopic images must be correlated with conventional images and multiplanar reformatted images to reduce false positive results and to avoid mistakes. In a study of 18 patients, Bernhardt et al. [6] found no significant difference between axial, MPR and VB images in the detection, localization and identification of the severity of stenosis, and recommended the combined use of images. Finkelstein et al. [17] reported a sensitivity of 82% and a specificity of 100% for VB, but identified no significant difference in terms of diagnostic accuracy when compared to high-resolution thoracic computed tomography scans in cancer patients. That said, the results from both methods were superior to axial images. Konen et al. [18] suggested that VBmakes no contribution to cross-sectional images. Summers et al. [30] suggested that orientation would be better if VB is performed together with axial, coronal and sagittal imaging. Minghui et al. [19] found that the examination of MPR and VB images yielded higher sensitivity than that of FOB, and the same researchers suggested that this combination would be advantageous in terms of demonstrating the outer extensions of endoluminal lesions. Ferretti et al. [20] also stated that combined evaluations would increase diagnostic efficacy. Based on all the above findings, it would seem that conventional images must be combined with MPR and VB images, given that they cover each other's deficiencies and direct the radiologist to the correct diagnosis in patients with a suspected airway pathology. In our study, two screens were used while evaluating the VB images, with the correlation with MPR images investigated on the second screen. As mentioned in literature, the authors of the present study suggest that an evaluation of VB images in combination with axial and MPR images would increase diagnostic accuracy in the detection and grading of lesions.

The sensitivity of the method used for the detection of intraluminal lesions is related to the size of the lesion in VB, which can easily detect 5mm or larger endobronchial lesions. One study reported a sensitivity of 47–88% and a specificity of 48–89% in a patient group with lesions measuring 3–10 mm, while sensitivity and specificity rates increased by 20% and 34% respectively in lesions measuring 5–10 mm [21]. A 2-mm red nodule at the level of the vocal cord detected on FOB in patient number 9 could not be identified in VB, despite a repeat examination.

VB has increasing use in the grading of benign and malignant airway lesions, with high accuracy rates reported in the measurement of the depth and length of obstructive tracheobronchial lesions. Burke et al. [22] reported an excellent level of correlation between VB and FOB in the evaluation of the contours and shape of the stenotic segment. The present study found only a 10% difference in the rates of stenosis and lumen on VB and FOB. In 2002, Hoppe et al. [5] evaluated 200 bronchial segments using a 4-slice-MSCT with 2-mm collimation in a series of 20 patients. Their study reported high accuracy for MSCT in the evaluation of tracheobronchial lesions (accuracy in VB: 98%, accuracy in axial images: 96%; accuracy in coronal MPR images: 96%; accuracy in sagittal MPR images: 96.5%). The same study also reported that VB images have same diagnostic value as FOB in the evaluation of stenosis (r=0.91), as well as the superiority of VB over other CT imaging methods in a semi-quantitative evaluation of stenotic segments. In another study by Hoppe et al. [23] comparing FOB and VB using a 4-slice MSCT and 1-mm collimation, VB was reported to have an accuracy of 95.5% in the evaluation of both central and segmental airway stenoses. Their study also reported that VB led to a higher number of false positive results in the segmental bronchi than in the central bronchia; and that VB has a positive predictive value of 40.9% in segmental branches and a positive predictive value of 84.4% in the central airways. Lacasse et al. [13] stated that a 3-mm collimation and a 1.5-mm slice interval could overlook 32% of lobar and segmental lesions,but that further studies of MSCT could increase the sensitivity and specificity. The present study compared central and segmental airway stenoses using statistical methods, and found no significant difference in the diagnostic accuracy of VB ($P<0.05$). This can be attributed to the use of a 64-slice device with a lower collimation and higher resolution, as this allows the completion of the procedure using a single-breath-hold technique that minimizes respiratory artifacts. Finkelstein et al. [24] reported a sensitivity of 90% for VB in endobronchial lesions, a rate of 100% in obstructive lesions and a rate of 16% in mucosal lesions. In a collective analysis, sensitivity and specificity were reported to be 83% and 100%, respectively. In a study evaluating stenoses in tracheobronchial carcinomas, Rapp-Bernhardt et al. [6] reported a sensitivity of 94% and a specificity of 99.7% for VB. Liewald et al. [25] reported similar characteristics for VB and FOB in their evaluation of obstructive lesions. Table 8 summarizes the success rates in the identification of endoluminal lesions reported by various studies comparing VB and FOB in literature. Consistent with previous studies, the present study reports a sensitivity of

92%, a specificity of 73%, a positive predictive value (PPV) of 82%, a negative predictive value (NPV) of 87%, and an accuracy of 84%.

Some studies in literature have suggested that VB is as effective as FOB in identifying stenosis associated with a mass lesion, but that VB is not able to identify small infiltrations and to differentiate between complete and partial obstructions [26, 27]. The present study also found that VB can show severe stenosis as an occlusion. FOB identified 16 stenoses, nine obstructions and four external compressions, whereas VB identified 12 stenoses, 16 obstructions and eight external compressions. We believe that a simultaneous evaluation of VB images with MPR and axial images may reduce such failures. VB provides accurate information about the lumen diameter and the length of the stenotic segment, and such information is required for endobronchial procedures such as accurate stent placement, laser photocoagulation, brachytherapy and endobronchial cryotherapy [28, 17, 22, 29]. VB and three-dimensional images allow for the identification of the general appearance of the tracheobronchial tree and the delineation of the relationship between the lesion/stenosis and the surrounding pathological and normal tissues. VB can be beneficial in postoperative follow-up forthe evaluation of the percentage of the remaining stenosis in the bronchial tree, the position of the stenosis and stent permeability [28, 26, 30]. It is also a useful noninvasive method for the evaluation of the suture line following organ transplantation, lobectomy and pneumectomy. McAdams et al. [28] showed that VB provides better results than axial CT images in the evaluation of the recipient's bronchial anastomosis following lung transplantation.

Obstructive lesions are one condition in which VB is superior to FOB. The clinician cannot pass beyond an obstructive lesion during FOB, and so the status of the more distal parts of the airway will remain uncertain. VB is not subject to such limitations and can easily pass beyond an obstructive lesion [28, 22, 25, 26]. The obstruction of distal parts of the tracheobronchial tree by secretion and blood prevents evaluation of these parts by VB, although this can be overcome through an examination of three-dimensional images together with axial images [26]. Bernhardt et al. [31] used VB to evaluate the parts distal to an obstructive lesion in five patients, and found no additional lesions. In our study, the distal parts of mass lesions that completely obstruct the lumen could not be evaluated in the "VB navigation mode", as the distal parts in all cases were filled with fluid (case numbers 6, 9, 17, 24 and 41). This problem was overcome, however, through the simultaneous examination of three-dimensional images together with axial and MPR images. No significant tracheobronchial lesion that would alter the statistical analysis was detected in any of these cases, although the need to delineate the airways that cannot be examined on FOB due to the presence of obstructive lesions seems to be one of the indications rendering VB inevitable. A clinician may proceed with a pathological diagnosis by carrying out a cellular sampling through bronchial lavage or biopsy, while VB offers no such opportunity. In addition, endoluminal surfaces are coded by a homogeneous single color tone in VB, making the identification of mucosal color changes, superficial lesions and infiltrative extensions, vascularity, fragility and other details all of which can be observed during FOB, impossible. Lesions such as blood clots, mucus, tumors and foreign bodies, being coded by the same color tone, also reduce the selectivity of VB [9, 6, 19, 26]. It is a striking finding that VB showed normal results in 11 cases who were found to have a mucosal lesion on FOB. It can therefore be clearly expressed that VB is unable to identify mucosal changes and lesions. Furthermore, mucus, secretion and purulent fluid in five cases analyzed with VB led to false positive diagnoses of "lesion". Studies in literature mention "inability to detect mucosal lesions" and "inability to perform biopsy" as the most significant disadvantages of VB [17, 32, 33]. The authors of the present manuscript believe that VB should not be considered as an alternative to FOB, due to the inability to obtain a biopsy and to observe mucosal details.

Blind mediastinal lymph node biopsies with FOB have low sensitivity, particularly if the lesion has caused no change in the bronchial tree. The success rate is 72% for lesions that are observed during examination and only 36% if the lesion cannot be observed [34]. Whether or not a biopsy is performed will depend on estimations if a lesion cannot be detected and bronchial mucosa is normal, and this is the cause of rare false positive biopsies and a vast number of false negative biopsies [35]. A high rate of false negative biopsy results causes a delay in the staging and initiation of appropriate therapy, and thus leads to further interventional procedures [36]. Performing the procedure under the guidance of axial, coronal and sagittal reformatted images combined with VB images would be useful in determining the localization of the most appropriate biopsy site for lesions that are not causing bronchial distortion or mucosal changes [29, 36]. VB also aids the FOB operator in accessing the lesion and finding the most appropriate passageway, and can increase the effectiveness of a transbronchial biopsy in peripheral pulmonary lesions. McAdams et al. [28] reported a sensitivity rate of as high as 88% for transbronchial fine needle aspiration biopsiesof the mediastinal and hilar lymph nodes under the guidance of VB in the detection of malignancy. Shinagawa et al. [37] reported the effectiveness of transbronchial biopsy using an ultra-thin bronchoscope guided by VB navigation in the diagnosis of peripheral pulmonary lesions smaller than 20 mm. Furthermore, biopsies of mediastinal lymph nodes smaller than 1.5 cm under the guidance of VB can be useful in increasing the accuracy of the results [36].

Conventional CT findings are also evaluated during VB, during which parenchymal findings, pleural thickening and effusions, pathologies of the thoracic wall and bones, pathologies of the abdominal structures that fall into the view of the examination, neck and thyroid pathologies, mediastinal pathologies and associated compressions-invasions, and vascular pathologies along with endobronchial lesions can be easily recognized. At the same time, when the mass lesions observed on VB are correlated with MPR images, the relationship with the surrounding tissues, the invasion findings and eligibility for

surgical resection can be evaluated. Bernhardt et al. [6] proposed VB as a useful method in the evaluation of mass invasion and staging when VB images are evaluated with axial and MPR images. Hoppe et al. [23] stated that axial and MPR images evaluated together with VB images yield similar sensitivity and specificity to VB, referring to it is a useful approach to the evaluation of mediastinal lymph nodes, and demonstrating their relationship with the surrounding tissue. In the present study, a mass lesion identified on VB was found to have invaded and narrowed the right pulmonary artery in one patient; A mass lesion in the upper lobe of the right lung in another patient extended into the spinal canal after eroding and destroying the upper thoracic vertebra and the neighboring ribs; and a mass lesion in another patient invaded the pericardium and mediastinal mass; while also invading most of the mediastinal vascular structures. The use of MSCT in examinations offers significant advantages. For example, it is highly possible to convert reconstruction algorithms into HRCT algorithms as thin slices are scanned with the spiral method. This allows soft tissue and bone tissue findings, while avoiding both interstitial findings and partial volume artifacts. Another advantage of a thin-slice examination is that it allows the three-dimensional reconstruction of the pulmonary nodules, thereby providing more detailed information about the nodule and allowing the more reliable follow-up of the nodule. Additional findings beyond the tracheobronchial tree were detected in most of the patients in the present study (Table 3).

VB is a useful and noninvasive means of evaluating foreign body aspirations and congenital airway anomalies in both pediatric and adult patients [15]. In their study, Konen et al. [18] reported that VB could be useful in the evaluation of the tracheobronchial tree for airway stenosis and compressive pathologies in pediatric patients. Tracheal stenosis was detected,the intermediary bronchi could not be observed, and the right upper, middle and lower lobes branched from the main bronchus in one patient in the present study, while another patient was found to have a medial accessory segmental bronchus in the left inferior lobe.

When compared to FOB, VB offers the advantages of being non-invasive, requires no anesthesia or sedation, can be repeated a number of times, permits imaging from different angles, allows investigations for tracheobronchial tumors, permits access beyond obstructive lesions that cannot be observed on FOB, has a high sensitivity rate, offers the ability to show additional lesions and findings in the bronchial tree together with axial and MPR images, thereby aiding in the evaluation of lesions for operability, and allows the characterization of anomalies in the tracheobronchial structure.

As of this time, however, VB does not seem to be an alternative to FOB due to such associated disadvantages such as the inability to perform a biopsy, the low sensitivity in detecting lesions smaller than 5 mm, the inability to detect mucosal infiltration, the relatively low specificity rate when compared to high sensitivity rates, and the inability to offer real-time evaluation.

Conclusion

The authors of the present manuscript believe that VB will find the place it deserves in routine use in time with the continued development of detector technologies and software, given its ability to guide interventional bronchoscopic procedures and biopsies, to aid in the initial evaluation and planning of treatment in foreign body aspirations, and to provide the clinician with the opportunity of practicing before following up tracheobronchial lesions with FOB.

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