Pathol. Oncol. Res. (2008) 14:313–319
DOI 10.1007/s12253-008-9059-3

ORIGINAL PAPER

Comparison of Virtual and Fiberoptic Bronchoscopy in the Management of Airway Stenosis

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Received: 20 March 2008 / Accepted: 18 April 2008 / Published online: 10 June 2008

Abstract Noninvasive imaging methods can be valuable tools for diagnosing thoracic diseases, especially malignancies. The aim of this study was to compare the effectiveness of conventional and virtual bronchoscopy in the follow-up of patients with large airway stenosis. Twenty-three consecutive patients with stenoses of the trachea and/or the main bronchi were enrolled in this prospective observer study. The causes of stenosis included malignant or benign tumours, goiter, and postintubation stenoses. Patients were evaluated before and after treatment (which included mechanical dilation, laser photocoagulation, stent implantation, radiotherapy, chemotherapy, and surgical resection). The mean time between baseline and follow-up endoscopy was 140 days. No significant differences were observed between the estimated and measured data from bronchofibroscopy and virtual bronchoscopy. Exact measurement of stenoses was performed with virtual bronchoscopy.

Keywords Bronchoscopy · Computed tomography · Interventional bronchoscopy · Virtual bronchoscopy

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Introduction

Virtual bronchoscopy (VB) was first described in 1993; subsequently, several studies compared the computer-generated images from VB with those obtained during fiberoptic bronchoscopy (FOB) [1–4]. The results showed that VB can provide accurate renderings of the tracheobronchial system and has many advantages over conventional techniques, including the ability to construct retrograde views of stenoses, to measure the total length of stenotic segments, and to visualize pathological lymph nodes near the tracheobronchial tree [5–11]. VB also makes it easier to perform endobronchial interventions, stent insertions, and endoscopic lymph node biopsies [5]. The disadvantages of VB include the inability to directly visualize the mucous membranes and perform biopsies [12–14]. *Only two studies compared the results of FOB and VB in the field of following main airway stenoses* [15, 16]. This study assesses whether VB can be used for the follow-up of patients treated for large airway stenosis.

Patients and Methods

Twenty-three consecutive patients, seven women and 16 men, with stenoses of the trachea and the main bronchi were enrolled in the study. The mean patient age was 50.5 (range 21–78) years. The patients' pathological conditions are listed in Table 1.

Conventional bronchofibroscopy, followed within 2 weeks by CT scans for VB, was performed in all patients. Follow-up examinations were done after a mean period of 140 (range 7–378) days. FOB was made by a chest physician, and a blinded radiologist interpreted the VB results.

Table 1 Patients' pathological conditions and interventions

Patients, *n*	Pathological condition	Intervention
10	Postintubation stenosis	Stent placement, follow-up, correction of the stent's position
1	Tracheal compression caused by goiters	Surgical resection
5	Malignancy of the trachea	Interventional bronchology and/or radio-/chemotherapy
1	Benign tumour of the trachea	Interventional bronchology
2	Malignancy of the right main bronchus	Interventional bronchology and/or radio-/chemotherapy
3	Malignancy of the left main bronchus	Interventional bronchology and/or radio-/chemotherapy
1	Benign tumour of the 6th segment of the left lung	Mechanical removal

Stenoses noted by FOB were placed in one of the following three categories: 1st degree stenosis: the diameter of the stenotic segment exceeded 6 mm, i.e. the fiberscope could be forwarded past the lesion; 2nd degree stenosis: the diameter of the stenotic segment was 6 mm, i.e. the size of the fiberscope; 3rd degree stenosis: the diameter of the stenotic segment was less than 6 mm, i.e. the fiberscope could not be forwarded past the lesion. Next, based on the VB images, the following measurements were made: lesion length, minimum diameter of the stenotic segment, and the distance of the lesion from the carina.

Spiral CT scans were obtained using a Somatom 4 Plus (Siemens, Erlangen, Germany) with collimation set to 3 mm and a table speed of 3 to 4.5 mm/s (resulting in a pitch of 1 to 1.5). Using raw scan data, areas of interest were reconstructed in 1 mm slices. The size of the examination field was 100 by 150 mm (512 by 512 pixels). Planar resolution was set at 0.2 to 0.3 mm. To eliminate artefacts associated with breathing, scans were obtained at the end of deep inspirations. Segments were examined (100–150 mm) in one breathing cycle. CT scans were forwarded to a separate workstation connected to the institutional network (Advantage Windows 4.0, General Electric) and models based on surface reconstruction were created on this workstation. Based on the CT examinations, we used the Advantage Windows 4.1 (General Electric) program for measuring the stenoses. Using the virtual bronchoscopy model, we looked at the region of the stenosis and the neighbouring healthy bronchus. We determined the diameters of the stenosis at the place of maximum stenosis on the pictures of the orthogonal transversal and longitudinal multiplanar reconstruction (MPR) compared to the longitudinal axis of the bronchus. We also measured the length of the stenosis and the diameters of the neighbouring healthy parts of the bronchus, and measured the smallest diameter of the airways. A flexible fibre optic bronchoscope (Olympus BF1T, Olympus, Tokyo, Japan) was utilized for bronchofibroscopy (outer diameter: 6 mm).

After the first examination, the following interventions were performed: mechanical dilation/mechanical extraction in 12 cases (three of these patients also received radiotherapy), stent insertion in four cases, percutaneous radiotherapy in three cases, combined radiotherapy and chemotherapy in one case, strumectomy in one case, and stent revision/reposition in three cases (see Table 1). The control of the airways was performed after these interventions.

Statistically significant differences between the groups were analysed using Wilcoxon's signed rank test. Values of $p<0.05$ were considered significant.

Results

At the baseline examination, 11 cases were classified as 1st degree stenosis by FOB. Exact VB measurement of these lesions found minimum stenosis diameters of 7 to 11.4 mm. In the cases of the four 2nd degree stenoses, the minimum lesion diameters were between 3 and 9.8 mm. Last, FOB results showed that eight patients had 3rd degree stenoses, and VB measurements showed that these had minimum lumen diameters of 0 to 6.6 mm.

Table 2 Follow-up results using fiberoptic bronchoscopy (FOB) and virtual bronchoscopy (VB)

Stenosis diameter			
Baseline measurement		Follow-up	
FOB	VB	FOB	VB
1st degree (11 cases)	7–11 mm	1st degree (14 cases)	7.8–10.9 mm
2nd degree (4 cases)	3.9–9.8 mm	2nd degree (2 cases)	5.0–6.6 mm
3rd degree (8 cases)	0–6.6 mm	3rd degree (4 cases)	0.0–3.9 mm

Table 3 Comparison of FOB and VB results

N	Sex	Age	Diagnosis by VB	First examination				Second examination			
				Stenosis estimated by FOB	Smallest diameter by VB	Length of stenosis by VB	Distance of smallest stenosis from the main carina by VB	Stenosis estimated by FOB	Smallest diameter by VB	Length of stenosis by VB	Distance of smallest stenosis from the main carina by VB
1	F	57	Postintubation tracheastenosis	1st	7	67.4	25.6	1st	7.8	51.3	8.6
2	M	54	Goiter	3rd	2	81.2	84.7	1st	10.7	72.9	82.6
3	F	73	Postintubation tracheastenosis	1st	11.4	29.8	68	1st	7.6	40	63
4	F	52	Squamous cell carcinoma of the trachea	2nd	3.9	35.4	5.6	norm	14.9	0	
5	F	78	Postintubation tracheastenosis	3rd	4.2	27.9	51.6	1st	7.2	34.3	66.8
6	M	49	Squamous cell carcinoma of the trachea	1st	8.8	39.7	15.3	1st	8.3	59.1	0
7	M	68	Trachea adenoma	2nd	5.8	35.8	93.9	1st	5.1	33.5	
8	M	29	Postintubation tracheastenosis	1st	7.8		97.5	1st	8	38.7	100.5
9	M	73	Carcinoid in left main bronchus	3rd	0	37.6	11.8	3rd	0	23	0
10	F	40	Squamous cell carcinoma of right main bronchus	3rd	2.1	28.1	28.8	3rd	3.9	6	31.6
11	M	56	Squamous cell carcinoma of right main bronchus	3rd	1.1	14	12.7	3rd	3.7	12	13.3
12	F	21	Postintubation tracheastenosis	1st	6.4	63.0	121.00	2nd	6.60	60.00	75.50
13	F	31	Postintubation tracheastenosis	2nd	6.6	30.0	67.40	1st	8.60	26.90	67.20
14	M	51	Squamous cell carcinoma of the trachea	3rd	2.2	36	22.9	2nd	5	36	11.2
15	M	47	Postintubation tracheastenosis	1st	7	41	121	1st	8.1	50	119
16	M	60	Postintubation tracheastenosis	1st	7	42	80	1st	9	40	80
17	M	73	Carcinoid in left main bronchus	1st	9.1	6.5	13.6	1st	9.1	6.5	13.5
18	M	61	Adenocarcinoma of left 6th bronchus	3rd	0	7		norm	13.5	0	
19	M	61	Postintubation tracheastenosis	1st	7.4	41	92.4	1st	8	37	92.5
20	M	58	Squamous cell carcinoma in left main bronchus	3rd	0	23	36.5	3rd		42	16.9
21	M	60	Squamous cell carcinoma of the trachea	2nd	9.8	15.3	10.5	norm	18.8	0	12.1
22	M	21	Postintubation tracheastenosis	1st	8	48.8	75	1st	7	50	
23	M	51	Squamous cell carcinoma of the trachea	1st	10.5	17	30.5	1st	10.9	35.4	27.2

Fig. 1 Brouchofiberoscopic (**a**) and virtual images of carcinoid causing significant stenosis of the left main brouchus

a

b

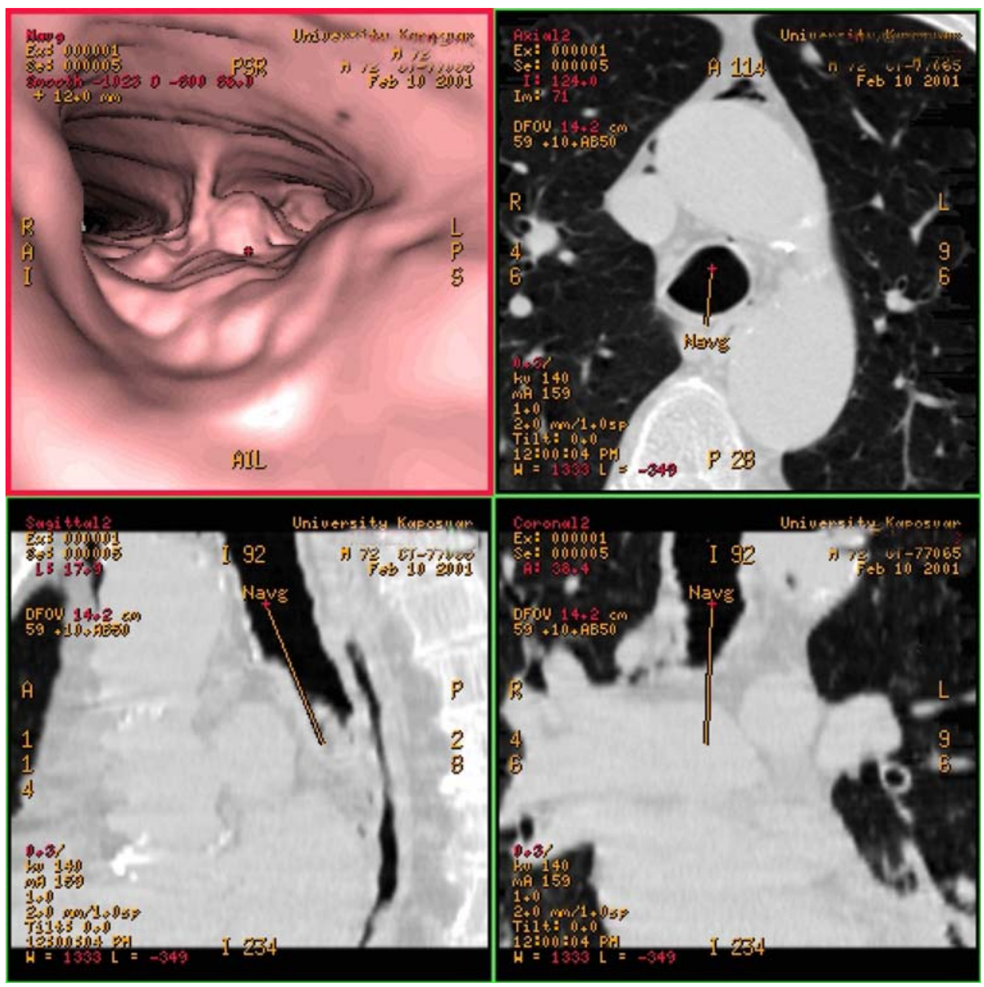
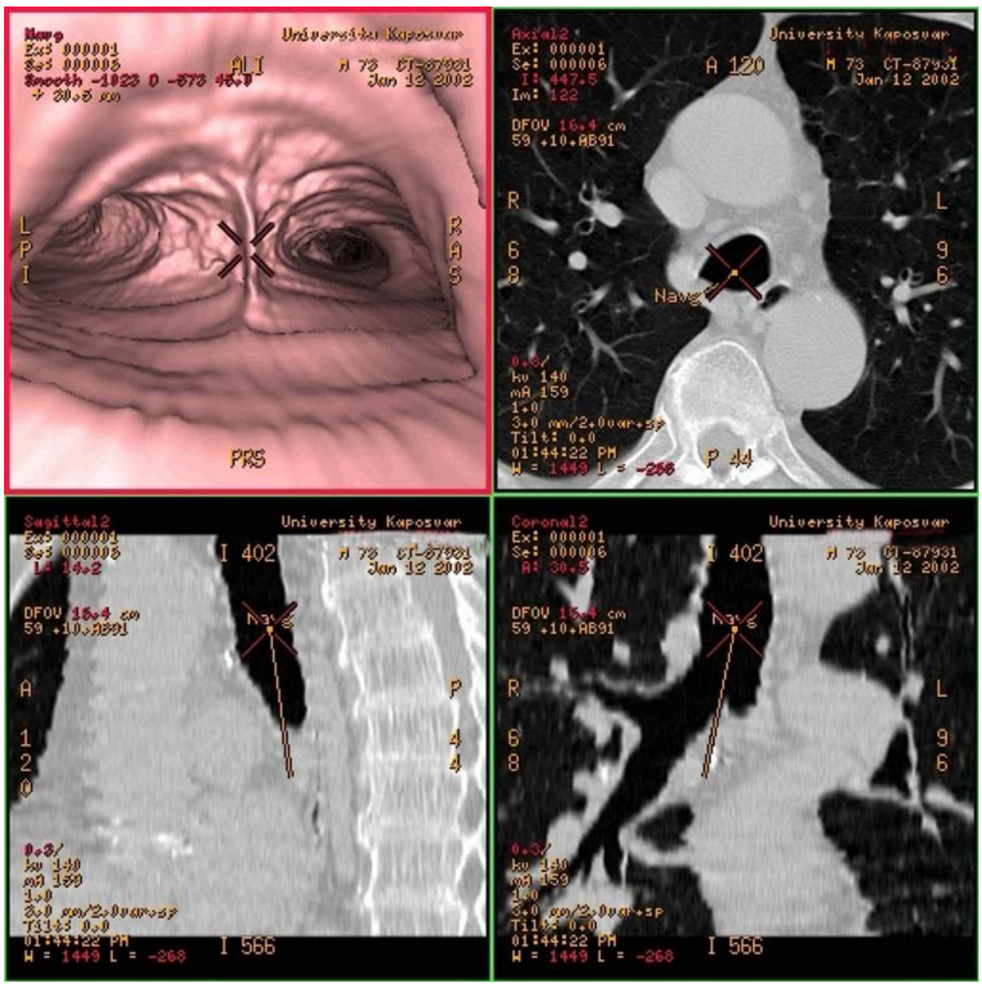


Fig. 2 Postinterventional brouchofiberoscopic (**a**) and virtual (**b**) images obtained in the same patient as in Figs. 1a and b show no signs of stenosis

a

b



After the interventions were performed, no stenosis was seen in three patients with either FOB or VB. We identified 14 first-degree stenoses (diameters between 5.1 and 10.9 mm), two second-degree stenoses (diameters 5.0 and 6.6 mm), and four third-degree stenoses (luminal diameters between 0 and 3.9 mm; see Table 2).

Comparing FOB and VB results from before and after the intervention, we found no significant difference between the techniques ($p=0.11$; see Table 3).

Figures 1a,b and 2a,b show bronchial tree before and after interventions with the two different methods (FOB and VB).

Discussion

Regular follow-up of large airway stenoses is necessary to detect changes in the patients' clinical status, to perform therapeutic interventions, and to review the position of stents. In our study, we followed-up 23 patients with airway stenoses using both bronchofibroscopy and virtual bronchoscopy; both methods gave similar results with no statistically significant differences. This suggests that for follow-up, non-invasive VB can be used as an alternative to FOB, which is an invasive technique [17].

FOB is currently an indispensable tool for diagnosing tracheal and bronchial stenoses, and is the only viable method for verifying the pathological processes that cause stenoses. VB can provide important complementary information when the fiberscope cannot be forwarded past the stenotic segment [18]. VB also helps the physician design interventions in the first stage of serial examinations of patients with 3rd degree stenoses. In this study, the information derived from FOB and VB was almost identical, although in many cases detailed VB data revealed more severe stenoses than FOB data. One possible explanation is that mucous plugs in the stricture were removed with the bronchoscope; the edema of the bronchial mucosa could also account for the small difference in measurements. The second examination was designed to follow-up on stenoses noted during the baseline examination. Both techniques provided accurate information regarding changes in the stenotic segment. We were able to use VB for the follow-up of stenosis length. Distance from the carina was a reliable measure of stent position control (these data were not detailed in this study). Interestingly, investigators used CT and FOB to follow-up patients with endobronchial stents; they, too, concluded that CT can be used for follow-up in this group of patients. In other prospective studies patients with tracheobronchial stenoses were followed-up and found *similar* result with VB [15, 16].

Data obtained from VB, a noninvasive method, are clinically valuable for the treatment of stenoses. In a study of 44 patients, Finkelstein et al. found that high-resolution CT scanning and VB were both excellent, objective, and reproducible imaging modalities with 100% sensitivity for detection of obstructive stenotic lesions [19]. In addition to its cost, the biggest disadvantage of VB is the time-consuming nature of the examination. FOB follow-up, although an invasive technique, can be performed in a matter of minutes (including anaesthesia). VB does not require more than 20 min of patient examination time, but image reconstruction and determination of accurate measurements are performed manually, which is time-consuming [20, 21].

Our study indicates that virtual bronchoscopy has a high diagnostical potential. With regard to lesion site, virtual bronchoscopy proved to be as informative as real fiberoscopy. It is an excellent tool for control patients with tracheobronchial stenoses with avoiding the repeated invasive procedure.

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