SPIRAL C.T, VIRTUAL BRONCHOSCOPY WITH MULTIPLANAR REFORMATTING IN EVALUATION OF POST-INTUBATION LARYNGOTRACHEAL STENOSIS

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Abstract

Objective: To evaluate the usefulness of spiral CT in detection and assessment of post-intubation laryngotracheal stenosis.

Patients and Methods: Fourteen post tracheostomy patients who were scheduled for surgical treatment of post intubation stenosis of the air way were subjected to spiral CT scan with multiplanar reformatting (MPR) and virtual endoscopy(VE) followed by conventional rigid bronchoscopy(RB). The following parameters were assessed: involvement of the subglottic larynx, site, number and length of the stenosis. The results were compared with the intra-operative findings.

Results: The detection rate of stenotic lesions was 94% by CT and 88% by rigid bronchoscopy. The sensitivity and specificity of CT scan and bronchoscopy in detection of the subglottic larynx was 100% and 100% for each. A significant correlation was found between the length of the stenosis measured intra-operatively and preoperatively with CT scan ($r=0.98$, $p<0.001$) and bronchoscopy ($r=0.94$, $p<0.001$). Laryngeal function was assessed only using rigid bronchoscopy.

Conclusion:Spiral CT scan with MPR and VE is an accurate and excellent technique for the measurement and definition of post-intubation laryngotracheal stenosis. Yet, it has no role in assessing laryngeal function.

Introduction and Aim of the work

Post intubation stenosis remains the most frequent indication for tracheal surgery despite the current use of endotracheal tubes with low pressure cuffs [1, 2]. It presents with sudden onset of dyspnea, stridor and can even result in death [3]. In selected patients, tracheal resection and reconstruction allows to obtain favorable results [4,6]. A correct preoperative assessment of such parameters as the length and the location of the stenosis are extremely important to improve surgical results and reduce morbidity. A variety of diagnostic examination has been described in the evaluation of air way [7].

Bronchoscopy is considered the "gold standard" for the detection and diagnosis of

tracheobronchial pathology because it permits direct visualization of the airway lumen. However, bronchoscopy has potentially hazardous complications in the severely ill patients (profound oxygen desideration in hypoxemic patients, tachycardia, cardiac arrhythmias, endoscopy-induced inflammation of the immunocompromised), and some technical limitations such as inability to evaluate airway caliber and morphology beyond a high-grade stenosis of the bronchial lumen. Furthermore, it is not an examination well-tolerated by all patients [8, 10].

On the other hand, spiral CT is a well-tolerated procedure by all patients, and permits rapid data acquisition during a single breath hold. The acquired images provide detailed information regarding the tracheobronchial tree and its pathology. Moreover, two and three-dimensional (2D, 3D) images generated by CT data, provide additional information regarding airway pathology. A variety of computer processing algorithms can be applied in CT acquired data such as: multiplanar reformatting (MPR) and virtual endoscopy (VE) [11, 18].

Virtual bronchoscopy is the specific application of VE for the tracheobronchial tree. It is non invasive and can produce views similar to those produced by conventional bronchoscopy. It can evaluate the airways beyond a high grade stenosis and it can be performed in patients who cannot tolerate bronchoscopy. The previously mentioned advantages of the computer-generated images render them as a constant demand for the evaluation of these patients [19, 21].

Hence, we studied the usefulness of spiral CT scan using the new processing techniques in detection and assessment of post-intubation laryngotracheal stenosis.

Patients and Methods

Fourteen post tracheostomy patients who were scheduled for surgical treatment of post intubation stenosis of the air way (9 men and 5 women; age range, 5-41; mean age, 24 years) were enrolled in this study, which was conducted between the otorhinolaryngology department and the radiology department, Ain-shams university hospitals between September 2006 and October 2007. Patients were referred from the ENT department with symptoms of stridor and breathlessness. The study was a prospective study and all patient were singed an informative consent prior to the examination and before surgery.

All patients were subjects to spiral CT scan (General Electric Medical System, HiSpeed DX-i) followed by rigid bronchoscopy. The time interval between the two examinations was 4± 2 days. Parameters to be assessed were the site, number and length of the stenosis. The evaluation of the length of stenosis was considered accurate if the preoperative measurement was within 5 mm of the actual length of the stenosis measures at time of surgery.

Patients underwent plain non contrast CT scan of the neck and upper chest using the following technical parameters: 120kV, 80 mAs, 3 mm collimation, pitch 1.5 and 512x512 matrix. The scan time ranged from 20-25 secs during one breath hold. The patients were scanned in the caudocranial direction to reduce motion artifact to a minimum. The acquired images were then reconstructed in 1 mm slice thickness. The axial CT images were transferred to an independent work station (Advantage Windows 4.0, General Electric Medical System) to create MPR and VE images.

We evaluated the time required to complete the CT examination and the quality of images produced. The assessment of image quality was based on the absence or presence of motion artifacts induced by involuntary movements associated with deglutition, respiration and throat clearing.

Data obtained from spiral CT and bronchoscopy were compared with the direct intra-operative findings. Pearson correlation analysis was used to compare the length of the stenosis evaluated by CT and bronchoscopy with the intra-operative findings. P value < 0.05 was considered significant.

Results

A total of 17 stenotic lesions were dedicted intra-operatively. Eleven patients had one stenotic segment while three patients have two stenotic segments.

Spiral CT detected 16 (94%) lesions (Fig 1), while bronchoscopy detected 15 (88%) lesions. Spiral CT failed to detect one low grade tracheal stenosis. Bronchoscopy failed to visualize distal stenosis in 2 patients as it failed to traverse a proximal high grade stenosis (Fig 2). Virtual endoscopy was very useful in evaluating the lumen of the trachea beyond the narrowed segment in order to determine the air way patency distal to the lesion (Fig 3). All lesions detected by CT and bronchoscopy were identified at the operative settings.

Table (1), shows the number and site of stenosis as detected by CT and bronchoscopy in comparison with the operative findings.

Site of stenosis	CT	Bronchoscopy	Operative
Subglottic	4	4	4
Tracheal	12	11	13

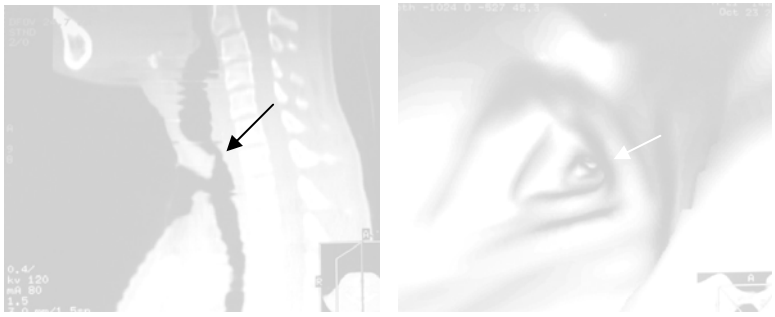
Table (1): Site and number of stenosis.

The sensitivity and specificity of CT and bronchoscopy in evaluation of the involvement of the subglottic larynx were 100% and 100% for each diagnostic methods (Fig 4).

The mean length of stenosis as assessed during surgical resection was 2.9 cm (0.5-5 cm), compared with a mean of 3 cm (0.4-5.2 cm) with spiral CT and a mean of 3 cm (0.3-4.5 cm) with bronchoscopy.

The preoperative assessment of the length of stenosis was considered accurate in 14 (87 %) of the 16 stenotic segments detected by CT and in 11 (73 %) of the 15 segments detected by bronchoscopy. There were 2 cases of tight stenosis detected by CT and bronchoscopy, but the stenotic length was assessed only by CT (Fig 3).

The length of stenosis as assessed intra-operatively significantly correlated with the data obtained with CT scan ($r = 0.98$, $p<0.001$) and RB ($r = 0.94$, $p<0.001$) (Fig 5).



(a) (b)

Fig (1): Spiral CT scan with (a) sagittal reconstruction and (b) virtual endoscopy shows post intubation tracheal stenosis (arrows).

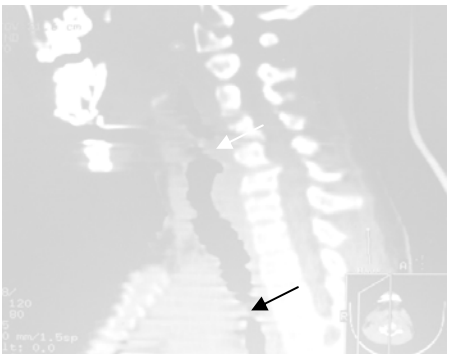
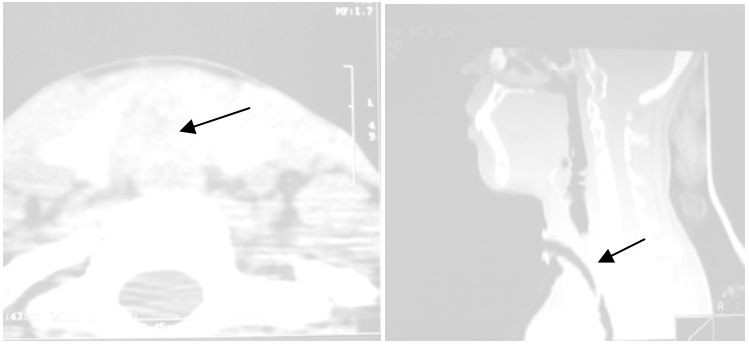


Fig (2): Suboptimal spiral CT scan with sagittal reconstruction shows two stenotic segments at different levels (arrows), bronchoscopy failed to demonstrate the distal lesion. Motion artifact is noted.



(a) (b)

(c)

(d)

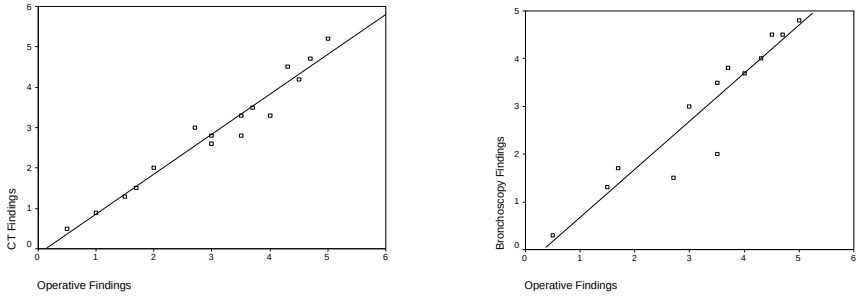
(e)

(f)

Fig (3): Spiral CT scan with (a) axial image and (b) sagittal reformat showing long stenotic segment with complete absence of the air way (arrows),(c) the length of stenosis and distal navigation till the carina was only available by MPR, (d) virtual endoscopy,(e) surgical field during resection of the stenotic segment and(f) the resceted segment measuring 43.7mm respectively.

(a) (b)

Fig (4): Spiral CT (a) sagittal reconstruction shows a high grade subglottic stenosis (arrow) (b) virtual endoscopy shows a concentric lumen stricture.



(a) (b)

Fig (5): The length of stenosis as assessed intra-operatively significantly correlated with (a) CT scan and (b) bronchoscopy.

The whole CT procedure took 20-25 min for each patient. The generated images were optimum in 11 (79 %) of the 14 patients. Two suboptimal images were caused by motion artifacts. Transverse, MPR and virtual images were complementary in lesion assessment. Laryngeal function was assessed only by rigid bronchoscopy.

Discussion

Air way resection and reconstruction is the treatment of choice of post-intubation tracheal stenosis. Despite the use of low-pressure cuffs, the incidence of these lesions hasn't decreased significantly in recent years, because of such factors as the increased use of prolonged ventilation and the misuse of low-pressure cuffs [(2)].

Bronchoscopy is the best diagnostic procedure for detection of tracheobronchial pathology because it permits direct evaluation of the endoluminal and mucosal lesions of the respiratory tract and can guide biopsies for histologic analysis. However, conventional bronchoscopy has some limitations: (1) it can't pass through severe airway narrowing and (2) it cannot be tolerated by some patients [22].

The majority of airway abnormalities are sufficiently evaluated by axial CT images, but there are some limitations of axial images for assessing the airways, such as: (1) limited ability to detect subtle airway stenosis; (2) underestimation of the craniocaudal extent of disease; (3) difficulty assessing the interfaces and surfaces of airways that lie parallel to the axial plane; and (4) generation of a large number of images for review [13, 23, 25].

The creation of 2-D and 3-D images reformatted from the original axial CT data set can help to overcome these limitations. Such images also allow virtual endoscopic perception of the disease, which consequently leads to improved diagnostic confidence of interpretation [12].To overcome the limitations of bronchoscopy, the above mentioned CT – computed generated images were applied for the evaluation of tracheobronchial pathology [22].

In the preoperative evaluation, parameters such as glottic function, involvement of the subglottic larynx, length of the stenosis and length of the residual air way must therefore be thoroughly evaluated [26].

In our study spiral CT missed one stenosis as it was subtle and not readily appreciated on axial, MPR and virtual endoscopy. Conventional bronchoscopy failed to diagnose two stenotic segments in two patients because it could not be negotiated beyond the proximal high grade obstructions.

We agree with Koletsis et al [22] who found that computer generated images detected the same stenosis with bronchoscopy with the advantage that virtual endoscopy found additional stenosis beyond the areas that the bronchoscope could not traverse. These findings can possibly indicate that virtual endoscopy has high diagnostic yield in the setting of multiple lesions. We believe among others that CT scan may play the role of preliminary study in patients that are not capable to undergo conventional bronchoscopy. McAdams et al [27] reported an accuracy of 97% with virtual bronchoscopy in stenosis detection.

Accurate evaluation for involvement of the subglottic larynx is extremely important, because specific surgical techniques have to be used to avoid recurrent laryngeal nerve lesions [26]. In our study CT scan as well as bronchoscopy showed high sensitivity and specificity in diagnosis of subglottic involvement, in contrast to Carretta et al [26] which showed that CT having low sensitivity and high specificity.

The precise measurement of the length of the stenosis and of the residual airway is also essential to determine if enough healthy airway is available to perform a well-perfused and tension-free anastomosis. In our experience 2D reformatting images were helpful in appreciating the vertical length of the lesion more precisely than conventional bronchoscopy which could not be negotiated beyond a tight stenosis. In two of our patient the length of stenosis was underestimated by CT scan and one stenosis was missed in another patient, which according to Filkenstien et al [28] was because of the limited accuracy of CT scan in the demonstration of low grade stenosis and subtle mucosal involvement.

Assessment of laryngeal function is of great importance in the evaluation of candidates for reconstructive surgery of the air way. Bronchoscopy allows an ideal assessment of the laryngeal function, a merit that is not possible by CT scan.

The potential limitation of our study was the use of a single –detector rather than a multidetector scanner. Hoppe et al [(29)] stated that multidetector scanners produce better quality MPR images, because of their superior z-axis resolution, and a reduction of motion artifacts, because of the short acquisition time. The improvements afforded by multidetector scanners have a great impact on the quality of MPR and virtual images than on the axial images.

We believe among others that VE in multiview mode may also substitute conventional bronchoscopy in the follow-up of patients after endobronchial procedures in cases where the monitoring of changes in stenosis degree is important and successive bronchoscopy are unpleasant for the patient. Moreover, spiral CT scan may be the preliminary study in patients that are not capable to tolerate bronchoscopy.

In conclusion, spiral CT scan with MPR and VE is an accurate and excellent technique for the measurement and definition of post-intubation laryngotracheal stenosis. Yet, it has no role in assessing laryngeal function.

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