ORIGINAL ARTICLE

Endotracheal and tracheostomy tube-related complications: imaging with three-dimensional spiral computed tomography

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Abstract

Aim: To present our experience from the use of three-dimensional (3D) spiral computed tomography (CT) reconstructions for the detection of endotracheal and tracheostomy tube-related complications.

Material and Methods: The CT-scans of thirteen patients who were subjected to spiral computed tomography for the evaluation of possible tracheal complications due to the use of endotracheal or tracheostomy tubes were retrospectively studied. In each case, a spiral scan of the airways from the larynx to the main bronchi was performed. Axial images were reconstructed with the use of the following three-dimensional visualization methods: volume rendering (VR), tissue transition projection (TTP), shaded surface display (SSD) and virtual endoscopy (VE). Detected complications were subdivided into acute and late, according to the time of appearance (during presence of tracheal tube or after its removal, respectively).

Results: Six patients showed acute complications (wrong placement of the tube with compression of tracheal wall in three cases, perforation of tracheal wall in two cases, tracheal stenosis in one case). Seven patients showed late complications (tracheal stenosis in all cases). Three-dimensional reformatted images contributed significantly to the detection of both acute complications (position of tube in relation to tracheal wall), and late complications (number, position, length and degree of stenoses), providing a non-invasive evaluation of the outer tracheal wall and tracheal lumen.

Conclusion: Three-dimensional spiral CT reconstructions are a valuable adjunct of transverse images for the evaluation of trachea in cases of suspected tracheal tube-related complications. Hippokratia 2009; 13 (2): 97-100

Key-words: spiral computed tomography; three-dimensional reconstructions; tracheal complications; tracheal stenosis, tracheal perforation, tracheal compression

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The placement and use of endotracheal and tracheostomy tubes for mechanical support of ventilation can cause a variety of acute or late complications[1,2]. Acute complications include haemorrhage, infection, tube obstruction and accidental decannulation. Tracheal stenosis is the commonest among late complications, while more unusual ones include tracheomalacia, tracheoesophageal fistula and tracheoinnominate artery erosion. Laryngotracheoscopy is considered as the gold standard modality for the intraluminal evaluation of the upper airways in cases of suspected tube-related complications[3,4]. It remains, however, an invasive method, not always well tolerated, that cannot provide information concerning the outer tracheal wall and surrounding structures. During the last decade, the spread of spiral computed tomography and the improvement of image post-processing software enabled visualisation of the airways in the form of three-dimensional reconstructed models[5]. Apart from the already well-established advantages of spiral computed tomography (speed, safety, reproducibility, excellent resolution of anatomic structures), three-dimensional reconstructions achieve a more realistic representation of the anatomy than axial slices do, providing also the ability of inspection of both the outer wall and the lumen of the airways. In this retrospective study we present our experience from the use of three-dimensional spiral CT reconstructions for the detection of tracheal tube-related complications.

Material-methods

We retrospectively studied the CT-scans of thirteen patients (9 male, 4 female, mean age 46), who were subjected to a spiral CT examination for the evaluation of possible tracheal tube-related complications (endotracheal tubes in 6 cases, tracheostomy tubes in 7 cases) during a three-year period (January 2005 to December 2007). Six patients had the tube in place during the examination, while the rest had a history of previous tracheostomy (n=5) or endotracheal intubation (n=2) and presented with stridor and a clinical suspicion of upper airway stenosis. A Picker PQ5000 spiral CT scanner was used. A spiral scan of the upper airways was performed, from the level of the larynx down to the main bronchi, after intravenous bolus administration of 100ml of iodinated contrast medium. The scanning parameters were set as follows: collimation 3mm, pitch 1, reconstruction index 1.5, kV120, mA 175. Patients were instructed to hold their breath at full inspiration. In each case, duration of the scan did not exceed 35 sec.

The volume data set of each examination was transferred to an independent workstation (Picker Voxel Q). The original axial slices were post-processed with the use of the following visualisation methods: volume rendering (VR), tissue transition projection (TTP), shaded surface display (SSD) and virtual endoscopy (VE). The first three methods produced reformatted images that allowed evaluation of the upper airways from an external point of view with 360΄I rotation of the reconstructed 3D model. The fourth method (VE) allowed evaluation of the laryngeal and tracheal lumen from an internal point of view, also permitting virtual navigation through the lumen.

The original axial images and 3D models were consensually interpreted by two head-and-neck subspecialized radiologists (I.T., C.T.). Detected complications were divided into acute and late, according to the time of appearance (during the presence of the tracheal tube or after its removal, respectively).

Results

The quality of axial slices and 3D reconstructions was judged as adequate in 11 patients. Minor circular artefacts were observed in three of these patients, due to their inability to sustain prolonged apnea. The remaining two patients showed heavier artifacts due to severe dyspnea; as a result, the VE reformats of these patients were of suboptimal quality and judged as nondiagnostic.

Six out of thirteen patients demonstrated acute complications, and seven patients demonstrated late complications. Three patterns of acute complications were recognized: compression of the tracheal wall by the distal end of the tracheal tube (3 patients, Figure 1), perforation of the tracheal wall by the tube (2 patients, Figure 2) and tracheal stenosis immediately above the level of the stoma (1 patient, Figure 3). Tube misplacement had been the common cause of the first two patterns of complications; in these cases, posterior tracheal wall was the most frequent site of damage (3 patients), followed by

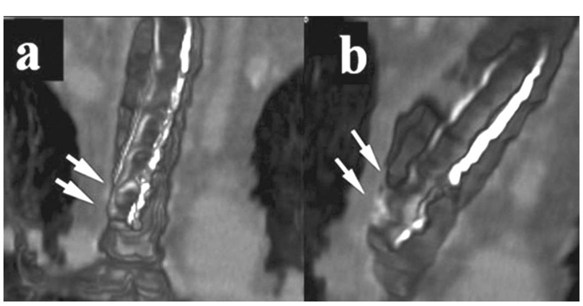

Figure 1 (a,b): Intensive care unit patient, presenting bleeding from the endotracheal tube two days after intubation. Volume-rendered (VR) 3D reconstructions of trachea show impaction of the distal end of the tube in right lateral wall of trachea (arrows). Hemorrhage ceased after proper repositioning of the tube.

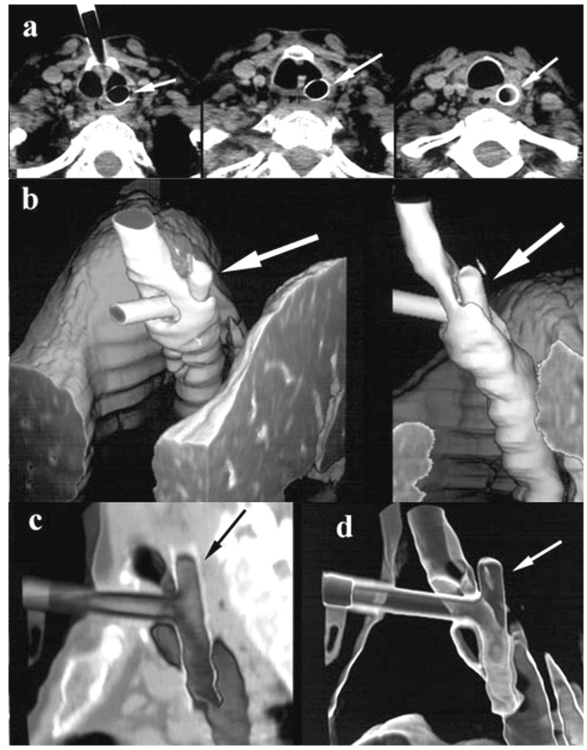

Figure 2 (a-d): Perforation of posterior tracheal wall by a tracheostomy T-tube; a: The axial slices (first row) show the presence of part of the tube outside the tracheal lumen and into the soft tissues of the neck; b: 3D reconstructions with shaded surface display (SSD); c: volume rendering (VR) and d: tissue transition projection (TTP) techniques demonstrate the exact position of the posterior tracheal wall perforation and the protrusion of upper end of the T-tube outside trachea (arrows).

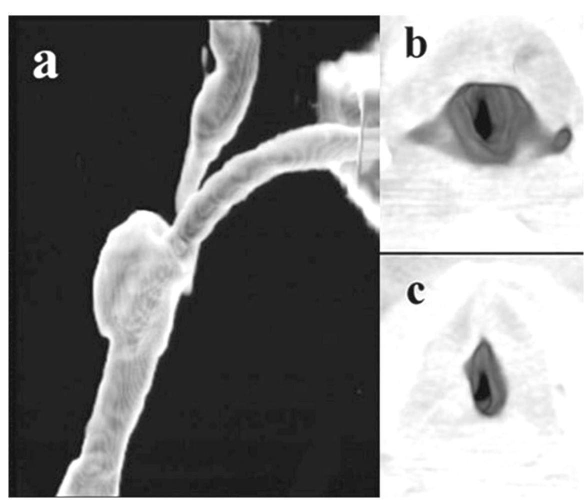

Figure 3 (a-c): Subglottic stenosis immediately above the level of the stoma. Right lateral projection of the lesion in a TTP reconstruction (a), and observation of the stenotic lumen through virtual endoscopy (VE, b-c). This case of stenosis was classified among acute complications, as it was detected with the tracheostomy tube in place.

the right lateral (1 patient) and left lateral (1 patient) wall of trachea.

Late complications were detected in seven patients; they were, in every case, stenoses of the upper airway lumen. The study of each patient's original axial slices excluded the presence of any extramural cause of compression, intraluminal lesion or mural thickening of the upper airways, thus allowing characterization of stenoses as fibrous. The study of VR, TTP and SSD three-dimensional reconstructed models helped define the site of stenoses (tracheal lumen: 3 patients, subglottic laryngeal lumen: 2 patients, combination of two: 2 patients), the number of stenoses (solitary stenosis: 6 patients, two stenoses: 1 patient), the length of the stenotic segments and the diameter of the stenotic lumen (Figures 4-6). Virtual endoscopic reformats confirmed the presence of the stenoses and provided the ability of virtual navigation through the stenotic parts and inspection of poststenotic lumen (Figures 3,4).

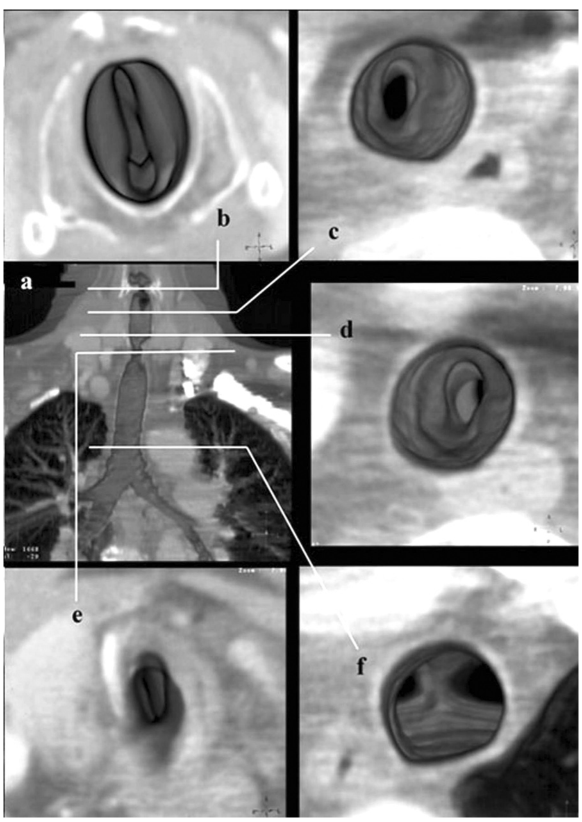

Figure 4 (a-f): Short circumferential tracheal stenosis. a) VR reformatted image. White horizontal lines have been drawn, corresponding to the different levels (b through f) of VE images. b: level of true vocal cords, c,d: prestenotic lumen, e: level of stenosis, f: poststenotic lumen (the carina can be seen).

Discussion

Both acute and late upper airway complications secondary to the use of tracheal tubes constitute a significant cause of morbidity in patients who are subjected to endotracheal intubation or tracheostomy[6]. Direct laryngotracheoscopy is classically considered as the gold standard method for intraluminal evaluation of the upper airways, as it provides the ability of direct visual inspection of the pathology, also allowing in some cases the performance of diagnostic and therapeutic manoeuvres[3,4,7]. It remains, however, an invasive method, not always well tolerated, and not able to provide information concerning the outer tracheal wall and surrounding structures. Intubated patients cannot easily undergo direct laryngotracheoscopy; moreover, even in extubated patients it is often extremely difficult to pass through severe stenoses and assess the poststenotic lumen with direct endoscopy.

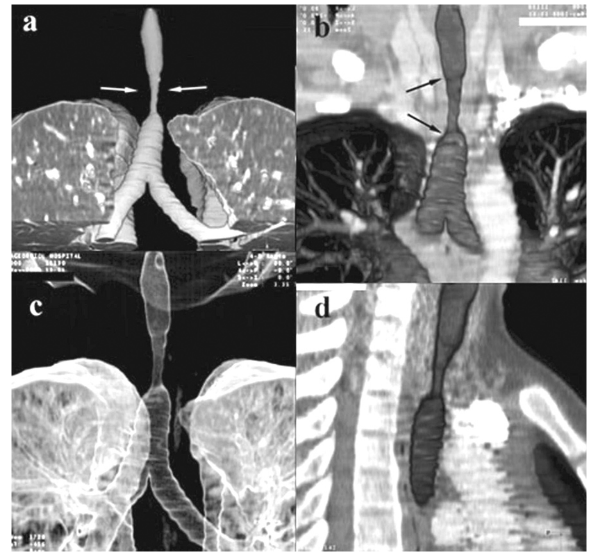

Figure 5 (a-d): Severe long circumferential tracheal stenosis (arrows), after prolonged intubation. 3D reconstructed models with the visualization methods of SSD (a), VR (b,d) and TTP (c).

Spiral computed tomography is a fast, accurate, safe, non-invasive and easily repeatable diagnostic modality

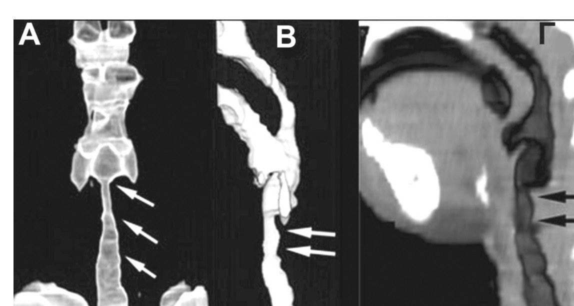

Figure 6 (a-c): Severe subglottic stenosis, extending to the upper part of trachea (arrows), in a 3-year-old patient. Frontal view of the upper airways with a TTP reconstruction (a), left lateral projection with SSD (b) and VR (c) reconstructions.

with an excellent imaging resolution of anatomic structures; thanks to these advantages it has gained wide acceptance for the evaluation of the airways. However, axial slices show certain inherent disadvantages regarding image interpretation of the upper airways, such as limited ability to detect subtle airway stenosis and underestimation of the craniocaudad extent (length) of the lesion[5]. Moreover, the large data volume that results from the use of thin collimation is often confusing for the radiologist and the clinician, who are obliged to review large numbers of transverse images without the ability of mentally recreating a view of the lesion in space.

The development of visualisation methods of the original transverse slices in the form of three-dimensional reconstructed models contributed to the effacement of the aforementioned limitations of axial imaging. The produced reformats not only display anatomic structures and underlying pathology in a more realistic manner, but also provide new capabilities such as external 360Ί rotation of the 3D model or virtual navigation through lumens with simultaneous observation of possible luminal abnormalities[8,9]. At the same time, measurements in the reconstructed images can be performed as accurately as in the original axial images; consequently, evaluation of lesions displayed in 3D models retains the advantage of objectivity.

In our study, we found the VR and TTP reformats to be sufficient for the evaluation of acute complications, as they provided detailed information concerning the position of the tracheal tube in relation to the tracheal wall. SSD reconstructions displayed adequately only cases of tracheal perforation and protrusion of the tube outside the lumen, while they were unable to evaluate possible wrong intraluminal position of the tracheal tube. Virtual endoscopy models did not add any significant information regarding the position of the tube. All cases of remote complications in our study were subglottic or tracheal stenoses. Fibrous tracheal stenosis constitutes indeed the most frequent among late complications of endotracheal intubation and tracheostomy tubes[2,10]. A multitude of aetiopathogenic factors are implicated in the development of postintubation stenosis; these include ischemic damage of the tracheal wall from compression by the tube cuff, infection, mechanical irritation, steroid administration and positive pressure ventilation[11]. It is worthwhile noticing that one of the cases of tracheal stenosis was considered as an acute complication, as it was detected while the tracheostomy tube was still in place. Although the complication of tracheal stenosis is usually detected after extubation, it can develop during endotracheal intubation or tracheostomy[10.] The VR, TTP and SSD reformatted images demonstrated accurately the position, number, length and degree of stenosis in every case, while the virtual endoscopic models confirmed the presence of the stenoses, providing also the ability of virtual inspection of both prestenotic and poststenotic lumen. The original axial images played also an important role in the interpretation of identified pathology, as their study excluded the presence of any extramural cause of compression, intraluminal lesion or mural thickening of the upper airways, thus allowing characterization of stenoses as fibrous ones. Therefore, it should be stressed that three-dimensional reconstructions do not actually create new information but they rather offer a different, complementary and often more familiar way of viewing the acquired data.

The retrospective nature of our study constituted an inherent limitation, as no direct endoscopic findings were available for comparison; in this way, we were not able to estimate the true sensitivity and specificity of three-dimensional spiral CT in relation to a gold standard method. In addition, the characterization of stenoses as fibrous ones was based on the exclusion of other causes of stenosis and not in histology data that could result from a direct diagnostic method such as laryngotracheoscopy. A high accuracy of 3D visualization methods compared to direct endoscopy in the upper airways has been reported[4,12,13], in a limited, however, number of patients. Based on our limited experience, we believe that spiral CT three-dimensional reconstructions are an essential adjunct of the axial slices for the evaluation of the trachea in cases of suspected tube-related complications, and at the same time they offer a valuable alternative in cases of inability to perform direct laryngotracheoscopy.

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