Utility of multidetector CT and virtual bronchoscopy in tracheobronchial obstruction in children

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Abstract
Purpose: The aim of this study was to evaluate the potential use of multidetector CT (MDCT) and virtual bronchoscopy (VB) in the evaluation of tracheobronchial patency in children with suspected bronchial obstruction and to compare its findings with fibroptic/rigid bronchoscopy or surgery.

Patients and methods: A total of 43 children (15 girls, 28 boys) with clinically suspected bronchial obstruction underwent contrast enhanced MDCT, using an age- and weight- adjusted low dose protocol. Post-processing was performed and VB and multiplanar reformations (MPR) were obtained at the same sitting. Findings obtained at MDCT and VB were compared with fibroptic/rigid bronchoscopy and surgery.

Results: Obstructive pathology was found in 26 children, which included endoluminal foreign body, mucus plugs in 13 children, endobronchial tumour in three children and extrinsic compression (lymph node, aberrant Vessels, mediastinal cysts/tumours) of the tracheobronchial tree in 10 children. In 17 children, no obstructive lesion was identified. Excellent positive correlation was obtained, between MDCT-VB and bronchoscopy/surgery, however, in one child with endobronchial obstruction caused by tracheitis, low dose MDCT-VB was normal, but bronchoscopy revealed granularity and plaques.

Conclusion: MDCT-Virtual bronchoscopy is useful in evaluating bronchial stenosis and obstruction caused by both endoluminal pathology and external compression and has the advantage of looking beyond stenosis. Its main application lies in providing the exact location of suspected foreign body, prior to bronchoscopy. However, it fails to disclose exact nature of obstructing pathology.

INTRODUCTION
Multi detector computed tomography (MDCT) is a recent advancement of CT technology with which it has now become possible to acquire multiple images per single rotation and to obtain a larger volume of data in a much shorter interval. Multidetector system makes it possible to acquire 3-dimensional (3-D) data with isotropic voxels (same dimension in all orthogonal planes) (1–3). This enables the radiologist to choose the optimum plane for the evaluation of the anatomical region or the pathological process. The principal applications that are significantly improved by introduction of MDCT include all areas of CT angiography, evaluation of patients with limited ability to cooperate such as children and mentally disabled and applications requiring advanced post-processing such as studies with multiplanar and 3-D reconstruction (1–3).

Virtual bronchoscopy (VB) of the tracheobronchial tree is one of the advancement in MDCT technology that pro-vides realistic 3D view of the tracheobronchial tree that can be evaluated non-invasively in children (4,5). In children, VB has an important complementary diagnostic role before fibroptic bronchoscopy in preoperative planning of patients, preendoscopic road mapping and for postopera-tive follow-up (6–8).

The experience with MDCT and VB in children is limited especially in cases causing extrinsic bronchial obstruction and in this study we have tried to evaluate its role in tra-choebronchial obstruction in children.

PATIENTS AND METHODS
A total of 43 children (15 girls, 28 boys) were enrolled in the study. The study was approved by institutional ethics review board. Informed consent was obtained from patients before start of the study in all the cases. The indications for MDCT and VB included children with suspected radiolucent for-eign body aspiration, tracheobronchial anomalies, and suspected cases of airway compression or obstruction. Chest radiographs were obtained in all children prior to CT. All examinations were performed on multislice CT scanners (4row scanner -light speed plus, GE medical systems or 16 row scanner- Somatom sensation 16, siemens, Germany or 64row scanner-TOSHIBA Acquillon,Toshiba America Medical System). MDCT was performed from the level of
larynx up to domes of the diaphragm. In all patients intravenous contrast agent with approximate dose of 1.5 ml/kg (iohexol, omnipaque) was administered manually via peripheral vein. All the examinations were performed under light sedation (intravenous midazolam) by an anaesthetist.

Scanning parameters for 16 section scanner were 16 · 1 mm detector collimation, 80–100 kVp, 0.5 sec gantry rotation and 50–80 mA. The typical parameters for four row CT scanner included 4 · 2.5 mm detector collimation, 80–100 kVp, 50–80 mA, pitch of 0.75:1, speed 7.50 mm/rotation, scanning duration of 9.5 sec. Data were acquired in craniocaudal direction. MDCT images were recon-structed to 1 mm to 2 mm slice thickness.

3D reconstructed multiplanar reformatted (MPR) images were analysed in coronal, axial and sagittal planes in a separate workstation (Wizard, siemens for 16 section scanner and Sdc, GE medical systems for four section scanner and Terrarecon for 64 row Toshiba). VB was accomplished using these images and two experienced paediatric radiologists evaluated all the images and final consensus was made if there was any discrepancy. All images were analysed for the presence of tracheobronchial narrowing caused by endoluminal pathology (foreign body, mucus plugs and tumour) as well as extrinsic compressions (lymphnodes, tumours and aberrant vessel). Presence of tracheobronchial anomalies was also noted.

Bronchoscopy was performed within the same day under analgesia and sedation if any obstructive abnormality was detected in VB and MDCT. Rigid or fibreoptic (Olympus 340) paediatric bronchoscope was used depending upon the indication by an experienced paediatric pulmonologist or surgeon who was aware of the MDCT-VB findings. Nine cases, which were normal on MDCT-VB, did not undergo bronchoscopy. These patients were excluded from the study. Nine children underwent surgical management, results of which were correlated with VB findings.

RESULTS

The mean age of the study group was 4 years, 5 days (age range, 5 months to 12 years). In 16 of 43 patients, endoluminal obstructive lesion was identified, in which the findings of MDCT and VB correlated with either bronchoscopy or surgery. However, one case was false negative, in which MDCT-VB missed findings of mucosal plaques and granularity of trachea because of inflammation (tracheitis). In this case fibreoptic bronchoscopy correctly demonstrated the findings. The calculated effective dose using our protocol was 1.2-3.6 mSv. Of the 16 cases with endoluminal obstruction on MDCT-VB, there were nine cases of foreign body, four cases of mucus plugs, and three cases of endoluminal growth.

The locations of foreign body were in left main bronchus (n = 3), right main bronchus (n = 2), left lower lobe (n = 2) and right lower lobe bronchus (n = 2). One patient underwent surgery for foreign body removal following failure through bronchoscopic removal as foreign body was adherent to bronchus and in all eight remaining patients foreign body was removed through rigid bronchoscope (Fig. 1). The foreign body encountered were peanuts (n = 5), pen tip (n = 1), pills (n = 1), plastic foreign body (n = 2).

Mucus plugs as the cause of endoluminal obstruction was observed in four children. Two children with mucus plugs had cystic fibrosis. One of them had multiple bronchi involvement with narrowing and the other had multiple mucus plugs in the same bronchus. Mucus plugs were observed in left main bronchus (n = 2), right main bronchus (n = 1), right lower lobe bronchus (n = 1), left lower lobe bronchus (n = 1). In all these cases bronchoscopic removal of mucus plugs was performed. The lung findings, on CT scan in these cases were segmental atelectasis (n = 5), peri-bronchial thickening (n = 2), consolidation (n = 3), hyper-inflation (n = 3). In these 13 cases with foreign body and mucus plugs, in the absence of definite documented history, MDCT and VB could not differentiate between foreign body and mucus plugs. Of the three endoluminal growth encountered during our study, two of them turned out to be inflammatory pseudotumour on bronchoscopic guided biopsy, which was removed surgically. Both of them were observed in left main stem bronchus. The other endoluminal growth that was observed in right main bronchus was proven as mucoepidermoid carcinoma and this patient also underwent surgical management.

Tracheobronchial obstruction caused by extrinsic compression of the trachea and bronchus by mediastinal pathologies was observed in 10 children. Out of these 10 cases of extrinsic tracheobronchial obstruction, five cases were due to mediastinal lymph nodes causing compression of trachea (n = 2), right main stem bronchus (n = 2), left main stem bronchus (n = 1). Associated lung findings in the form of consolidation (n = 3), bronchiectasis (n = 1), atelectasis changes (n = 2) and obstructive hyperaeration (n = 1) were observed in four cases. Remaining five cases of extrinsic compression showed aberrant vessel (n = 2), hydatid cyst of

Figure 1 4-year-old female child presenting with bronchial obstruction. Virtual bronchoscopy confirms the exact location of the obstruction (arrow) in the right main bronchus (foreign body confirmed at fibreoptic bronchoscopy).
lung with mediastinal extension (n = 1), mediastinal foregut cyst (n = 2) as cause of extrinsic tracheobronchial obstruction. Of the two aberrant vessels, one was due to patent ductus arteriosus aneurysm compressing left main bronchus (Fig. 2) and other due to retrooesophageal aortic arch causing compression of trachea. Mediastinal foregut cysts were causing compression of both main stem bronchi and hya-tid cyst was causing compression of right main stem bronchus. All these five patients underwent surgery, which correlated with MDCT and VB findings.

Of 17 cases with non-obstructive pathology, two of them showed lung hypoplasia on right side, which was responsible for the opacification of hemithorax, and one of them had chronic non-obstructive collapse of the middle lobe (middle lobe syndrome). Right-sided tracheal bronchus was identified in one patient on MDCT-VB (Fig. 3), which was later confirmed at fibreoptic bronchoscopy. Remaining 13 cases were normal on MDCT and VB. Of them nine cases did not undergo fibreoptic bronchoscopy and four of them underwent fibreoptic bronchoscopy. Of these four patients, three turned out to be normal. Remaining one case that underwent fibreoptic bronchoscopy was false negative, in which MDCT-VB missed findings of mucus plaques and granularity of trachea because of inflammation (tracheitis). In this case fibreoptic bronchoscopy correctly demonstrated the findings. The nine patients who did not undergo fibre-optic bronchoscopy/surgery were excluded from study.

Of 43 children who underwent multidetector CT and VB, fibreoptic/rigid bronchoscopy/surgical correlation was available for 34 children. Excellent correlation was observed in all but one above-mentioned false negative case of tracheitis.

Figure 2 5-month-old female child with PDA aneurysm and respiratory complaints. (A) Axial MDCT image reveals compression of the left main bronchus (thick arrow) by the enlarged pulmonary artery. (B) Virtual bronchoscopy confirms the narrowing in the left main bronchus.

Figure 3 8-year-old male child with tracheal bronchus. (A) Coronal reformatted MDCT image suggests an right-sided tracheal bronchus (arrow). Carina is marked by double arrow. (B) Virtual bronchoscopy confirms the exact origin and site of the tracheal bronchus (arrow). Normal carinal bifurcation is also clearly demonstrated. (double arrow).
DISCUSSION

Virtual bronchoscopy is a non-invasive technique that provides a 3D view of the internal surface of the trachea and major bronchi by using multidetector CT images (4,5). VB enables simultaneous visualization of inner and outer structures of the tracheo bronchial tree thus clearly depicting the cause of obstruction (4). The virtual technique does not require additional radiation exposure in children, but provides additional information to the multidetector CT images, that is indicated anyway for suspected narrowing or compression of the tracheo bronchial tree (6). As opposed to fibre-optic bronchoscopy, the virtual technique is non-invasive and does not require general anaesthesia and can be performed with simple sedation. The other advantages of VB include visualization of airway distal to obstruction (5,9,10), segmental and subsegmental bronchi can be evaluated easily with thin section multidetector CT images (10), simultaneous evaluation of mediastinal and lung pathologies (11) responsible for symptoms of the child, evaluation of vascular anomalies in children (12). In addition, the VB images are visually pleasing and help the paediatric surgeon planning bronchoscopy for the child (10).

One of the main drawbacks of virtual bronchoscopy in adults is that it cannot be used to obtain biopsy specimens. This limitation is less significant in children because evaluation of neoplastic process is relatively rare in this group (7). Even in this group the most appropriate site for sampling can be chosen interactively (8). The other limitations of VB are its inability to assess mucosal morphology, vascularity and colour, secretions and artefacts may lead to false positive results (10). It is pertinent to add that a normal CT Virtual bronchoscopy does not exclude bronchial foreign body and in any suspected case of bronchial foreign body, bronchoscopy is mandatory.

Other concern in MDCT is radiation exposure. The radiation risk is related to the magnitude of the corresponding absorbed dose, which is of two types: (1) deterministic risks, which occur at high doses and are therefore extremely unlikely to occur in computed tomography (CT) scanning; and (2) stochastic (random) risks. Deterministic radiation risks, such as the cataract formation, induction of skin burns and epilation, are associated with a threshold dose and only occur if the most highly irradiated tissue exceeds this threshold dose. The principal concern of any radiation exposure is the induction of stochastic (random) risks. These stochastic radiation risks are radiation-induced cancer (carcinogenesis) and genetic effects that would appear in the offspring of an irradiated individual (13). Various authors (14) have suggested that paediatric CT exposures could be reduced by at least 30–50% relative to adult exposures by reducing the milliampere-seconds to obtain essentially the same information. In this study, we used the lowest possible dose of 80–100 kVp and 50–80 mA to minimize the radiation risk involved.

In our study, we encountered 16 cases with endoluminal obstruction, which were correctly diagnosed using MDCT and VB. The role of VB in foreign body aspiration is well documented in the literature. In a recent study by Adaletli et al. (10), there were 82% true positives in VB when compared with bronchoscopy and in another study by Kosucu et al. (15) low dose MDCT and VB picked up all foreign bodies and all of them were true positives.

Although MDCT-VB has high sensitivity and specificity in picking up the endobronchial lesion, it is not highly specific for characterizing the lesion. In our study, in the absence of definite history, MDCT-VB was not able to differentiate between mucus plugs and foreign body in 13 cases. In our study, we did not find any significant differentiating feature radiologically between foreign body and mucus plugs as reported by the previous studies (4,10,13). So in a given case of endobronchial lesion causing obstruction in a child foreign body, mucus plugs, granuloma and soft tissue mass should be considered as differential diagnosis (10).

We did not encounter any false positive or negative in cases causing extrinsic compression of the trachea and bronchus. Although vascular anomalies are common cause of airway obstruction in children, we encountered mediastinal lymphnodes (50% cases) as the most common cause of extrinsic compression in our study. This is probably because of the fact that we see more cases of pulmonary tuberculosis in this part of the world.

In our study, MDCT-VB was helpful in establishing alternate diagnosis in four cases of non-obstructive pathology. Two of them were due to lung hypoplasia while middle lobe syndrome and tracheal bronchus were observed in one patient each.

There are few limitations in our study. The number of cases is less. We did not encounter cases of functional air-way obstruction like tracheobronchomalacia, which usually cannot be diagnosed on routine MDCT-VB (16). Further, the paediatric surgeon/pulmonologist performing the bronchoscopy was aware of the MDCT-VB findings, indicating a probable bias. But this was important, considering the patient management in mind.

In conclusion, MDCT-VB is a non-invasive method for evaluation of both endoluminal and extrinsic compression of the tracheo bronchial tree in children. It has high sensitivity in evaluating both endoluminal and extrinsic pathologies involving the airway. However, it is not specific and does not indicate the aetiology/cause of obstruction.

References