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ORIGINAL ARTICLE

Utility of 64-row MDCT in assessment of neonates with congenital EA and distal TEF

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KEYWORDS

MDCT;
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Abstract *Introduction:* Esophageal atresia (EA), with or without trachea-esophageal fistula (TEF), is one of the most challenging congenital anomalies in neonates, due to its high morbidity and mortality. The anatomy of the EA should be clearly known before surgery because the surgical approach of congenital EA with distal TEF depends on the correct evaluation of the trachea–bronchial tree and the distance between the proximal pouch and distal fistula.

Aim: To evaluate the application of multiple planar reformatting (MPR) and three-dimensional (3D) transparency lung volume rendering (TL-VR) with virtual tracheo-bronchoscopy by 64-row multidetector computed tomography (MDCT) in neonates with congenital EA and distal TEF.

Methods: Twenty-three neonates (10 boys and 13 girls) born with EA and distal TEF were enrolled in this study. All patients were preoperatively examined by 64 multidetector non-enhanced CT examinations with multiplanar reformatting, 3D volume rendering TLVR and virtual endoscopy. The MDCT findings were correlated with operative findings in 19 cases.

Results: MDCT could detect the proximal esophageal pouches, gap distance in all patients. The gap distances ranged from 7 mm to 38 mm (mean 18 mm). The gap distances by MDCT were the same of surgical findings in 14 cases and less than surgical findings by 1–2 mm in 5 cases. No statistically significant difference was detected between the two measurements, $P = 0.908$. The site of the fistula was seen by the axial images in 23 patients, followed by sagittal MPR and 3D TL-VR (20 patients), coronal MPR images in 18 patients while the virtual tracheo-bronchoscopy showed the site of the fistula in 16 patients. The most common site of distal fistula in this study was main trachea in 10 of 23 neonates (43.5%).

Conclusion: Preoperative MDCT scan with MPVR, 3D TL-VR of 64-row MDCT which is a noninvasive technique could provide more accurate information about the assessment of the

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origin of the fistula, the distal esophageal pouches and inter-pouch distance in neonates with EA and distal TEF.

1. Introduction

In neonates, esophageal atresia (EA), with or without tracheaesophageal fistula (TEF), is one of the most challenging congenital anomalies for pediatric surgeons because of its high morbidity and mortality (1).

In EA the proximal and distal portions of the esophagus do not communicate. The upper segment of the esophagus is a blind-ending pouch while the distal esophageal portion is an atretic pouch small in diameter with a thin muscular wall. It extends to a variable distance above the diaphragm. TEF is an abnormal communication between the trachea and distal esophagus. When associated with EA, the fistula most commonly occurs between the distal esophageal segment and the trachea, just above the carina (1) (Fig. 1). The reported incidence of EA and TEF is one in 3000–4500 live births (2,3).

EA and TEF should be suspected if a newborn is noted to have inability to swallow food and saliva or transient cyanosis shortly after birth. On the other hand, infants may present with a sudden onset of respiratory distress following attempts at feeding due to aspiration. Diagnosis can be confirmed by failure of passage of the nasogastric tube with the feeling of distal resistance at the blind end of the upper esophageal pouch (2,3).

The first diagnostic steps in patients presenting with symptoms suggestive of TEF are antero-posterior and lateral chest radiography; that can confirm the location of the catheter in the blind esophageal pouch and it shows the pouch length. The presence of gastric or intestinal gas bubbles confirms the distal TEF (4,5) (Fig. 2).

Radiographic contrast studies can evaluate the proximal esophageal pouch and also to look for the rare proximal fistula; however, it cannot evaluate the atresia gap distance or the site of distal fistula (Fig. 3). Moreover, this procedure requires a high degree of pediatric radiology expertise, and it has radiation hazards and may be associated with complications including aspiration pneumonia (6).

Furthermore, the esophagogram can give false negative results when the fistula is occluded by mucus or false positive results when the contrast passes through the tracheobronchial tree which is more likely to be aspirated through the larynx rather than through a proximal TEF (6,7).

Some studies recommend the routine use of bronchoscopy just before the corrective surgery for patients with EA and distal TEF to show the anomalies of the trachea–bronchial tree and locate the orifice of the distal fistula reference. In neonates bronchoscopy has well-known limitations. Rigid bronchoscopy requires general anesthesia. Both flexible and rigid bronchoscopy may cause several complications including hypoxia, laryngospasm, pneumothorax, and airway edema and bleeding (3).

On the other side, MDCT with three-dimensional (3D) imaging and recently developed virtual bronchoscopy is a noninvasive technique that provides realistic 3D views of the tracheobronchial tree (8). The display of Virtual bronchoscopy images increases the confidence of clinicians in CT results (9). Three-dimensional imaging of the tracheobronchial system

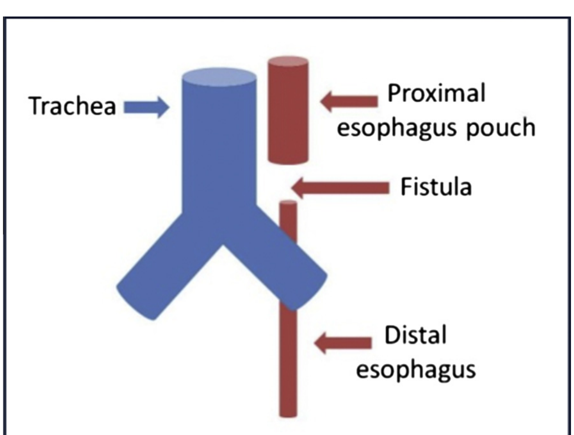

Fig. 1 Diagram showing the anatomy of the EA with the distal TEF.

Fig. 2 Frontal plain radiography shows kinking nasogastric tube within the proximal esophageal pouch (arrow) with esophageal atresia and the gastric gas bubble (arrow head) indicates the presence of distal tracheoesophageal fistula.

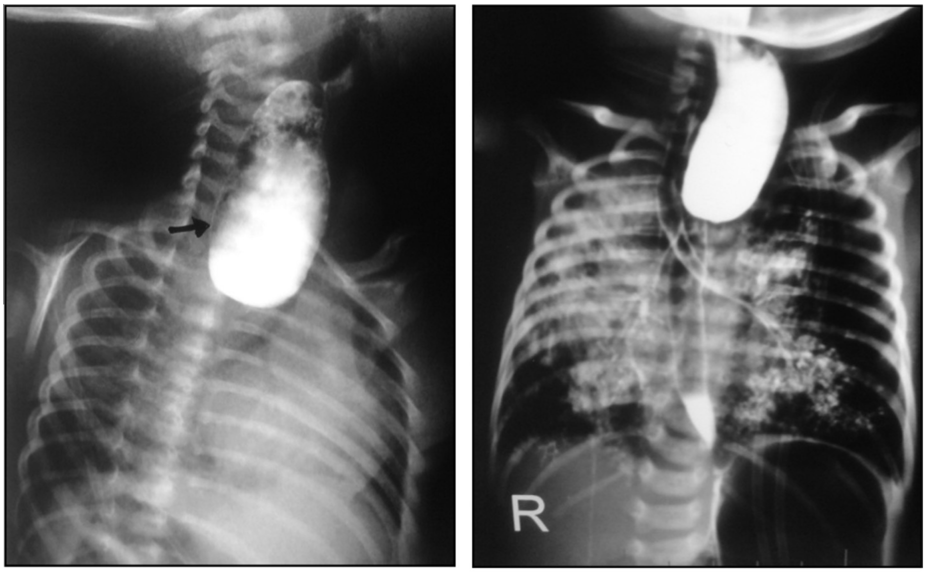

Fig. 3 Frontal radiography with contrast study for TEF patient shows proximal esophageal pouch arrow in (a) and aspiration of contrast within trachea and bronchial tree in (b).

is well established in adults, but experience with pediatric patients is limited (5,10).

Surgical approach of congenital EA with distal TEF depends on a correct evaluation of the tracheobronchial tree and the distance between proximal pouch and distal fistula. The site of entry of the lower fistula into the tracheobronchial tree is variable; it may enter at any point from 2 cm above the carina to the proximal centimeter of either bronchus. The most common site, however, is 0.5–1 cm above the carina (3).

Depending on the size of gap between esophageal ends, EA is divided into short-gap and long-gap EA. The latter, accounting for 10–31% of EA cases, is described by a significant gap between the esophageal ends, making repair more complicated. The gap length not only determines the type of surgical management, but also is a prognostic indicator of mortality and morbidity in EA patients irrespective of the neonate's size (11,12).

Primary anastomosis is feasible for patients with short-gap atresia (length $\leqslant 2$ cm), whereas either delayed primary anastomosis or esophageal replacement may be required for patients with long or ultra long gaps (length > 2 or 3.5 cm). Therefore, the anatomy of the esophageal atresia should be known before surgery. Although a few investigators had emphasized the advantages of preoperative CT scan in patients with EA–TEF, which defined the anatomy of the fistula and the inter-pouch distance, this procedure is still not used routinely in the diagnostic approach in many neonatal surgical centers (12–14).

2. Aim of the work

The aim of the work was to evaluate the application of multiple planar reformatting (MPR) and three-dimensional (3D) transparency lung volume rendering (TL-VR) with virtual endoscopy by 64-row multidetector computed tomography (MDCT) in neonates with congenital EA and distal TEF.

3. Patients and methods

3.1. Patients

Twenty-three neonates (10 boys and 13 girls), all with EA and distal TEF, were enrolled in this study at Assiut University Hospitals in the period from July 2011 to February 2014. Patients' birth weights ranged from 1750 to 3100 g (mean 2170 g). Mean gestational age was 36.5 weeks (range, 34–39 weeks). Their age at the time of MDCT scan was 2–20 days after birth.

All patients had different degrees of respiratory distress and were not able to swallow fluids and saliva. Initial diagnosis was expected according to their clinical symptoms and chest radiography showing the inserted catheter in the proximal blind-ended esophageal pouch and intestinal gas in the upper abdomen. This study was approved by the Faculty of Medicine, Assiut University local Ethics Committee; written informed consent was obtained from parents of patients.

3.2. Procedures and techniques

All neonates were subjected to preoperative non-contrast MDCT examination before surgery using 64-row MDCT scanner (Aquilion 64, Toshiba Medical system). No sedatives were used to avoid respiratory distress. Neonates were examined in supine position with head first and scanned from the level of larynx down to diaphragm. Body straps were used to immobilize the patients and decrease the motion artifacts. Light upper abdomen compression was applied to pouch gastric gas toward the distal esophageal segment to open up the fistulous connection with the trachea. Images were reconstructed in the axial plane at a 0.5 mm interval with a standard reconstruction algorithm. Automated anatomic tube current modulation was used.

CT images were transferred to an independent workstation (Vitrea workstation) "Vitrea® 2; Version 3.9" for further image reconstruction. Chest multi-planar volume rendering (MPVR) images were collected at the axial, sagittal and coronal views, 3D transparency lung volume rendering (TLVR) models of the tracheobronchial system and the esophagus, and virtual trachobronchoscopy (flythrough method) were used for evaluation of the tracheobronchial system, EA, TEF and inter-pouch gap distance. The total image processing time in each patient was 20–30 min.

After MDCT scan, 19 patients out of the 23 patients studied were subjected to surgery within 24 h (average 19 h), and the other 4 patients were excluded from surgical intervention due to associated congenital heart anomalies and poor general condition of the patients at presentations.

Intra-operatively a silk thread between two artery forceps was used to define the gap between the lower most limit of the upper pouch and the highest point of the lower esophageal pouch. This distance, in centimeters, was measured with a ruler. Findings of MDCT images were compared with the findings at surgery.

3.3. Image analysis

MDCT findings were recorded by two consultant radiologists with experience in pediatric radiology and pediatric computed tomography. Data interpretation was based on the examination of the entire set of images.

3.4. Statistical analysis

Descriptive statistical analysis was done with IBM SPSS Statistics software release 21; SPSS Inc. for windows (Microsoft).

4. Results

By using MDCT, the proximal esophageal pouches were detected in axial, sagittal, coronal and TLVR images in all patents. The gap distance represented the atretic esophageal segment could be detected in all patients by axial, sagittal, coronal and 3D TLVR images. The gap distances ranged from 7 mm to 38 mm (mean 18 mm). Gaps were short gap $\leqslant$ 20 mm in 14 patients and long gap > 20 mm in 9 patients.

The gap distances by MDCT were the same of surgical findings in 14 cases and less than surgical findings by 1–2 mm in 5 cases. No statistically significant difference was detected between the two measurements, $P = 0.908$ (Table 1).

The site of the fistula was detected by the axial images (in all the twenty-three patients), followed by sagittal MPR and 3D TL-VR (20 patients), coronal MPR images in 18 patients while the site of the fistula was revealed in virtual tracheo-bronchoscopy in 16 patients (Table 2 and Figs. 4–6).

The distal esophageal segment was connected with the main trachea in 10 patients, with left main bronchus in 6 patients, it connects with right main bronchus in 4 patients and the distal esophageal segment connected with tracheal bifurcation (carina) in the remaining 3 patients (Table 3 and Figs. 4–6).

Table 1 Comparison of gap distance, measured by CT with that measured at surgery in 19 patients with EA and distal TEF.

	CT	Surgery	*P*-value
Mean ± SD	17.74 ± 7.13	18.05 ± 7.5	0.908[a]
Range	7–30 mm	7–32 mm	

[a] Wilcoxon signed ranks test.

Table 2 The difference in the rate of detection of fistula orifice by different MDCT image planes.

MDCT Images	Number of patients
Axial images	23(100%)
Sagittal MPR images	20(86.9%)
3D TLVR	20(86.9%)
Coronal MPR images	18(78.2%)
Virtual trachobronchoscopy	16(69.5%)

Varying degrees of aspiration pneumonia with pneumonic consolidations were seen in 21 patients. Eighteen patients had right upper and right middle lung lobe pneumonia while three patients had bilateral lung lobes pneumonia and two patients had normal lungs. Three patients had dextrocardia and one patient had bronchomalacia involving the right main bronchus.

5. Discussion

With the use of MDCT, Volume Rendered images of the trachea and esophagus can be quickly and noninvasively generated. They provide better delineation of the anatomy and 3D relation between the two structures more clearly and accurately, and provide valuable guidance for surgical approach to cases of congenital EA with distal TEF.

In the present study the MDCT was done 2–20 days after birth. This delay in performing MDCT was due to the late referral from hospitals far from Assiut University Hospital, which is the main referral center in Upper Egypt. Other patients needed longer time for preparation to CT exam due to their bad general condition.

All anatomic structures of EA with the distal TEF were visualized using MDCT. The axial image was the best imaging plane for detection of the distal fistula and their orifice where this plane showed the EA and TEF in all the 23 patients. The second best planes were the sagittal MPR and 3D TL-VR (detected the lesions in 20 patients) followed by the coronal MPR images (detected the lesions in 18 patients) while the virtual tracheo-bronchoscopy showed the site of the fistula in 16 patients. In the study by Wen et al. (12), MPVR showed the distal fistulae and their orifice in 13 cases out of 20 patients studied, whereas TL-VR revealed the fistulae and their orifice in only 4 cases. In contradiction to the present study, the study by Tam (15) mentioned that axial images can be difficult to interpret; a fistula may be demonstrated only partially or missed and his study mentioned that direct Sagittal CT has been used in newborns to accurately diagnose EA and TEF, enabling visualization of the entire length of the esophagus, complete with atresias, fistulas, and gap length. The better detection of site of fistula by axial images in this study can

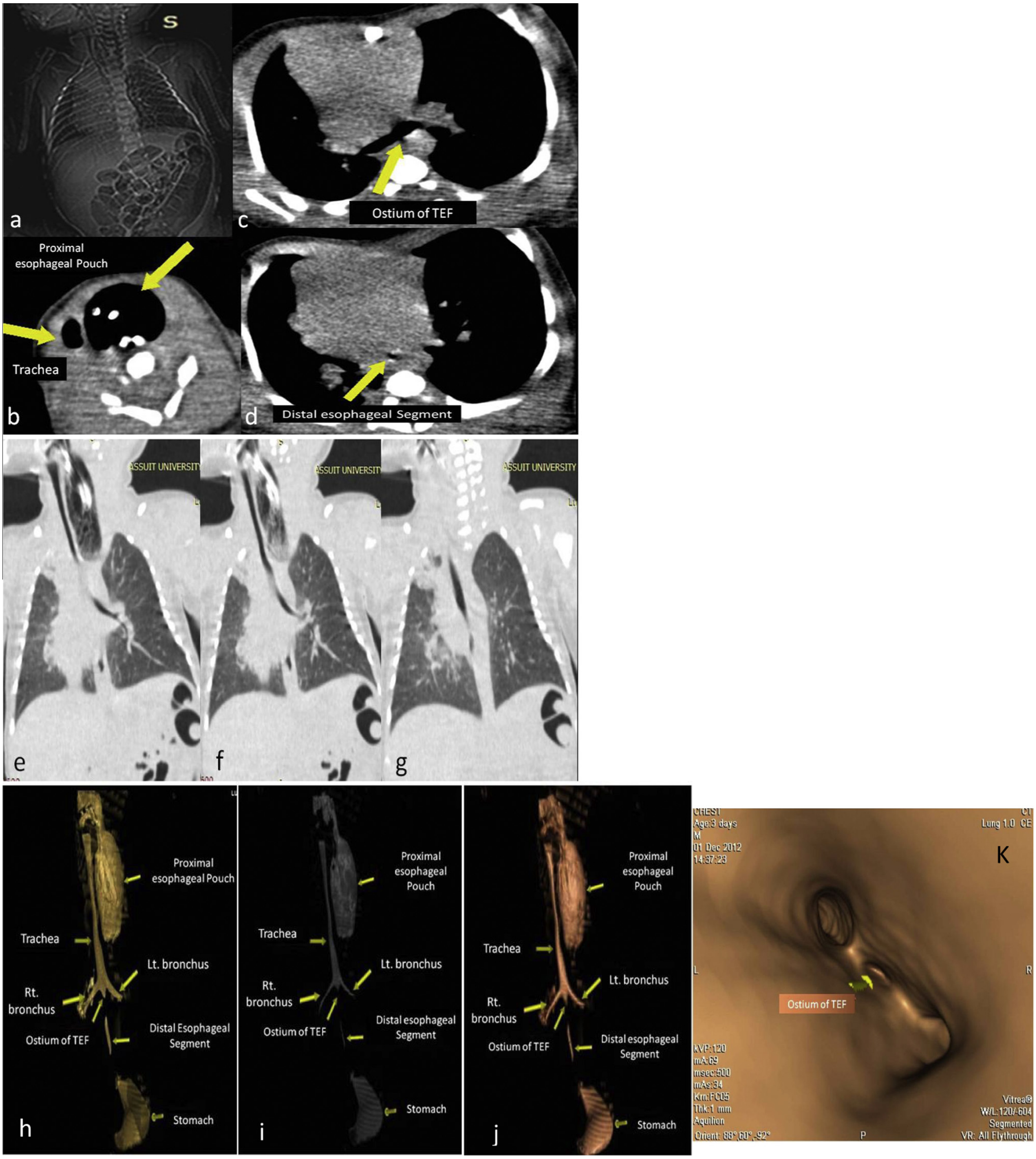

Fig. 4 (a) Chest X-ray view revealed proximal esophagus pouch containing kinking nasogastric tube with gas shadows within intestine suggesting type C TEF, (b–d) non-contrast Axial image of TEF, (b) proximal esophagus pouch with kinking nasogastric tube inside it, (c) orifice of TOF connected with the trachea bifurcation and (d) distal esophageal pouch, (e–g) coronal reformatting shows proximal esophagus pouch and distal segment connected with carina, (h–j) 3D TRVR shows proximal esophagus pouch and distal esophagus segment connected with carina, and (k) virtual CT tracheo-bronchoscope revealed ostium of TEF within the trachea bifurcation (carina).

be explained by the use of 64 MDCT that provides high resolution images than the older versions of CT scanners used in the study by Tam (15).

Virtual bronchoscopy is a noninvasive technique that provides realistic 3D views of the tracheobronchial tree. In this study virtual tracheo-bronchoscopy showed the site of the fistula in 16 patients, and this is lower than other imaging planes (Axial, MPR and 3D TL–VL). This may be explained by the early experience with the virtual endoscopy in pediatrics. Other

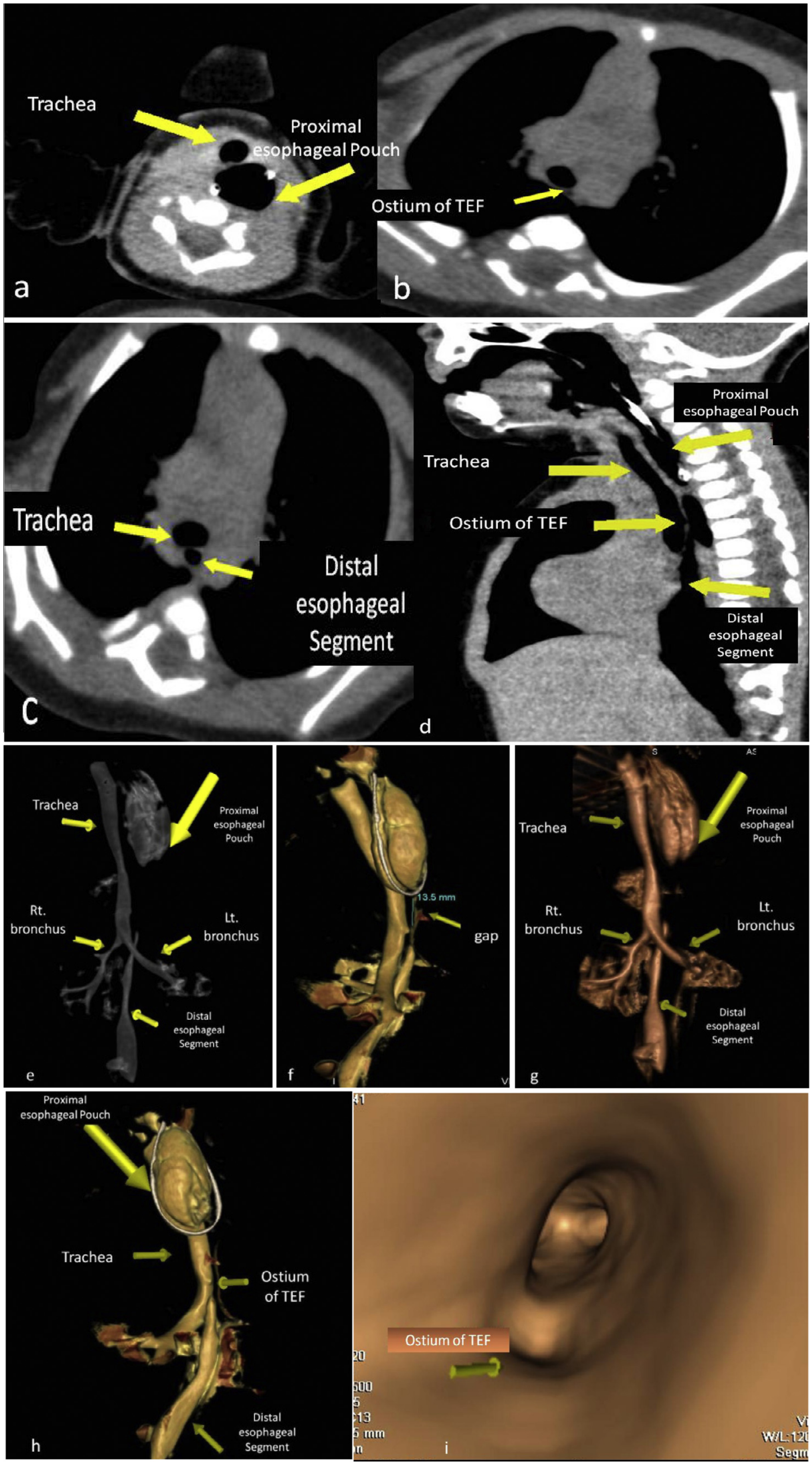

Fig. 5 (a–c) Axial images, (d) sagittal image, (e–h) 3D TLVR revealed TEF type with proximal esophageal pouch, gap (esophagus atresia) 13.5 mm in length and distal esophagus opening with posterior aspect of distal trachea and (i) virtual CT tracheo-bronchoscope revealed orifice of TEF within the posterior aspect of distal trachea proximal to its bifurcation.

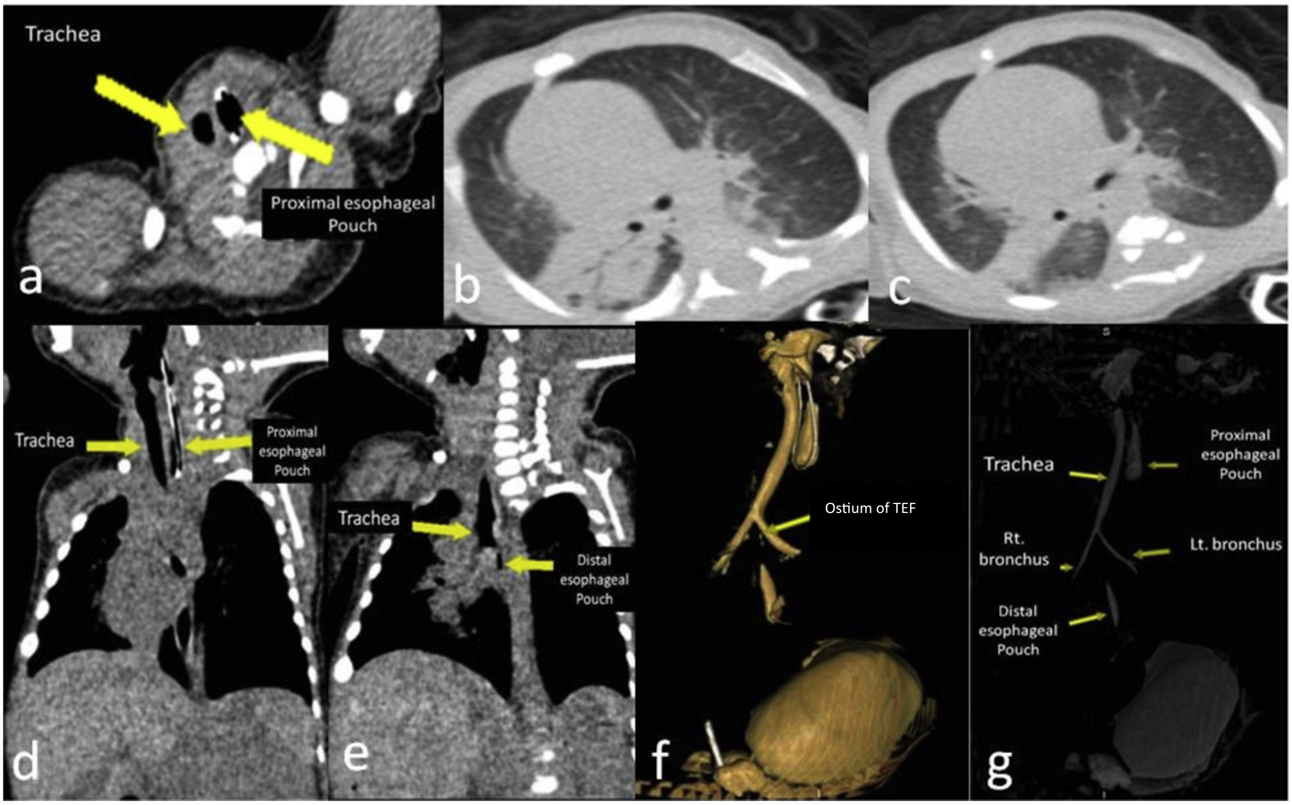

Fig. 6 (a–c) Non-contrast axial image of TEF, (a) proximal esophagus pouch with coiling nasogastric tube inside it, (b) ostium of TEF connected with left bronchus and (c) distal esophageal pouch. (d–e) Coronal reformatting shows proximal esophagus pouch and distal segment connected with left bronchus. (f–g) 3D reformatting shows proximal esophagus pouch and distal esophagus segment connected with left bronchus.

Table 3 Site of fistula in 23 neonates with TEF.

Site of fistula	Number of patients
Main trachea	10(43.5%)
Left main bronchus	6(26.1%)
Right main bronchus	4(17.4%)
Carina	3(13%)
Total	23(100%)

studies showed the limited experience of the use of MDCT in pediatrics as well (5,10).

MPR images, 3D TL–VL and virtual tracheo-bronchoscopy did not add important diagnostic data over thin axial images, but had important confirmatory role and had been facilitated the visualization of the complex anatomic features of EA and TEF by the surgeon, enabling a better orientation before surgery. The same results were achieved by other studies (3,16,17).

The most common site of distal fistula in this study was main trachea in 10 of 23 neonates (43.5%), similar to previous studies and the same results were achieved in a study by Su et al. (14).

No statistically significant difference in the distance between the lower end of proximal esophageal pouch to the highest point of the lower esophageal pouch as measured by MDCT and at surgery in the operated cases. The gap distances by MDCT were the same of surgical findings in 14 cases and less than surgical findings by 1–2 mm in 5 cases. Same findings were reported in other studies (3,5,14,18). In contradiction to our study and the aforementioned studies, the study by Wen et al. (12) reported significant difference between the gap distance measured by CT and that measured at surgery. The authors explain this difference due to (12) the injection of 5 ml air into the proximal esophageal pouch through the catheter in order to demonstrate the pouch, which could be the cause, as air extended the proximal pouch and could be the cause of shortening the inter-pouch distance. In our study and other studies, CT data correspond well with the findings at surgery with no gas injected into the proximal esophageal pouch (3,5,14,18).

In a study by Fitoz et al. (3), zigzag artifacts occurred in most patients because of motion and respiration as the data were obtained using Helical CT; however, these artifacts did not interfere with their visualization of the orifice of the distal fistula. In this study we used 64 MDCT in evaluation of EA and distal TEF, and this markedly reduced the zigzag artifacts result from cardiac and respiratory motion.

Previous studies discussed the radiation dose and its importance in neonates and pediatrics and considered radiation dose very important issue in pediatrics. It is well established that the lifetime cancer mortality risk attributable to CT examinations is considerably higher than in adults and although a modern CT gives low grade exposure, this examination is still associated with radiation hazards (19,20). In this study we used automated anatomic modulation software and neonate application with selection of appropriate scanning parameters to significantly minimize radiation dose to the minimum.

The aim of this study was to focus on visualization of the esophageal pouch and distal fistula and comparison of the gap distance between the proximal pouch and distal fistula by MDCT and surgery. Details of operative procedures and follow-up of patients were not discussed.

6. Conclusion

MDCT is rapid, noninvasive examination that plays a complementary role in diagnosis of congenital EA and distal TEF. In MDCT examinations, sedations and hazards of contrast radiography are avoided. Preoperative MDCT scan provide more accurate information about the origin of the fistula and the inter-pouch distance in EA with distal TEF. This information is essential for better orientation in planning the surgical strategy.

Conflict of interest

The authors declare that there are no conflicts of interest.

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