0.1 mg/kg body weight was used for sedation. Non-contrast sections were obtained, followed by injection of intra-venous contrast at a dose of 2 ml/kg body weight, at the rate of 2.5 ml per second at a pressure of 150 to 175 psi followed by 5ml saline flush using a dual head medrad pressure injector. The contrast used was iodixanol 270 mg/ml. Using bolus tracking method, arterial phase images were acquired when pulmonary attenuation crossed 120HU and venous phase following a delay of 20 seconds.

Discussion

Based on classification proposed by Freitag airway narrowing can be grouped under structural and dynamic causes [5]. Structural narrowing of airway may be due to intraluminal lesions, extrinsic compression or narrowing due to airway kinking or scarring. Dynamic or functional airway narrowing refers to triangular or tent
shaped airway due to damaged cartilage and inward bulging of the floppy posterior membrane.

The degree of airway narrowing is graded as grade 0 when there is no narrowing, grade I when there is less than 25% narrowing, grade II when there is 26 – 50% narrowing, grade III when there is 51 – 75% narrowing, grade IV when there is 76 – 90% narrowing and grade V when there is 91 – 100% narrowing.

The location of the airway narrowing may be in upper, middle and lower thirds of trachea or in right or left main bronchus.

Symptoms of airway compression are variable and may range from dysphagia, recurrent respiratory infections and stridor to acute respiratory distress to death [6]. In older children symptoms such as discomfort in chest, dyspnoea, cough and wheezing are often wrongly diagnosed as asthma [7]. Affected children may require mechanical ventilation and some may remain ventilator dependent even after surgery.

During embryonic development, six pairs of aortic arches connect the two primitive ventral and dorsal aortae [8]. The first,
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Figure 3: CTA a. axial image showing a defect in inter-atrial septum (blue arrow). b. sagittal & c. VR image showing common origin of aorta and left pulmonary artery (blue arrows). d. VR image showing the duct dependent origin of the right pulmonary artery (blue arrow) and aortic arch on the right side of the trachea. e., f. VR & g. axial images showing left subclavian artery (blue arrows) arising as the last branch of right sided aortic arch and taking a retroesophageal course and forming an incomplete vascular ring. h. VR image showing the left subclavian artery causing mild tracheal compression.

Figure 4: CTA a. axial, b. coronal c. & d. VR images showing right subclavian artery (blue arrows) which is arising as a last branch of left sided aortic arch and taking a retroesophageal course. The left vertebral and left subclavian arteries are seen to originate separately from arch of aorta. e. MIP image showing minimally compressed trachea. f. VR image showing associated congenital scoliosis.

Figure 5: CTA a. axial image showing mediastinal shift towards right with hypertrophy of right atrium and right ventricle and non-visualization of right sided pulmonary vasculature. b. axial & c. VR images showing left pulmonary artery (blue arrow) forming a sling around the trachea (white arrow). d. & e. VR images showing right sided aortic arch and descending aorta with right brachiocephalic artery (white arrow) causing compression of trachea. f. VR image showing tracheal narrowing (blue arrow).
Figure 6: CTA a. axial image showing a defect in inter-ventricular septum b. axial image showing stenosis of main pulmonary artery (white arrow). c. axial image showing dilated right pulmonary artery (blue arrow) compressing the right main bronchus (white arrow). d., e. MIP & f. VR images showing compression of right main bronchus by dilated right pulmonary artery (white arrow).

Figure 7: CTA a. axial image showing VSD. b & c. axial and coronal images showing aneurismal dilatation of right pulmonary artery. d. coronal VR image showing narrowing of right main bronchus.

Table 1: Demographic, imaging and treatment data of the patients who were included in the study.

<table>
<thead>
<tr>
<th>N</th>
<th>Age</th>
<th>Sex</th>
<th>Symptoms</th>
<th>Level of airway compression</th>
<th>Grade of compression</th>
<th>Cause of compression</th>
<th>Cardiovascular anomalies</th>
<th>Other findings</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 y</td>
<td>F</td>
<td>Cyanosis, Respiratory distress</td>
<td>Mid 3rd trachea</td>
<td>II</td>
<td>DAA</td>
<td>VSD, Infundibular PS, PDA, DAA with hypoplastic RAA(Figure 1)</td>
<td>None</td>
<td>Resection of minor arch</td>
</tr>
<tr>
<td>2</td>
<td>2 m</td>
<td>M</td>
<td>Respiratory distress</td>
<td>Lower 3rd trachea</td>
<td>III</td>
<td>DAA</td>
<td>DAA with mirror image branching (Figure 2)</td>
<td>Consolidation</td>
<td>Division of right arch</td>
</tr>
<tr>
<td>3</td>
<td>11 d</td>
<td>F</td>
<td>Cyanosis</td>
<td>Mid 3rd trachea</td>
<td>II</td>
<td>RAA and aberrant LSCA</td>
<td>ASD,TA,PDA,RRA, aberrant LSCA (Figure 3)</td>
<td>Consolidation</td>
<td>Correction of underlying CHD</td>
</tr>
<tr>
<td>4</td>
<td>10 y</td>
<td>F</td>
<td>Palpitation</td>
<td>Lower 3rd trachea</td>
<td>I</td>
<td>Aberrant RSCA</td>
<td>Aberrant RSCA (Figure 4)</td>
<td>Scoliosis</td>
<td>Conservative management.</td>
</tr>
<tr>
<td>5</td>
<td>5 m</td>
<td>F</td>
<td>Respiratory distress</td>
<td>LMB and upper 3rd trachea</td>
<td>IV, I</td>
<td>LPA sling, innominate artery RAA and absent pulmonary vessels on the right (Figure 5)</td>
<td>Rt lung hypogenesis</td>
<td>Trachea- left bronchial repair &amp; reanastomosis.</td>
<td></td>
</tr>
</tbody>
</table>

second, and fifth arches regress. The third arches become the carotid arteries. A branch from the ventral bud of the sixth arch meets the lung bud to form the pulmonary artery. On the right side, the dorsal contribution to the sixth arch disappears; on the left, it persists as the ductus arteriosus. The seventh intersegmental arteries arise from the dorsal aorta and form the subclavian arteries. Normally, a portion of the right fourth arch regresses, leaving only left aortic arch.

Airway compression by aorta and its branches

A vascular ring refers to an encirclement of the trachea by an abnormal combination of derivatives of the aortic arches. The common vascular rings are double aortic arch, right arch with aberrant left subclavian artery [9]. A left arch with aberrant right subclavian artery is a less common cause of tracheal compression. Aberrant right subclavian artery sometimes takes origin from a diverticulum arising from the descending aorta, called the Kommerell diverticulum. Rarely aneurysms can be seen in Kommerell diverticulum [10]. Persistence of both right and left fourth arches leads to a double aortic arch formation. One of the arches may be atretic or both the arches may be patent. The trachea is encircled and compressed by the two arches which form a vascular ring. The ring may be patent as in double aortic arch or it may be completed by an atretic arch or ligamentum arteriosum as in right-sided aortic arch with aberrant left subclavian artery [11]. Surgical division of the ring formed by double aortic arches is indicated in patients with symptomatic airway compression and in patients undergoing surgery for repair of associated cardiovascular or thoracic anomalies. This is achieved by dividing the minor arch through an ipsilateral thoracotomy. When the minor arch is atretic, the atretic segment is ligated and divided. When the minor arch is patent, it is usually ligated and divided between the subclavian artery and descending aorta. Aberrant right subclavian artery is repaired by ligating and dividing it at its origin from aorta and reimplanting it to the right common carotid artery [12]. The standard procedure for vascular ring formed by right aortic arch and aberrant left subclavian artery is division of ligamentum arteriosum. Primary translocation of the aberrant left subclavian artery to the left carotid artery with removal of the Kommerell diverticulum is also practiced [13].

Airway compression by pulmonary artery

Pulmonary sling refers to a less common cause of airway compression. Pulmonary artery sling refers to anomalous or aberrant left pulmonary artery causing anterior tracheal displacement [14]. It occurs due to failure of formation of left sixth aortic arch. The term sling is usually applicable when the proximal portion of the abnormal vessel impinges on the right main bronchus causing obstructive emphysema of the entire right lung or the right middle and lower lobes, depending on the site of the compression. Dilated pulmonary arteries can also cause bronchial compression as seen in our cases. Pulmonary sling can be repaired by dividing the left pulmonary artery and translocating and reimplanting it anterior to the airway. The second option consists of resection and anastomosis of the stenosed airway along with reimplantation of left pulmonary artery [15]. Repair of the underlying congenital heart disease with repair of stenotic pulmonary artery will normally relieve the symptoms caused by post stenotic dilatation of right or left pulmonary artery. Otherwise the bronchial compression can be treated by division of the pulmonary artery and its prolongation by interposition of a conduit [16].

Imaging plays a crucial role in the diagnosis and treatment of vascular compression of the airway in children. MDCT is being increasingly used for the evaluation of children with suspected vascular compression. Other investigations like barium swallow studies and magnetic resonance imaging (MRI) are also used for the diagnosis of these conditions. Echocardiography is essential for the evaluation of normal vascular structures but direct evaluation of airway compression is limited [2]. Though barium swallow is accurate for diagnosis of a vascular ring, it does not delineate the precise anatomy required for surgical planning [6]. MRI is superior to CT in evaluation of cardiac anatomy and physiology. However, MRI studies are usually quite prolonged (>30 min) and may require general anesthesia [7]. Axial MDCT images are generally sufficient to diagnose the type and severity of airway compression, but multiplanar reconstruction and 3D volume rendered images may provide further useful information [17]. The main disadvantage of MDCT is exposure of the patient to ionizing radiation at the age of greatest sensitivity to its carcinogenic effects.

Conclusion

MDCT plays a pivotal role in evaluation of airway compression in patients with CHD. Complete delineation of the anomaly and grading of the stenosis with detailed measurements and virtual surgery can prognosticate the outcome of the surgery.

References

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