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# Techniques of Linear Endobronchial Ultrasound

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## 1. Introduction

Endobronchial ultrasound (EBUS) visualizes structures within and adjacent to the airway (1). Most operators do not follow any standard positions of imaging during EBUS and use the computed tomography scan as a roadmap for imaging of the lymph nodes. A small window angle (50 to 75 degrees) in linear EBUS as compared with linear endoscopic US (130 to 180 degrees) makes visualization of the anatomic ultrasound landmarks difficult with EBUS. For better orientation, it is useful to recognize key anatomic landmarks and their relationship to the airways, apart from observing the position of the probe while performing EBUS. In this section we describe the mediastinal and parabronchial anatomy of different parts of the respiratory tract which is practically important during EBUS.

## 2. The ten commandments of imaging

### 2.1 Instrument and comparison of available scopes

Two types of scopes are available. Broadly the major difference is in the diameter and field of view. The diameter of pentax scope is larger than Olympus scope (7.4 mm vs 6.9 mm.) The field of vision and depth in imaging of the pentax scope is larger (field of vision 75° vs 50°, depth 5 cm vs approximately 2 cm)

### 2.2 Indication of EBUS

The main indications are evaluation of benign and malignant mediastinal lymphadenopathy. The role of linear EBUS for T staging of lung cancer is not yet defined. Limited assessment of M staging and loco regional spread of lung cancer is possible.

### 2.3 Alternative modalities of imaging and tissue sampling

Majority of lymph nodes can be seen by EBUS and EUS both while doing endoscopic imaging. The choice to do FNA by EBUS or EUS rest on the experience of the endosonographer. Some endosonographer are more experienced in EBUS while others are more experienced in EUS. However for persons who are experienced in both it may be difficult to choose between the two for FNAC if both are approachable.

### 2.4 Optimization of the imaging

- a. The ultrasound waves are high frequency sound waves.

- b. Ultrasound beam loses strength of the beam over time or distance travelled and the echoes that return from deeper structures are weak compared to those returning from the close structures. This phenomenon is called attenuation.
- c. Attenuated waves need to be amplified before analysis. The echoes that come from deep within the body are more attenuated and need more amplification to make a smooth image. This is done by Time-Gain Compensation (TGC). The images thus amplified contain echoes of approximately equal strength from all the depths of tissue.
- d. The waves make image. Images have resolution. The ability of the beam to differentiate two objects is called spatial resolution. Higher spatial resolution shows two points as separate while low spatial resolution shows them as a single blurred point.
- e. Resolution has two main dimensions. Analysis along the length is called axial resolution, analysis along the breadth is called lateral resolution.
- f. Axial resolution is determined by the frequency. Axial resolution is most important in determination of quality. High frequency shortens the pulse length and gives a better axial resolution. The frequency is inversely proportional to the penetration depth. At 5 M Hz ultrasound penetrates approximately 6 cm while at 10 M Hz the penetration field of ultrasound is about 3 cm.
- g. Lateral resolution is determined by focal length. Lateral resolution differentiates between two points lying horizontal to the ultrasound beam. It is determined by the width of the Ultrasound beam. Changing focus of the beam to the level of investigation gives optimum lateral resolution at the point of focus.
- h. Image depends on resolution. Changing frequency improves axial resolution while changing the focus improves lateral resolution.

So optimization of image is done by following techniques.

1. Choose the correct frequency
2. Focus the area

## 2.5 Orientation of imaging

The cranial caudal convention for longitudinal abdominal imaging and linear EBUS varies throughout the world. Endosonographers and radiologists all over the world do not yet have a universal convention on the demonstration of images in linear EBUS so far as cranial and caudal is concerned. In UK, USA and France the patient's cranial (head) and caudal (feet) are to the right and left of the screen respectively. In Japan and Germany the direction is reversed. We will follow the cranial to right and caudal to left convention for our presentation.

## 2.6 Providing anaesthesia

Some professionals prefer local anaesthesia for EBUS. Others prefer general anaesthesia.

## 2.7 Position of patient. Supine, left lateral or sitting. To each his own

Most of the conventional bronchoscopist use two hands to manoeuvre the scope. The EBUS operator who hold the echoendoscope in both hands cannot get used to manipulating the knobs of the ultrasound screen. The left lateral position of EBUS allows the operator to intermittently remove the right hand for manipulation of the screen.

## 2.8 Artifacts in imaging

There are two main artifacts during imaging from tracheobronchial tree. The artifacts of cartilage gradually disappear as the scope is advanced more distally into the trachea-bronchial tree. Mirror image artifact is created by vessels.

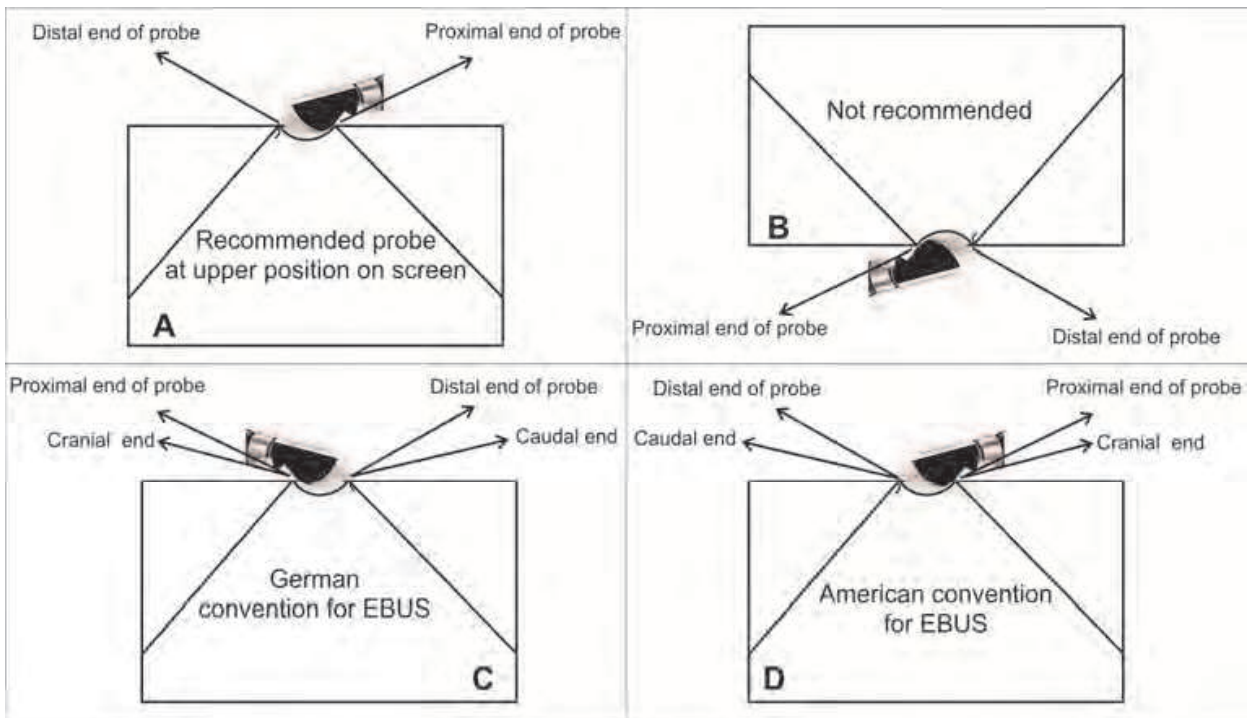


Fig. 1. Fig. A. The standard method of screening for EBUS requires positioning of the probe in the upper part of screen. Fig B. Keeping the probe in the lower part of the screen is generally not recommended Fig. C & D. show the different convention of imaging followed by operators all over the world.

**2.9 Air is the enemy water is the friend**

There are two methods of establishing contact. Simple apposition of the probe against the wall may be enough to establish contact and use of balloon is not usually required with pentax scope. Generally the limited range of imaging 50° vs 75° requires contact with a balloon in Olympus EBUS scope.

**2.10 There are three main movements of echoendoscope**

**2.10.1 In and out movement**

In and out movements are done to position the scope at the desired cm landmark of imaging and is the key movement for changing the position.

**2.10.2 Clockwise or anticlockwise rotation**

In a linear EBUS scope where the imaging is in a longitudinal axis clockwise or anticlockwise rotation is the key movement for changing the view. Rotation changes the field totally in a linear scope only. Rotation alone brings no change in view in a radial EUS scope.

**2.10.3 Angulations of scope, up or down**

Angulations of scope, up or down is required for achieving close contact with the wall of trachea.

3. The CM landmarks in EBUS during imaging from mediastinum

While doing EBUS the operator generally enters the trachea approximately at 15 cm distance from the incisor. The trachea is about 10 cm long so the carina is generally reached when the scope lies at about 25 cm distance. The left bronchus is about 5 cm long and the lower end of left main stem bronchus is reached at an approximate distance of 30 cm. Similarly the 30 cm distance is the lower limit of reach in the right bronchus which includes 2.5 cm of right main stem bronchus and 2.5 cm of intermediate bronchus. The diameter of EBUS scope generally does not allow any further negotiation beyond the reach of intermediate bronchus on the right and left main stem bronchus on the left side. While doing imaging from the respiratory tract an additional cm landmark of importance is upper border of arch of aorta which lies at about 22cm distance. The lower border of arch of aorta lies at about 23 to 24 cm. The lower border of azygos vein and the upper border of left pulmonary artery lie approximately at 25 cm distance.

The trachea lies in front of esophagus which commences at the level of the cricoid cartilage at about 15 cm distance from incisor teeth. For the purpose of description, the esophagus can be divided into cervical (CE) from cricoid to 18 cm, upper thoracic [TE (U)] from 18-25 cm, till approximately the tracheal bifurcation), mid thoracic [TE (M)] from 25-32 cm, till approximately below the subcarinal area and lower thoracic [TE (L)] from 32-38 cm segments. While doing imaging from the trachea certain cm landmark of importance are upper border of arch of aorta (23cm), the lower end of trachea (25 cm), lower border of arch of aorta (25 cm), the lower border of azygos vein (25 cm), the upper border of left pulmonary artery (25 cm) and the upper border of left atrium (30 cm). While pushing the EBUS scope into esophagus the crux of diaphragm is seen at 40 cm.

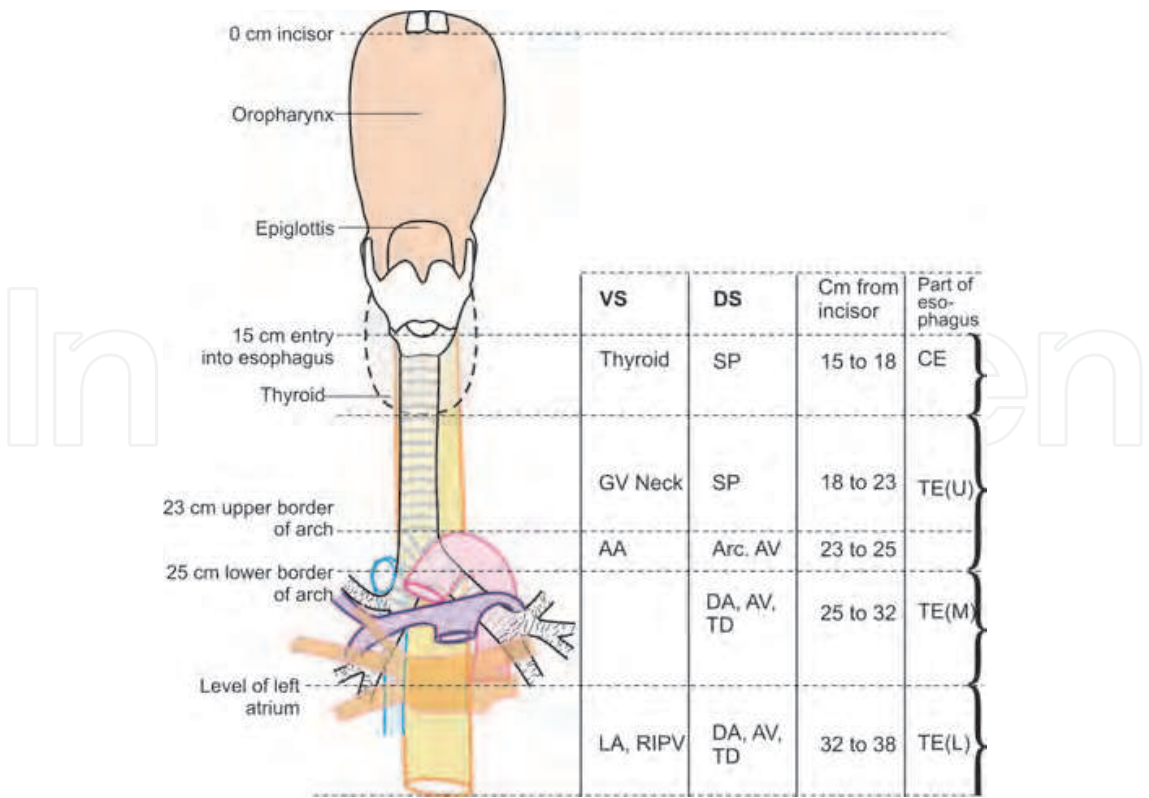


Fig. 2. This figure shows the important CM landmarks while imaging with EBUS scope.

## 4. Applied anatomy of mediastinum

### 4.1 The compartments of mediastinum

It is important to have a brief idea of mediastinum before discussing the mediastinal structures. For descriptive purposes, the mediastinum is arbitrarily subdivided by a transverse plane that passes through the sternal angle and the lower border of the fourth thoracic vertebra. The superior mediastinum is above this plane and is limited superiorly by the superior thoracic aperture; the inferior mediastinum is below the plane, and the diaphragm limits it inferiorly. The inferior mediastinum is further compartmentalized based on its relation to the pericardial sac: the sac and its contents compose the middle mediastinum; between the sac and the sternum is the anterior mediastinum; between the vertebral bodies and the pericardial sac is the posterior mediastinum. The contents of the posterior mediastinum include the esophagus; the descending thoracic aorta and its branches; the veins of the azygos system and the thoracic duct.

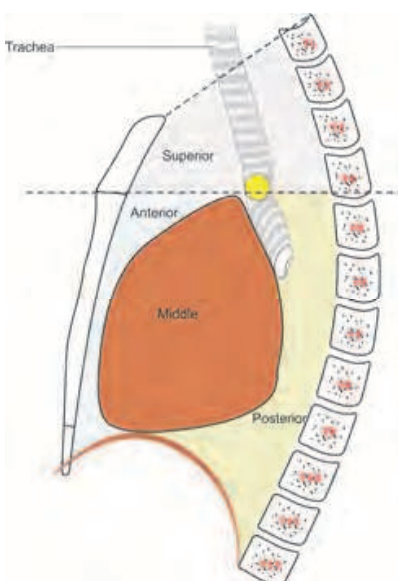


Fig. 3. The compartments of mediastinum are shown.

### 4.2 The trachea

The trachea is about 10 cm long and present from 15 to 25 cm distance from incisor. It is kept patent by a series of cartilages embedded transversely in its wall. The posterior wall of trachea is flat where the ends of cartilage bar are united by trachealis muscle and fibroelastic tissue. This surface is applied to esophagus. The cervical part of trachea is about 3-4 cm in length and is related to lobes of the thyroid gland before it enters superior mediastinum where it lies in midline. The division of the trachea into principal bronchi takes place behind the ascending aorta, to the right of, and below, the arch of the aorta, approximately at the level of sternal angle (level of fourth thoracic spine). The lower end of the trachea is displaced slightly to the right of the midline by the arch of the aorta, which occupies the angle between the trachea and the left bronchus.

On the right, the superior lobar bronchus branches off the principal bronchus before the later enters the hilum. The remaining main stem intermediate bronchus, gives off, more distally, the middle lobe bronchus, which runs forward and downward. The intermediate bronchus continues as inferior lobar bronchus. The left principal bronchus gives off the

superior lobar bronchus as soon as it has entered the hilum, and the remaining main stem becomes the bronchus of the inferior lobe.

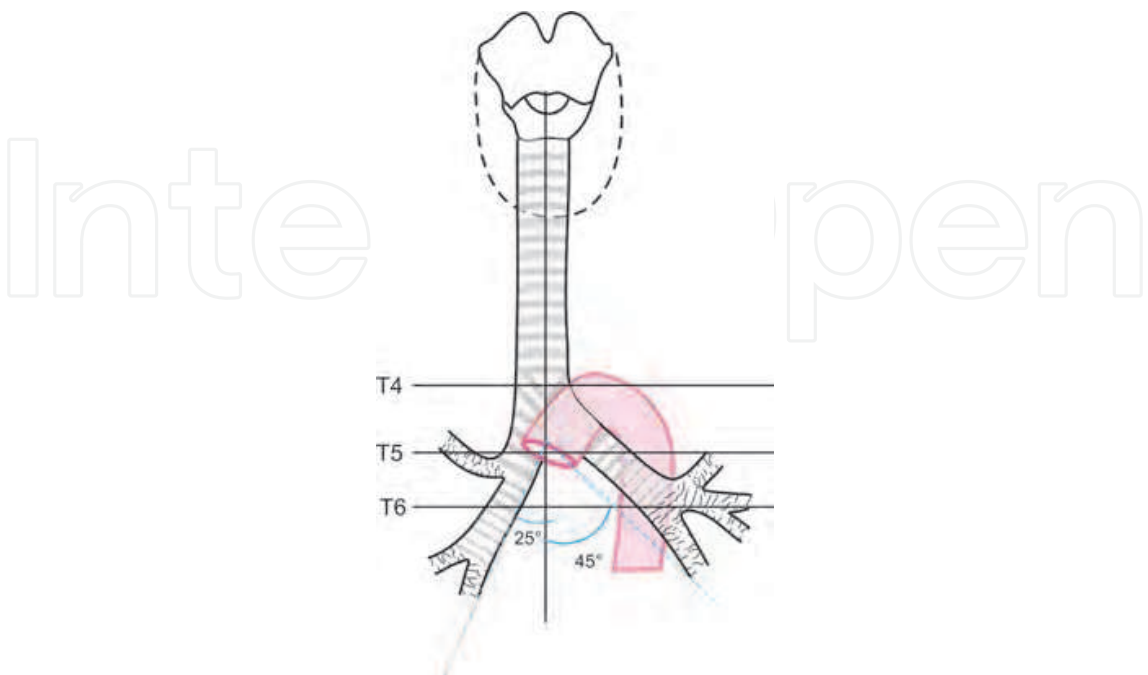


Fig. 4. The right principal bronchus is wider, shorter (about 2.5 cm) and more vertical than the left, leaves the trachea at an angle of about 25° and enters the right lung opposite the T5 vertebra. The left principal bronchus is narrower and more transverse than the right, leaves the trachea at an angle of about 45°, is nearly 5 cm long and enters the root of the left lung opposite the T6 vertebra.

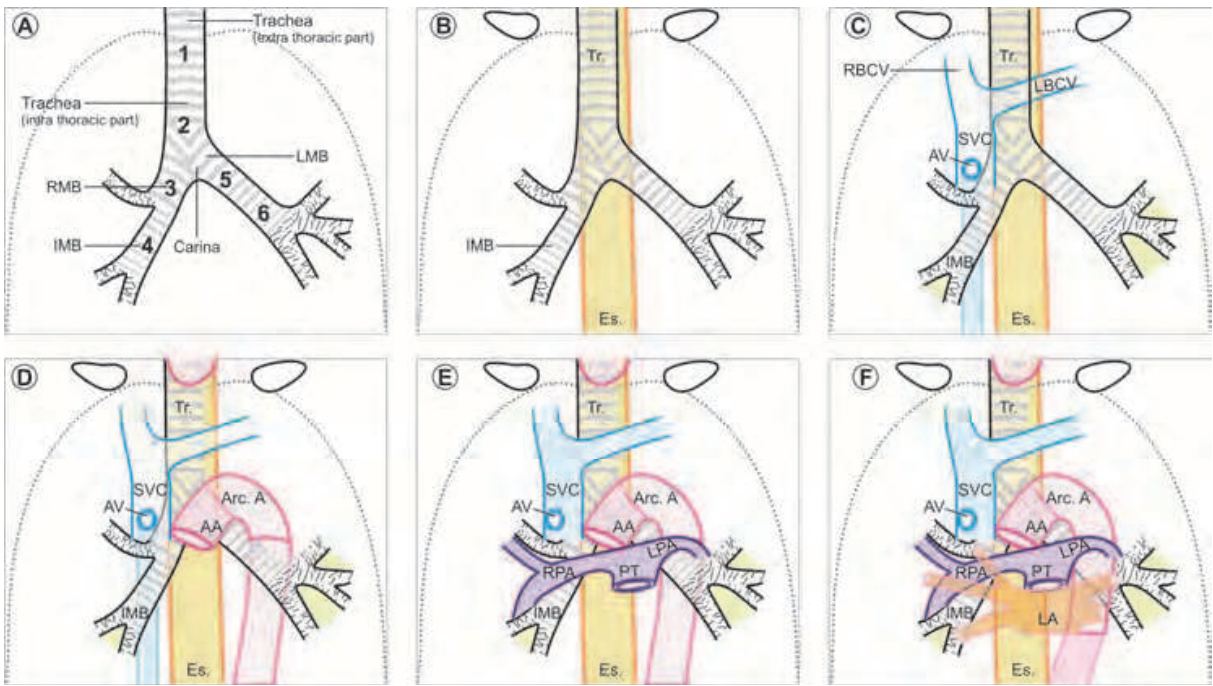


Fig. 5. The relationship of trachea to esophagus and paratracheal vascular structures

The figure 5 A shows six different positions (which will be discussed in later part of chapter) of imaging by Endobronchial ultrasound. 1 Imaging from the upper trachea, 2. Imaging from the lower trachea, 3. Imaging from the right main bronchus, 4. Imaging from Intermediate bronchus, 5. Imaging from upper part of left bronchus, 6. Imaging from the distal part of left bronchus. **Fig. B. to F** shows the relationship of parabronchial & vascular structures to trachea. **Fig. B** relationship of tracheobronchial tree to esophagus. **Fig. C.** relationship of tracheobronchial tree to azygos vein and superior vena cava. **Fig. D.** relationship of tracheobronchial tree to arch of aorta. **Fig. E.** relationship of tracheobronchial tree to pulmonary trunk and the two branches of pulmonary trunk. **Fig. F.** relationship of tracheobronchial tree to left atrium and the draining veins of the left atrium.

4.3 The right bronchus

The right bronchus passes behind the ascending aorta and the superior vena cava towards the root of lung. Two structures are related to anterior wall of right main bronchus, in the upper part the ascending aorta lies anteromedially and the superior vena cava is placed anterolaterally. The right pulmonary artery lies in close relationship with the intermediate bronchus. The right pulmonary artery initially lies first below and medial to intermediate bronchus, then in front of it and finally lies lateral and behind the intermediate bronchus. The azygos vein lies behind the right bronchus for some length and then arches over it to drain into superior vena cava.

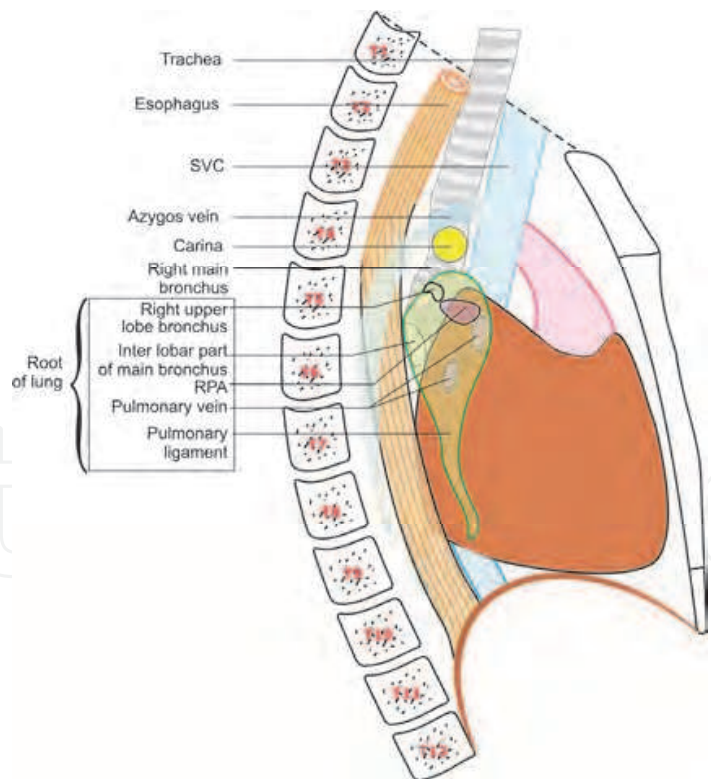


Fig. 6. The mediastinal surface of right lung is seen in this figure which shows relations of right bronchus. The right main bronchus is related anteriorly to superior vena cava and the azygos vein goes posterior to right main bronchus. It is important to note that azygous vein passes behind the root of lung and can be seen in posterior relation of right main bronchus as well as the intermediate bronchus.

#### 4.4 The left bronchus

The left bronchus, in its course toward the hilus, passes through the loop formed by the arch of the aorta, emerging from behind the ascending aorta and passing downward and to the left in front of the descending aorta before it enters the lung. Two structures are placed in anterior wall of left bronchus. The arch of aorta lies close to upper part of left main bronchus and the left pulmonary artery ascends over its anterior surface just distal to the arch of the aorta.

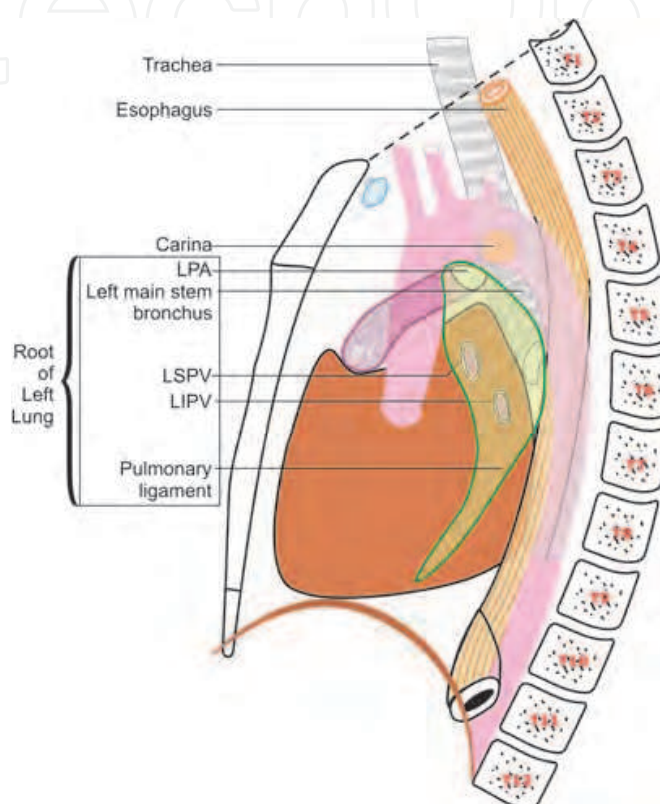


Fig. 7. The mediastinal surface of left lung is seen in this figure which shows relations of left bronchus. The left main bronchus is related anteriorly to ascending aorta in the upper part and the left pulmonary artery in the lower part. The descending aorta and esophagus lies behind the left bronchus.

#### 4.5 The root of lung and pulmonary ligament

The roots of the lungs are posterior to the upper part of the pericardial sac. Most posterior in the upper part of each root is the bronchus, in front of it are the pulmonary artery and, in an even more anterior plane, the superior pulmonary vein. The arrangement of the pulmonary artery, pulmonary vein and bronchus in right and left lung root is slightly different. The left pulmonary artery is located above, rather than directly in front of, the left bronchus.

Usually, two bronchi the upper lobe bronchus and the bronchus intermedius are seen at the right hilum when the entire lung is removed. In the left hilum, only one bronchus is seen. The pulmonary ligament is the inferior redundant part of the pleura that surrounds the root of the lung and provides the dead space in which the root of the lung may move up and down during respiration.

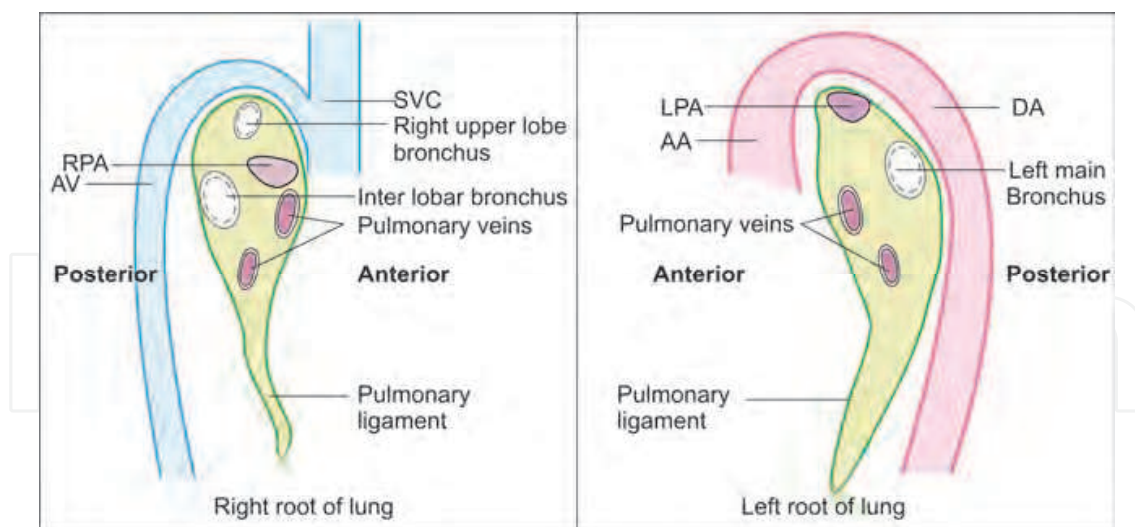


Fig. 8. It is important to know the relations at the root of the lung as the endosonographer is looking at structures from inside out. The relationship of the structures can be imagined after placing the scope inside the bronchus. Generally the veins lie most anteriorly. The artery lie behind the vein and the bronchus is the posterior most structure in the root of lung. The relations of structure at root of lung are different for right and left lung.

#### 4.7 The aorta

As soon as the ascending aorta emerges from the pericardial sac, it begins to arch backward, and the segment that runs in a nearly sagittal plane in the superior mediastinum is known as the arch of the aorta. The arch of aorta begins behind manubrium sterni and runs first upwards backwards to the left and in front of trachea. It is then directed backwards on the left side of trachea and continues downwards on the left side of T4 vertebra and at the lower border of T-4 continues as descending aorta. The left common carotid the left subclavian and the brachiocephalic arteries arise from the convexity of arch. They are crossed anteriorly by the left brachiocephalic vein just above the convexity of arch of aorta.

The space below the concavity of arch of aorta is sometimes called as subaortic tunnel. The bifurcation of pulmonary trunk the right pulmonary artery and the left bronchus lies in this inferior concavity. The trachea and esophagus fit into the slight concavity that faces to the right.

#### 4.8 The esophagus

For most of the length the esophagus lies in the posterior mediastinum, with the descending thoracic aorta posteriorly to its left. On its right side, it is covered by mediastinal pleura. The right pulmonary artery, the left principal bronchus, the transverse and oblique sinuses of the pericardium and the left atrium lie anterior to the esophagus.

#### 4.9 The pulmonary trunk, the right pulmonary artery and left pulmonary artery

The pulmonary trunk (length approximately 5 cm) lies a little to the left of midline in the chest and divides into left and right branches. The left pulmonary artery immediately leaves the pericardial sac and just outside the pericardial sac is connected to the arch of the aorta by the ligamentum arteriosum. The upper border of the left pulmonary artery lies at a little higher level than the upper border of right pulmonary artery. The RPA runs horizontally behind the

ascending aorta and superior vena cava before it leaves the pericardial sac in the concavity of the arch of the aorta. The right pulmonary artery emerges from the sac posterior to the superior vena cava and crosses the intermediate bronchus distal to the origin of the superior lobe bronchus. Soon after leaving the pericardial sac both right and left pulmonary arteries arch over the respective principal bronchi as they enter the hila of the lungs. The relationship of these pulmonary artery to the bronchus is more or less fixed and it gives a fair idea of the position to the endosonographer. The left pulmonary artery crosses the left principal bronchus and at the hilum, is superior to it, whereas the right pulmonary artery crosses the intermediate bronchus, having given off a major branch to the upper lobe before it enters the hilum. The ascending aorta, SVC and upper right pulmonary vein lie anterior to RPA. The esophagus and right bronchus lie posterior to RPA. The left bronchus and descending aorta lie posterior to LPA.

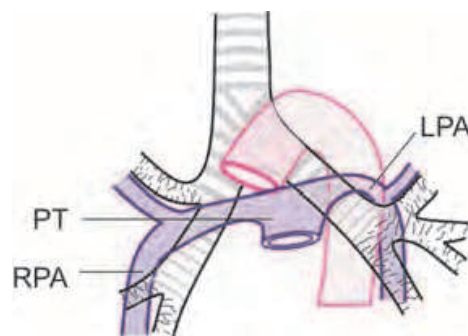


Fig. 9. The bifurcation of the pulmonary trunk takes place on the left of the ascending aorta in the concavity of the aortic arch. As a result the RPA (length approximately 2-3 cm) is longer than LPA and much of it is covered by serous pericardium.

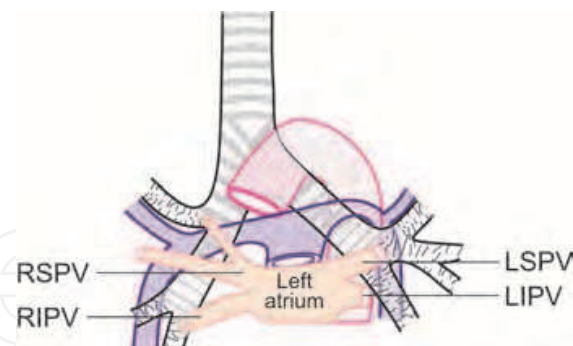


Fig. 10. The left atrium forms the lower boundary of subcarinal space. The veins coming to the left atrium have no intrapericardial course. The right superior pulmonary vein passes behind superior vena cava. Right inferior pulmonary vein crosses the esophagus.

#### 4.10 The pulmonary veins and the left atrium

The left atrium has two portions. The posterior half of the chamber, into which the four pulmonary veins empty and the anterior half. There are four pulmonary veins, two each (superior and inferior), on the right and left sides. On the left side the superior and inferior veins drain the upper and lower lobes of the lung, respectively. The superior pulmonary vein is the most anterior structure, and the inferior pulmonary vein is the most inferior

structure in the root of the lung. Thus on both sides, the principal order of the structures in an anteroposterior direction in root of lung is vein, artery, bronchus. The inferior pulmonary veins lie below the bronchus on both sides, and below them is the pulmonary ligament into which they can expand. The right inferior pulmonary vein crosses the esophagus and the right superior pulmonary vein crosses right pulmonary artery and right bronchus. On the right side the superior vein crosses behind the superior vena cava; and the inferior vein crosses behind the right atrium before they pierce the pericardial sac over the left atrium. The left inferior pulmonary vein cross the descending aorta.

Stations of EBUs Imaging

Structure	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6
Respiratory Landmark	Upper Trachea	Lower Trachea	Right Main Stem Bronchus	Right Intermediate Bronchus	Left Upper Bronchus	Left Lower Bronchus
Main Arteries	BT, LCC, LSCA	Arch of Aorta SVC	RPA	RPA	LPA, DA	LPA
Main Veins	LBCV, RBCV	AV, SVC	SVC	RPV	–	LPV
Group of Lymph Node	2R, 2L, 3a, 3p	4R, 4L, 5 & 6	7, 10R	7, 8, 11R	7, 10L	7, 8, 11L
Vertebral Landmark	T-3	T-4	T-5 Upper Border	T-5	T-6	T-6
Other Structures	Thymus	Thymus	–	Chambers of Heart	–	Chambers of Heart

Table 1. The Imaging of the peribronchial structures can be done from six stations. Although there is no sharp boundary between the six stations, the structures mentioned at each station are generally seen in the positioned mentioned in the table.

5. Technique of imaging by EBUS scope

This evaluation can be done in patients referred for EBUS on an outpatient basis, under conscious sedation using midazolam and oral xylocaine spray. A linear EBUS scope (Pentax EB-1970UK) with 100° field of view, 45° forward oblique angle, a window angle of 75° and a distal end optic width of 7.4 mm was used for the purpose of description in this chapter. Imaging was done after endoscopic visualization from intrathoracic part of trachea and bronchus from six positions. Clockwise or anticlockwise rotation was done after apposition against the wall to change the axis of imaging. Cranial side left and caudal side right imaging convention was followed.

5.1 Imaging from upper trachea

Imaging is done 5 cm above carina where a clockwise and anticlockwise rotation from anterior wall of trachea to 90° on either side will show the right and left lateral tracheal walls and 180° rotation will show the esophagus behind the posterior wall of trachea (Fig 11 & 12). The presence of air in trachea and cartilage in the wall create prominent artifacts during imaging (Fig. 13 & 14). On clockwise rotation, the brachiocephalic veins are seen joining near the right anterolateral wall of trachea to form the superior vena cava. The lower border of left brachiocephalic vein

forms the upper boundary of station 2R and superior vena cava forms the posterior boundary of station 3a.

On anti clockwise rotation, the upper margin of the arch of aorta is seen from which the origin of left common carotid artery (left posterior boundary of station 3a), left subclavian artery and brachiocephalic trunk can be seen (Fig 11). Brachiocephalic trunk crosses to the right side of trachea, the left common carotid artery runs close to left wall of trachea and the left subclavian artery goes close to apex of lung where it creates mirror image artifact (Fig. 15 & 16). The transverse plane through the superior border of aortic arch makes lower border of the station 2L on the left and a transverse plane through the lower border of brachiocephalic vein forms lower border of 2R lymph nodes on the right side (Figures 17 & 18).

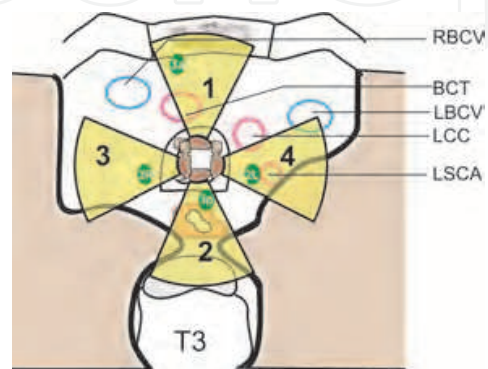


Fig. 11. Imaging from upper trachea - when the scope is positioned in upper trachea the great vessels of neck can be seen. Clock wise rotation of the scope shows the Right Brachiocephalic vein and Brachiocephalic Trunk. The Left common carotid artery and Left Brachiocephalic vein are seen anterior to the trachea and may be more easily seen on anticlockwise rotation. Further anticlockwise rotation may show the Left subclavian artery. A rotation of 180° shows the esophagus lying posterior to trachealis muscle behind the posterior wall of trachea. The yellow beam shows the area of imaging on rotation. 1 = Imaging anterior to trachea, where station 3a (prevascular) lymph nodes are seen, 2 = Imaging posterior to trachea, where station 3b lymph nodes are seen, 3 = Imaging of the right lateral side of trachea, where station 2R lymph nodes, 4 = Imaging of the left lateral side of trachea, where station 2L lymph nodes are seen.

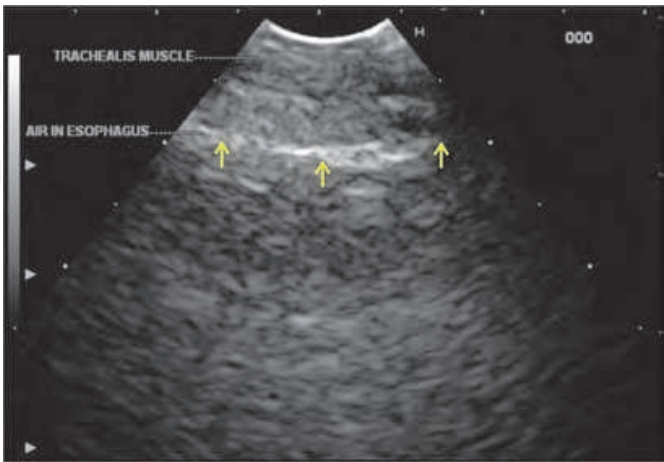


Fig. 12. Imaging of esophagus from trachea -180° rotation from the anterior wall of trachea shows membranous posterior wall of trachea made of trachealis muscle and the multilayered esophagus with air, forming a hyper-echogeneic line in the middle lying behind trachea.

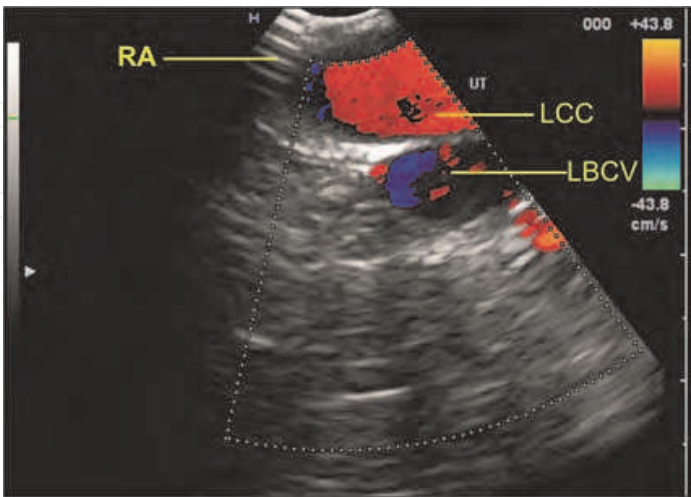


Fig. 13. Imaging of great vessels of neck: Imaging from upper trachea shows reverberation artifact. The trachea has 15 to 20 incomplete horizontally stacked ‘C’ shaped cartilaginous rings, each of 4 mm vertical diameter, which create alternating zones of reverberation artifact due to cartilage. The breadth of one artifact is likely to match with the breadth of each cartilage (4 mm). Once the arch of aorta is visualized pulling back a little will show the left common carotid coming out from the top of the arch of aorta.

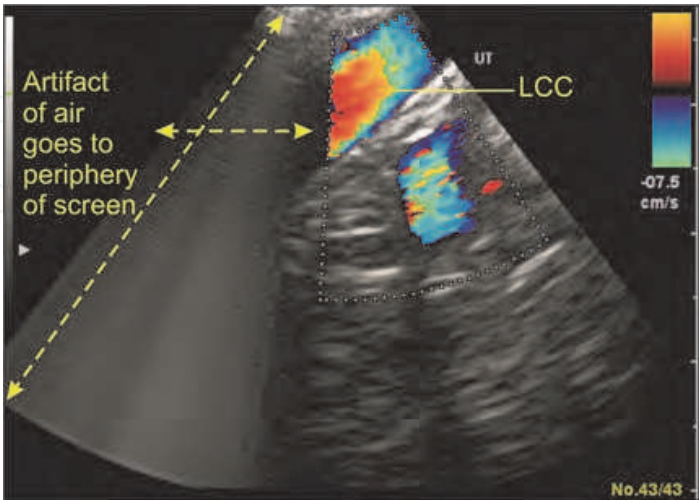


Fig. 14. Imaging from upper trachea. The air forms dirty comet tail artifact which goes to the periphery of the screen in this picture.

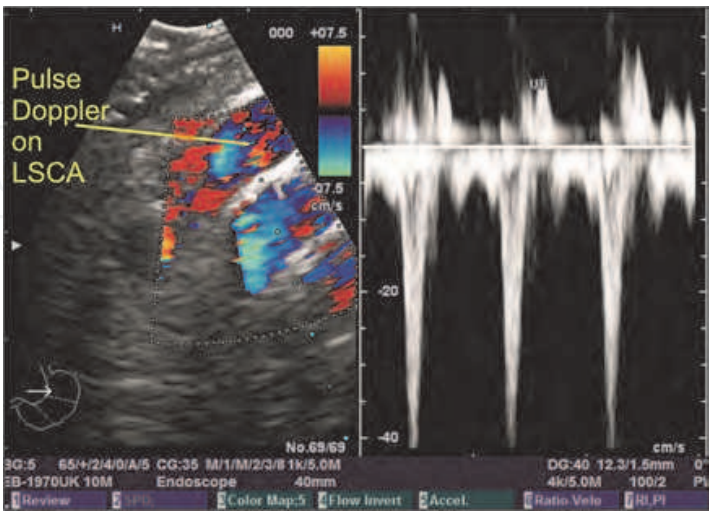


Fig. 15. The left subclavian artery is seen at a little distance away from the trachea with the mirror image artifact due to sharp interface with the left lung (the left common carotid artery generally lies closer to trachea). The application of pulse Doppler confirms the arterial wave form.

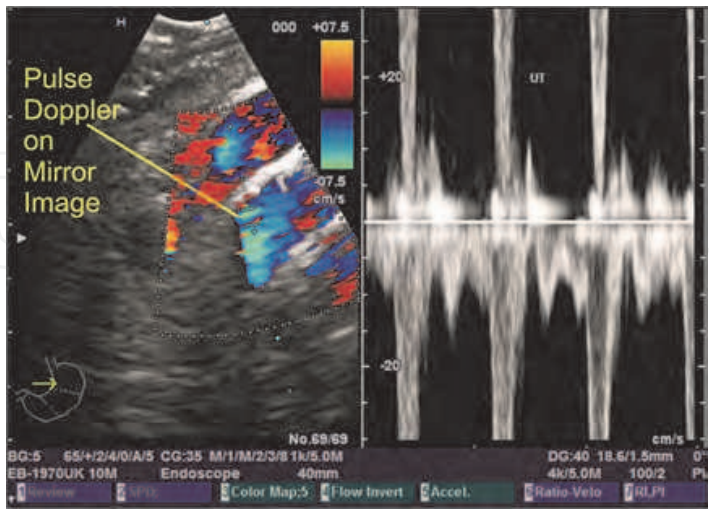


Fig. 16. A 28 year old lady is referred for evaluation of mediastinal lymphadenopathy. Imaging is done from upper trachea. The application of pulse Doppler on the mirror image confirms the arterial wave form on the mirror image also.

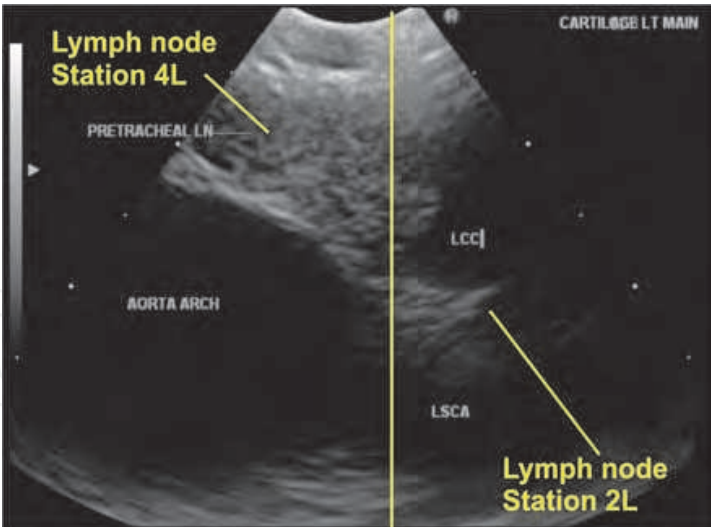


Fig. 17. Imaging is done from upper trachea and reveals a lymph node in front of trachea (Station-4L). The left subclavian artery is seen in the lower part of the screen and one lymph node is seen between the left subclavian artery and left common carotid artery (Station-2L).

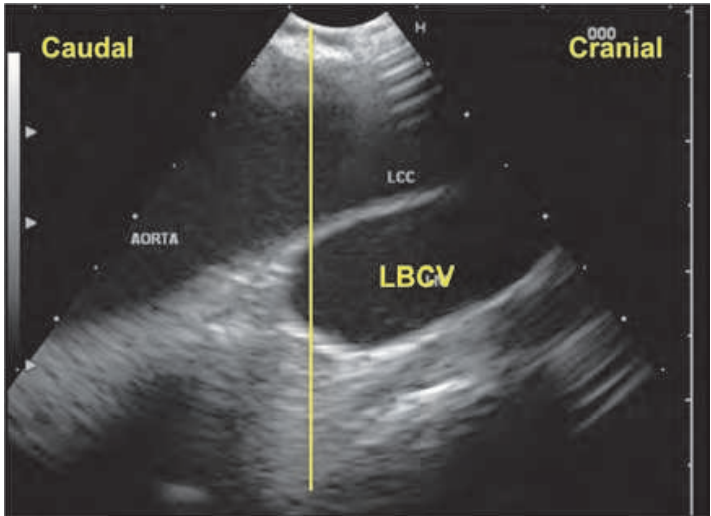


Fig. 18. Imaging is done from upper trachea. Once the arch of aorta is visualized pulling back a little will show the left common carotid coming out from the top of the arch of aorta. The left common carotid artery is seen in this figure and the left brachiocephalic vein is seen crossing in front of left common carotid artery. Vertical yellow line denotes the superior margin of the Aortic arch.

**5.2 Station 2: Imaging from lower trachea**

A clockwise rotation from above carina shows the right anterolateral wall of the distal one third of trachea where the superior vena cava is seen. If clockwise rotation is continued, the azygos vein can be seen joining the superior vena cava in the right tracheobronchial corner as a kidney-shaped vessel. The inferior border of station 4R is formed by the inferior margin of the azygos vein (Fig. 19, 20 & 21). An anti-clockwise rotation shows the pulsatile arch of aorta in the left anterolateral wall of distal one third of trachea, the superior margin of which forms the boundary between the

station 4L and 2L lymph node stations. Determination of the lower boundary of station 4L and 5 is done from left bronchus after clear visualization of upper rim of left pulmonary artery. Two transverse lines across the upper and lower border of arch are important in determining the area of lymph nodes of station 6 which are better seen by endoscopic ultrasound (Fig. 22).

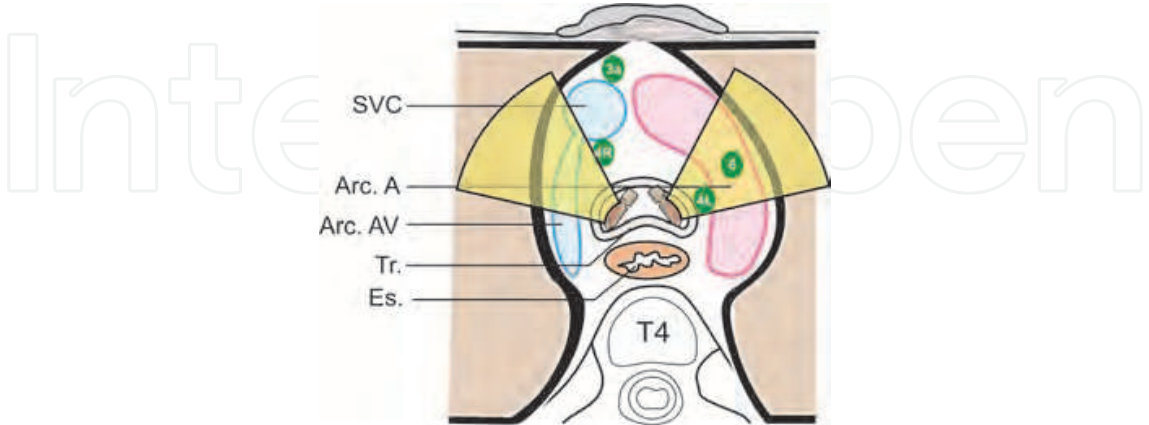


Fig. 19. Cross-sectional illustration from the lower trachea. The arch of the Azygos vein is seen entering the superior vena cava posteriorly on the right lateral side and the arch of aorta is seen in the left lateral side. The illustration shows the station 4R (right para- and pre-tracheal), 4L (lateral to the left lateral margin of trachea), 6 (lateral to the ascending aorta and arch) and 3a (prevascular) lymph nodes.

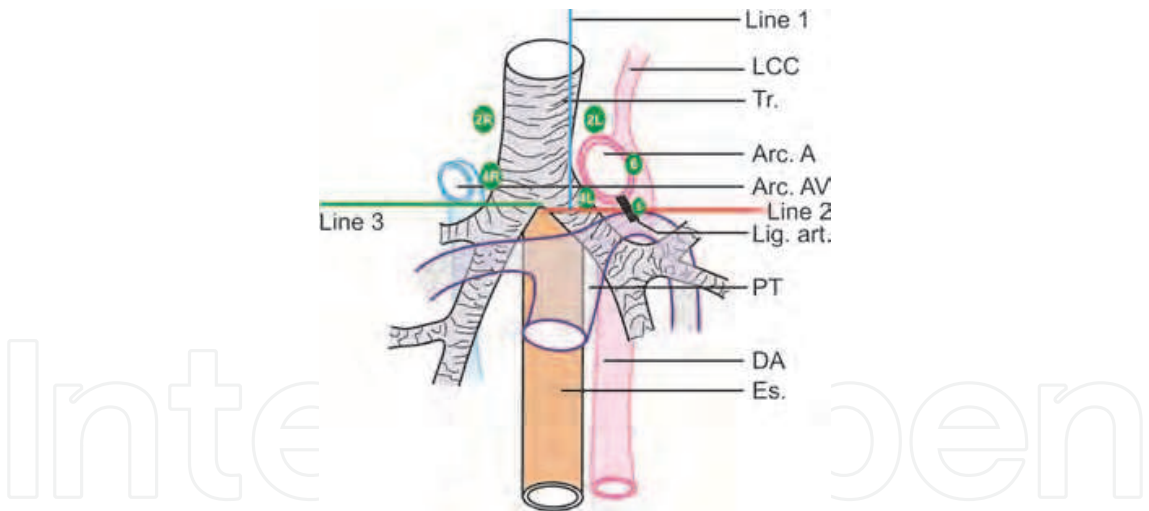


Fig. 20. Illustration of the structures at the lower trachea. The upper level of aortic arch lies anterior and to left of the distal one-third of the trachea. The arch of Azygos vein passes forwards arching over right stem bronchus to open into Superior vena cava, whereas the arch of Aorta passes backwards arching over the left stem bronchus to continue as descending Aorta. Blue line = left lateral border of trachea, the boundary between 2R/4R and 2L/4L, Green line = Inferior margin of Azygos vein = lower boundary of station 4R, Orange line = Superior margin of Left Pulmonary artery, lower boundary of station 4-L and 5. Lymph node stations: 3a = Pretracheal, 4L = Left Paratracheal, 4R = Right Paratracheal & pretracheal, 5= Subaortic nodes lateral to ligamentum arteriosum. 6 = Lateral to ascending Aorta and arch.

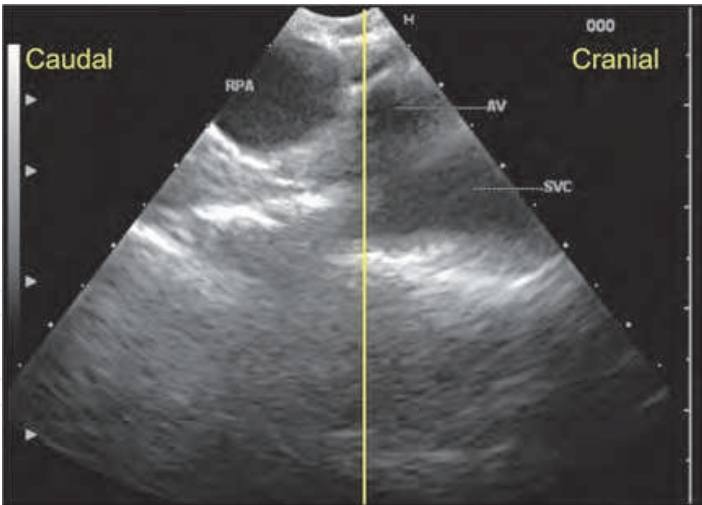


Fig. 21. EBUS image from lower trachea shows the azygos vein joining the superior vena cava posteriorly. The right pulmonary artery is seen just below the union of azygos vein joining the superior vena cava. Vertical yellow line depicts the caudal margin of the azygos vein as it joins superior vena cava.

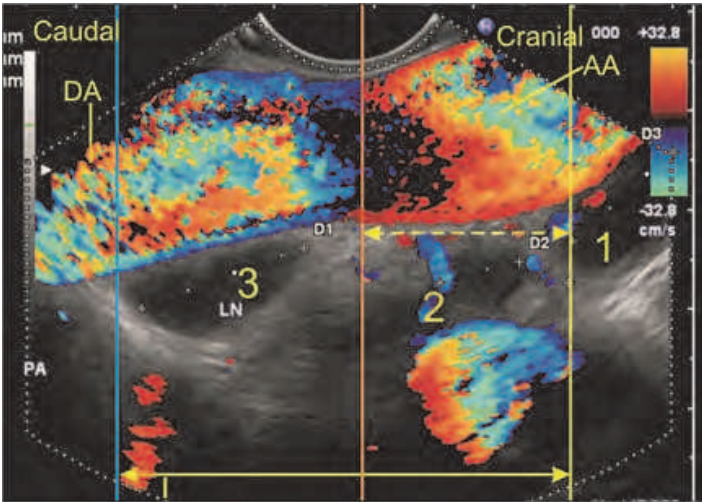


Fig. 22. This is the only EUS image in this article which is given to clarify the borders. EUS image shows the arch of aorta and the left pulmonary artery with lymph nodes (1, 2 & 3). Vertical lines represent-yellow line: upper margin of the arch of aorta, orange line: lower margin of the arch of aorta, blue line: upper margin of the left pulmonary artery. Left right dotted arrow = location of station 6 node. Left right solid arrow = location of station 4L node. As the ligamentum arteriosum can not be visualized clearly by EBUS, it is often difficult to differentiate the station 4L from the station 5 lymph nodes. Lymph node no. 1= station 2L, No. 2 = station 6 & No. 3= station 5 node.

### 5.3 Station 3: Imaging from right main bronchus

From the right main bronchus, the subcarinal space, the right pulmonary artery, right pulmonary vein, superior vena cava and ascending aorta are seen close to the anterior wall (Fig. 23, 24, 25 & 26, 27 & 28). Turning the scope anti-clockwise shows station 7 nodes of subcarinal area (Fig 29). Station 10R lymph nodes are seen close to the right main bronchus.

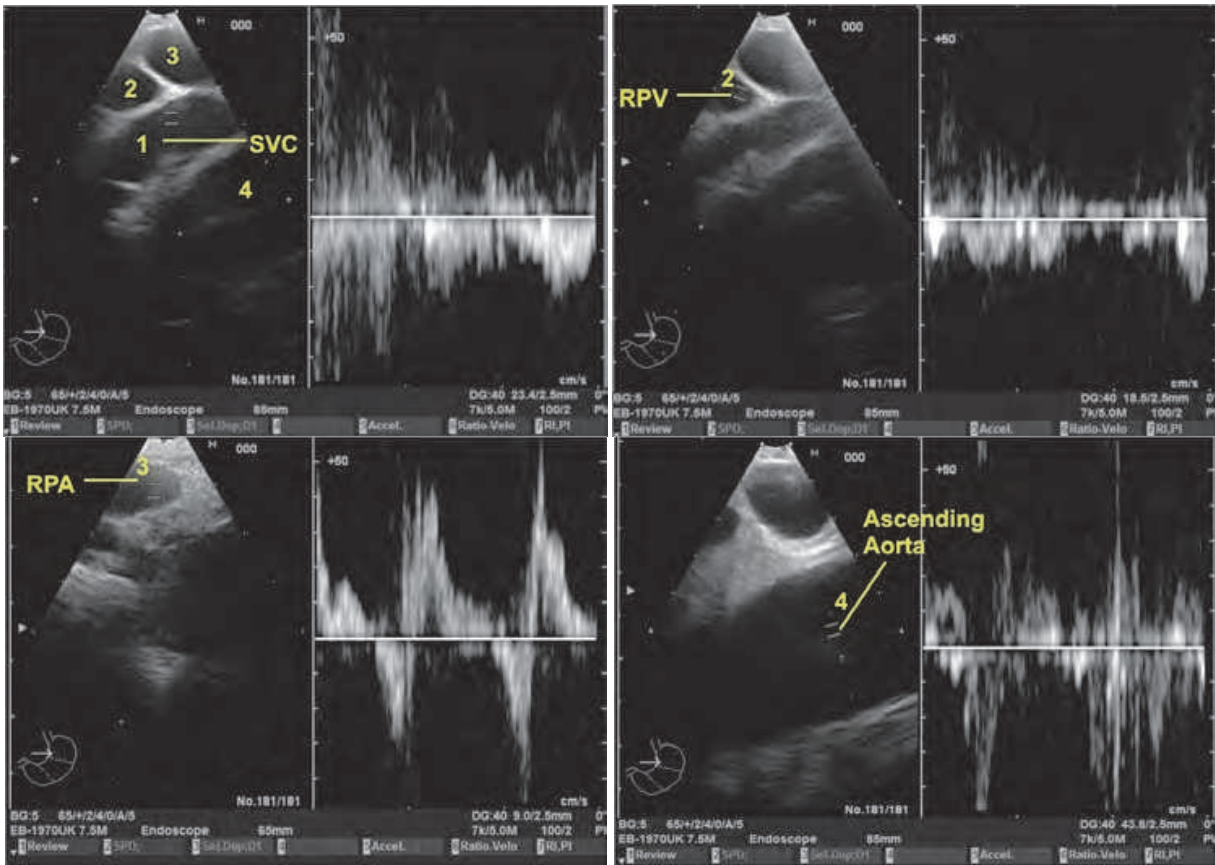


Fig. 23., 24., 25. & 26. Bronchoscopy showed extrinsic compression on the right bronchus. EBUS was done from the right bronchus. Four pulsations are seen. One by one placement of the pulse doppler is done over the pulsations. The pulse Doppler is placed on pulsation 1 in this figure and characterizes it as superior vena cava. The superior vena cava can be followed up by pulling up the scope into right lateral wall of trachea. The rest of the vessels are as follows-2: Right pulmonary vein, 3: Right pulmonary artery, 4: Ascending aorta. SVC = Superior vena cava

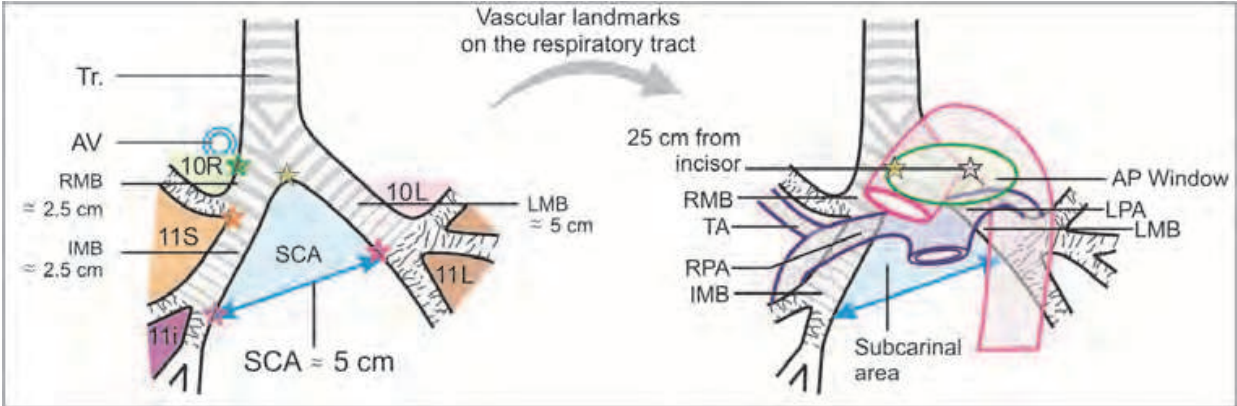


Fig. 27. The 25 cm landmark is an important landmark for EBUS as the trachea divides into right and left bronchus which move towards the respective lungs and opens up a subcarinal window anterior to esophagus. The new IASC classification has redefined the boundaries of subcarinal area (SCA). It is a pyramidal space the tip of which lies at the tracheal bifurcation.

The right boundary (5 cm) is formed by right bronchus (2.5 cm) and intermediate bronchus (2.5 cm). The left boundary is formed by left main bronchus. (5 cm) The lower limit of SCA is formed by an oblique line drawn from the lower border of intermediate bronchus to the lower border of left main bronchus. Just above the origin of apical segment of left lower lobe bronchus (approximately 5 cm long). The upper border of the left atrium is about 3 to 4 cm in breadth and occupies the middle part of this oblique line. More laterally the inferior pulmonary veins form a part of the lower border of subcarinal area which is generally  $\geq 1$  cm for the RIPV and  $\leq 1$  cm for LIPV. The dotted blue line shows an axial plane through sub-carinal area which roughly corresponds to the upper border of 10R and 10L. The green line shows the lower border of 10 R. The green bracket shows the area of hilum on the right side which lies opposite sub carinal area on the right side. There is a division between 11s and 11i on the right side. The former indicate the nodes between upper lobe and intermediate bronchus, the latter are situated in between middle and lower lobe. The orange line shows the lower border of 11S on the right side and lies opposite sub carinal area on the right side. The orange arrow shows the inter lobar area on the right side which lies opposite SCA. The blue line with arrows shows the lower limit of SCA. The magenta line shows the lower border of 10 L on the left side and the magenta bracket shows the area of 10 L lymph node which lies opposite SCA on the left side. The 11i lymph node lies above the purple line on the right side and the 11L lie above the brown line on the left side. The hilar nodes of station 10 are situated immediately adjacent to the mainstem bronchus but caudal to the inferior border of azygos vein on the right and superior rim pulmonary veins and artery on the left. Yellow star on 25 cm line = carina, white star on 25 cm line = upper margin of AP window.

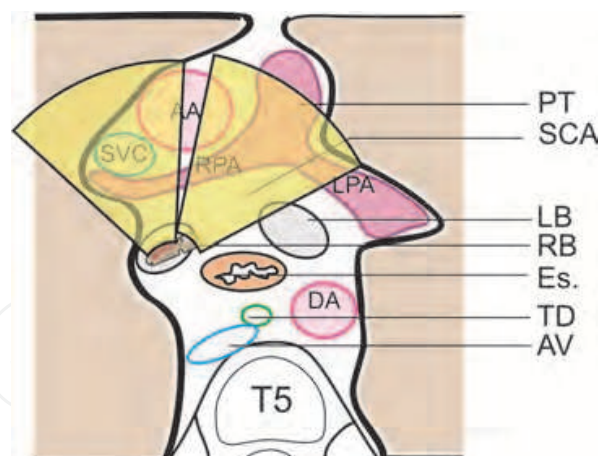


Fig. 28. Imaging from the right main bronchus (Station 3A) – the right main bronchus is Broader, more vertical and about 2.5 cm long. The right pulmonary artery lies immediately anterior to the right main stem bronchus near the origin of the right upper lobe bronchus. The superior vena cava and the ascending aorta lie in front of right pulmonary artery. Imaging from the right bronchus can be done by clockwise and anticlockwise rotation. Clockwise rotation will show the right pulmonary artery superior vena cava and ascending aorta. Anticlockwise rotation will show the subcarinal space. Yellow beam shows the area of imaging.



Fig. 29. E-BUS Image from the right main bronchus with anti-clockwise rotation demonstrates station 7 lymph node (subcarinal).

5.4 Station 4: Imaging from intermediate bronchus

Imaging from right intermediate bronchus the subcarinal area (station 7 & 8 nodes) left atrium mitral valve and left ventricle are seen anteriorly (Fig. 30 & 31). On pushing down endoscopic visualization of inferior border of right intermediate bronchus demarcates the lower boundary of station 7 on the right side. Station 11 lymph nodes are seen close to intermediate bronchus.

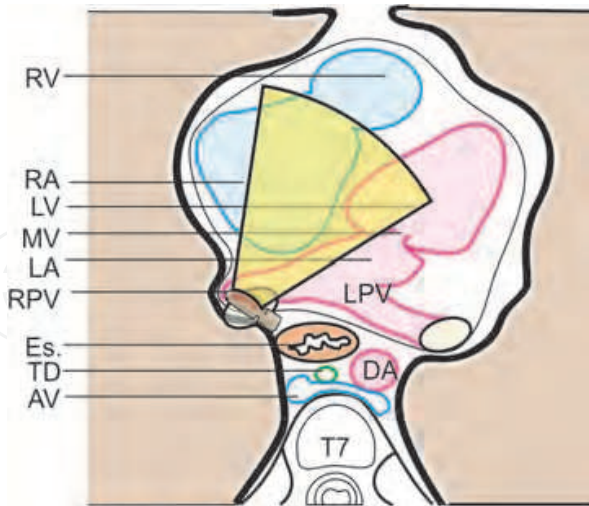


Fig. 30. Imaging from the intermediate bronchus (station 4). The intermediate bronchus lies posterior to the pulmonary veins and the left atrium. On a clockwise rotation the pulmonary veins can be followed into the lung and on anticlockwise rotation they can be followed into the left atrium. From the left atrium the left ventricle and mitral valve can be visualized. Yellow beam shows the area of imaging.

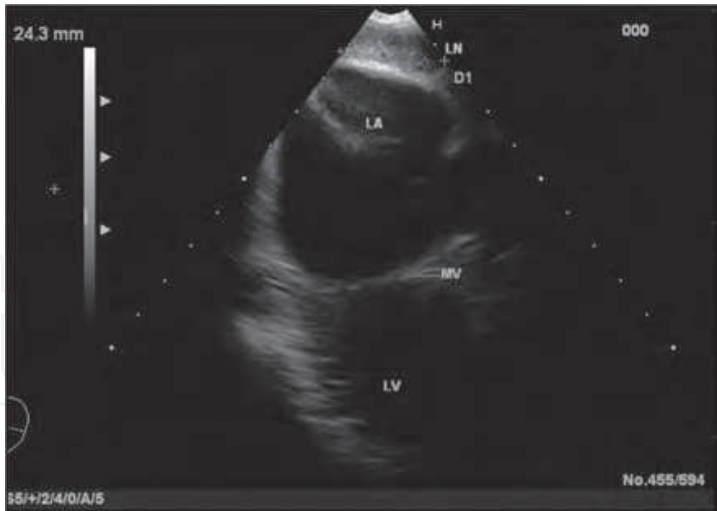


Fig. 31. E-BUS from the lowest part of right intermediate bronchus shows a lymph node between the bronchus and left atrium (Station-8). The left atrium mitral valve and left ventricle are seen in this image.

5.5 Station 5: Imaging from upper part of left main bronchus

The left pulmonary artery is seen in the anterior wall of bronchus. On anticlockwise rotation, the probe faces the posterior wall of left main bronchus where the descending aorta, esophagus and vertebral column are seen (Fig. 32, 33). A clockwise rotation shows station 7 lymph nodes (Fig. 34). Station 10 L lymph nodes are seen near the left main bronchus on anti-clockwise rotation (Fig. 35).

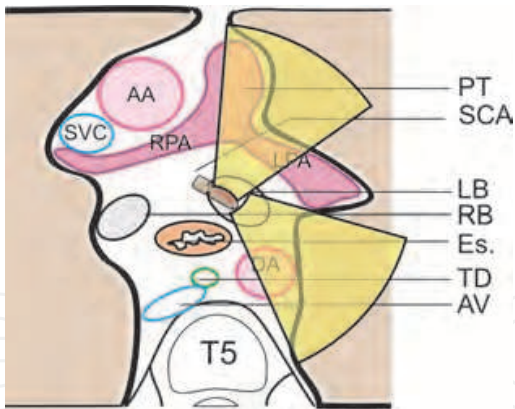


Fig. 32. Imaging from the left main bronchus-The left main pulmonary artery is seen in the anterior wall. The left main bronchus is narrower, less vertical and 5 cm long. It passes to the left inferior to aortic arch through Subaortic Tunnel. From the left main bronchus subcarinal area is identified from the left side by turning the scope in a clockwise direction. It is important to note that in left main bronchus clockwise rotation is required to see the subcarinal area whereas in right main bronchus anticlockwise rotation is required to see the subcarinal area. Identification of the main pulmonary trunk is also possible by clockwise rotation. On anti-clockwise rotation the descending aorta can be visualized and followed up by slow withdrawal along the left wall of bronchus to the aortic arch. Yellow beam shows the area of imaging.

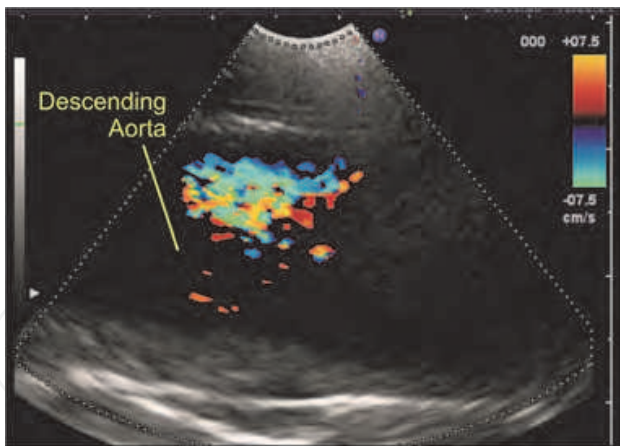


Fig. 33. EBUS Image demonstrates the descending aorta after anticlockwise rotation from the left main bronchus.

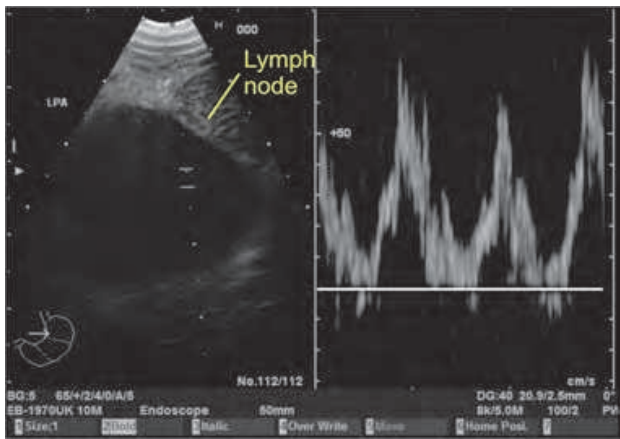


Fig. 34. EBUS image from the left bronchus on clockwise rotation shows station 7 lymph node with the pulmonary trunk lying near the lymph node.

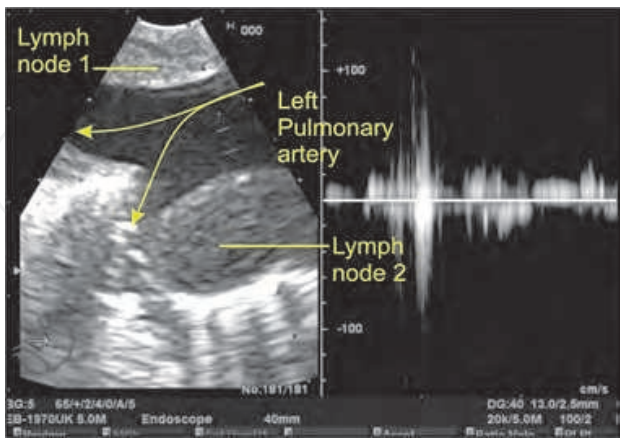


Fig. 35. EBUS from the left bronchus shows the left pulmonary artery anterior to the left bronchus. The lymph node 1 is seen lying close to the bronchus below the upper rim of left pulmonary artery and belongs to station 10-L. The lymph node 2 is lying away from the pulmonary artery after its branching and belongs to station 11-L. Yellow arrow shows the course of pulmonary artery dividing into two branches.

### 5.6 Station 6: Imaging from lower part of left main bronchus

With the scope in lower part of left bronchus just above the secondary carina the left atrium and station 8 lymph nodes can be identified anteriorly. It is often possible to get a four chambered view of heart with a 75° EBUS scope (Fig. 36). The lymph nodes of station 11L are seen below the secondary carina.

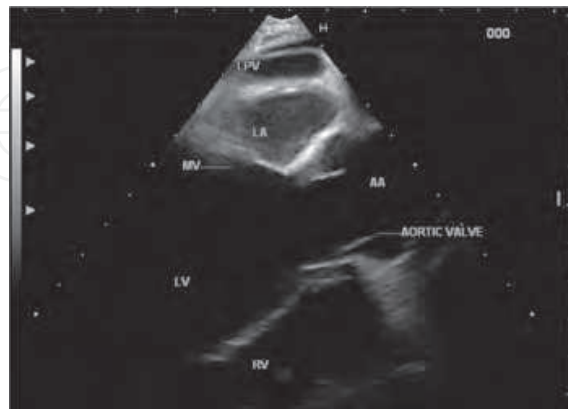


Fig. 36. When the scope is pushed further Down into the left bronchus (Station 6). The left pulmonary vein is seen draining into the left atrium. The mitral valve, the left ventricle, the aortic valve and the ascending aorta are seen in this position. It is important to note that the aortic valve is seen in the root of ascending aorta in front of upper part of left atrium. The lymph node for station 8 is seen at the level of left atrium.

## 6. Comparison of EBUS and EUS

No standard comparison has been made till now and the choice of procedure (EBUS first or EUS first) is still under debate. The reasons to choose EUS FNA over EBUS FNA for lymph nodes are—

1. EUS scope has a large diameter and it is easier to pass the FNAC needle through the channel of the scope.
2. The field of vision is more with a EUS scope (130° to 180°) as compared to EBUS scope (50 to 70°).
3. The use of elevator allows more angles for the operator to enter the lymph node.
4. The use of right and left knobs allows more angles for entry into the lymph node.
5. The presence of cartilage during entry from trachea may be difficult

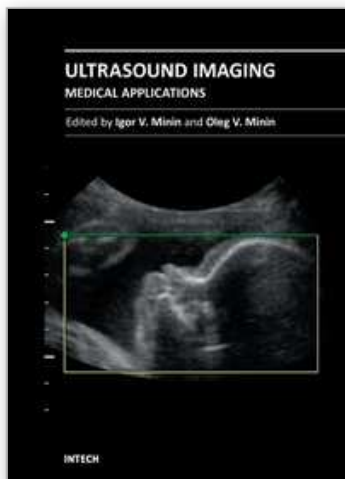
## 7. Abbreviations

GV neck = great vessels of neck, AA = arch of aorta, Arc. AV = Arch of azygos vein, BT = Brachiocephalic Trunk, LCC = Left Common Carotid Artery, LSCA = Left Subclavian Artery, SVC = Superior Vena Cava, RPA = Right Pulmonary Artery, LPA = Left Pulmonary Artery, DA = Descending Aorta, LBCV = Left Brachiocephalic Vein, RBCV = Right Brachiocephalic Vein, AV = Azygos Vein, RPV = Right Pulmonary Vein, LPV = Left Pulmonary Vein, T = Thoracic Vertebra, R = Right, L = Left. Fig. 5 SVC = Superior vena cava, Arc. A = Arch of aorta, AV = Azygos vein, AA = Ascending aorta, RPA = Right pulmonary artery, DA = Descending aorta, LPA = Left pulmonary artery, PT = Pulmonary trunk, LB = Left bronchus, RB = Right bronchus, UT = Upper trachea, LT = Lower trachea,

Es = esophagus. Tr. = Trachea, Es. = Esophagus, PT = Pulmonary trunk, DA = Descending aorta, Es. = Esophagus, Lig. art. = Ligamentum arteri-osum. SCA = Subcarinal area, TD = Thoracic duct, LA = Left atrium, MV = Mitral valve, LV = Left ventricle, RV = Right ventricle, RA = Right atrium, RPV = Right pulmonary vein, LPV = Left pulmonary vein, RA = Reverberation artifact, SCA = sub carinal area, RMB = right main bronchus, LMB = left main bronchus, TA = Truncus anterior, AP window = aortopulmonary window

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## **Ultrasound Imaging - Medical Applications**

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This book provides an overview of ultrafast ultrasound imaging, 3D high-quality ultrasonic imaging, correction of phase aberrations in medical ultrasound images, etc. Several interesting medical and clinical applications areas are also discussed in the book, like the use of three dimensional ultrasound imaging in evaluation of Asherman's syndrome, the role of 3D ultrasound in assessment of endometrial receptivity and follicular vascularity to predict the quality oocyte, ultrasound imaging in vascular diseases and the fetal palate, clinical application of ultrasound molecular imaging, Doppler abdominal ultrasound in small animals and so on.

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