Title:

The phrenic nerve with accompanying vessels: A silent cause of cardiovascular border obliteration on chest radiograph

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For this retrospective study the requirement for informed consent was waived by the institutional review board.

The authors declare that they have no conflict of interest.

Type of manuscript: Original article

Abstract

Purpose

To clarify the frequency of cardiovascular border obliteration on frontal chest radiograph and to prove that the phrenic nerve with accompanying vessels can be considered as a cause of obliteration of cardiovascular border on otherwise normal chest radiograph.

Materials and Methods

Two radiologists reviewed the chest radiograph and CT images of 100 individuals. CT confirmed absence of intrapulmonary or extrapulmonary abnormalities in all of them. We examined the frequency of cardiovascular border obliteration on frontal chest radiograph and summarized the causes of obliteration as pericardial fat pad, phrenic nerve, intra-fissure fat, pulmonary vessels and others comparing with CT in each case.

Results

Cardiovascular border was found obliterated on frontal chest radiograph in 46 cases on the right, and in 61 on the left. The phrenic nerve with accompanying vessels was found as a cause of obliteration in 34 of 46 cases (74%) on the right and 29 of 61 (48%) cases on the left. The phrenic nerve was the most frequent cause of the cardiovascular border obliteration on both sides.

Conclusion

The phrenic nerve with accompanying vessels forming a prominent fold of parietal pleura can be attributed as a cause of cardiovascular border obliteration on frontal chest radiograph.

Key words

Thorax, Radiograph, Computed tomography, Phrenic nerve, Cardiovascular border

Introduction

An intrathoracic lesion touching a border of the heart, aorta, or diaphragm will obliterate the border on the chest radiograph. This phenomenon has been named "silhouette sign" [1]. Felson emphasized the importance of this sign and stated that a lesion in the right middle lobe or lingula may be suspected by obliteration of the cardiac border [1]. However, he also pointed out that obliteration of the cardiac border may be observed in normal individuals. He mentioned that there was unexplained silhouette sign on either cardiac border in approximately 3% of normal individuals. According to the glossary for thoracic imaging published in 2008 from Fleischner Society, "silhouette sign" is not always indicative of disease [2]. Pericardial fat pad and overlapping pulmonary vessels have been well documented as a cause of cardiac border obliteration [3]. However, there are many cases with cardiovascular border obliterations of which reason is not able to be explained only due to pericardial fat pad or overlapping pulmonary vessels.

We speculated that the phrenic nerve and its surrounding structures could be a cause of obliteration of the cardiovascular border on frontal chest radiograph. The phrenic nerve descends anterior to the pulmonary hilum, between the fibrous pericardium and mediastinal pleura, to the diaphragm accompanied by the pericardiophrenic artery and vein [4, 5]. The right phrenic nerve passes lateral to the brachiocephalic vein, the superior vena cava and the fibrous pericardium covering the right surface of the right atrium and inferior vena cava (Fig. 1). The left phrenic nerve passes anteromedially superficial to the aortic arch, lateral to the fibrous pericardium covering the left surface of the left ventricle (Fig. 1). Sanchez-Quintana et al. also described this anatomic pathway of the phrenic nerve on the basis of gross dissection and histological examination of human cadavers [6,

7]. The phrenic nerve and its accompanying pericardiophrenic artery and vein form the pericardiophrenic neurovascular bundle, which is surrounded by a fat pad of variable thickness (0.1-1.2mm) adherent to the pericardium [6, 7]. Fukumoto et al. reported that the running courses of the right and left pericardiophrenic bundle generated by 3-D CT and the ipsilateral phrenic nerves generated by the 3-D pacemap were visually matched [8]. The phrenic nerve with accompanying pericardiophrenic artery and vein often forms a prominent fold of the parietal pleura and appears as a spicular or triangular structure on CT (Figs 2, 3) [9-12]. This additional structure can contribute to conceal the cardiovascular border tangential to the X-ray beam, thus obliterate the clear demarcation between the heart and lung.

The purpose of this study was to clarify the frequency of cardiovascular border obliteration on frontal chest radiograph and to prove that the prominent fold of the pleura formed by the phrenic nerve with accompanying vessels can cause obliteration of the cardiovascular border on otherwise normal chest radiograph.

Materials and Methods

Study population

For this retrospective study the requirement for informed consent was waived by the institutional review board. The study population consisted of 100 individuals (53 women and 47 men; age range, 12-83 years; and median age; 53.5 years) who were studied for suspected pulmonary pathologies excluding the cases of portable chest radiograph, post-operative patients and infants from January 2009 to December 2009. Radiograph and CT of the chest were obtained within an interval of 30 days from each

other. CT confirmed absence of intrapulmonary or extrapulmonary abnormalities in all of them.

Chest radiograph and CT scanning

Chest radiograph was obtained by using flat-panel detector system (RADspeed Safire, Shimadzu, Kyoto, Japan).

Whole-lung CT images were obtained with two 64-detector row CT scanners (Aquilion 64; Toshiba Medical Systems, Otawara, Tochigi, Japan or Somatom Definition; Siemens Healthcare, Erlangen, Germany) using the following settings: 1.0-mm section width with 1.0-mm reconstruction interval, beam pitch, 0.828, tube voltage, 120 kVp, tube current, volume EC, SD11 (Toshiba), beam pitch, 0.9, tube voltage, 120 kVp, 100–200 mA (Siemens).

Interpretation of chest radiograph and CT

We reviewed three issues as follow:

1. Presence or absence of obliteration of the cardiovascular border on frontal chest radiograph. The degree of obliteration of cardiovascular border was classified into two scales; “probably present”, and “definitely present”. Location of cardiovascular border obliteration was divided into 4 segments “above the hilum”, “hilum”, “below the hilum” and “above the diaphragm” on both sides as shown in the schematic diagram of frontal chest radiograph (Fig. 4). The area up to the first horizontal line crossing through the superior lobar branch of pulmonary artery on both sides was considered as the segment “above the hilum”. The lower most segment “above the diaphragm” was outlined using

another horizontal line crossing through the entry point of both inferior pulmonary veins into left atrium and vertically up to the diaphragm. The area between the previous two horizontal lines was divided at the midportion and upper portion and lower portion was considered as “hilum” and “below hilum” respectively.

2. Presence or absence of the spicular or triangular structure corresponding to the course of the phrenic nerve (Figs. 2, 3), pericardial fat pad, intra-fissure fat and overlapping pulmonary vessels on CT. When these structures were seen with 5mm in cranio-caudal length or more (5 slices or more with 1mm reconstruction interval on axial images), the finding was judged as “presence”. We examined the presence of these structures at 4 segments (above the hilum, hilum, below the hilum and above the diaphragm) on both sides similarly as we did on the chest radiograph.

3. Comparison of CT images and chest radiograph to determine the causes of cardiovascular border obliteration on chest radiograph. The spicular or triangular structure corresponding to the course of the phrenic nerve, pericardial fat pad, intra-fissure fat and overlapping pulmonary vessels were analyzed in each segment on CT if these can cause the obliteration of the cardiovascular border on chest radiograph.

Each chest radiograph and CT scan was evaluated by consensus of two radiologists. When the interpretation between the two readers was in disagreement, another experienced radiologist joined the discussion to reach the consensus.

Results:

Cardiovascular border was found obliterated on chest radiograph in 46 individuals (46%) on the right and in 61 (61%) on the left side (Table 1). There were some cases

where cardiovascular border obliteration was probably present in one segment, but definitely present in another segment in the same patient. So these were the overlapped cases for which total number of presence of obliteration did not correspond to the total of probably and definitely obliterated cases.

Number of cardiovascular border obliteration on chest radiograph in 4 segments is shown on Table 2. Cardiovascular border was most commonly obliterated at the level of hilum on both sides, and secondly below the hilum on the right and above the diaphragm on the left.

Number of structures on CT as possible causes of the cardiovascular border obliteration on frontal chest radiograph is summarized in Table 3. The possible causes were most commonly found at the segment of above the diaphragm on both sides. Among these cases, pericardial fat pad-was found in 23 of 48 cases on the right side and 47 of 54 cases on the left side. At the segment of below hilum, the phrenic nerve was seen in 23 of 30 cases on the right and in 19 of 21 cases on the left side. At the segment of hilum and above the hilum, all cases were due to the phrenic nerve on both sides.

The causes of cardiovascular border obliteration on frontal chest radiograph analyzed by comparison with CT images are summarized in Table 4. Phrenic nerve was the most frequent cause of bilateral cardiovascular border obliteration on chest radiograph being 34 of 46 cases (74%) on the right side and 29 of 61 cases (48%) on the left side (Figs. 5, 6). They were most frequently seen at the segment of below hilum, followed by hilum and above hilum on the right side, and were most frequently seen at the segment of the hilum, followed by below hilum on the left side. The cardiovascular border obliteration due to intra-fissure fat was observed in 7 cases on the right and 3 case

on the left. There were other 25 cases on the right side and 18 cases on the left side where cause of cardiovascular border obliteration on the frontal chest radiograph could not be explained by the phrenic nerve, pericardial fat pad, intra-fissure fat or overlapping pulmonary vessels.

Discussion

In the present study, the cardiovascular border obliteration was seen on chest radiograph in 46% subjects on the right side and in 61% subjects on the left side; the frequency was much higher than that of Felson's study, which showed the obliteration in 8% on the right side and in 11% on the left side in asymptomatic patients [1]. This discrepancy is accounted by the fact that we regarded very short segment obliteration (≥5mm) as positive.

To our knowledge, this is the first study that evaluated relationship between the cardiovascular border obliteration on frontal chest radiograph and the phrenic nerve. Cardiovascular border obliteration due to the phrenic nerve was confirmed in 34 of 46 cases (74%) on the right and 29 of 61 (48%) cases on the left. Based on this result, we have concluded that the prominent fold of the parietal pleura due to the phrenic nerve with accompanying vessels was the most frequent cause of the cardiovascular border obliteration mainly at the segment of hilum and below hilum on both sides, while, pericardial fat pad is the main cause of cardiovascular border obliteration above diaphragm on both sides.

We assumed that a spicular or triangular structure seen on the cardiovascular border on axial CT images represent the phrenic nerve and its accompanying vessels.

This is based on the results of several studies on CT appearance of the phrenic nerve [9-12]. Taylor et al. reported that a 1-3mm rounded structure adjacent to the pericardium may represent the phrenic nerve [9]. Godwin et al. reported that they have observed in a cadaver that the nerve forms a prominent tent of the parietal pleura as it sweeps from the mediastinum to the diaphragm [10]. Berkmen et al. proved, on the basis of a cadaveric study, that the line seen on CT scans extending from the right margin of the inferior vena cava is not the inferior pulmonary ligament but prominent folds of parietal pleura formed by the mediastinal fat wrapping the right phrenic nerve [11]. Matsumoto et al. reported that on multi-detector CT, the left pericardiophrenic bundle, which contains the phrenic nerve, pericardiophrenic artery and pericardiophrenic vein, could be visually identified in 74% cases where most of them came in contact with the left atrial appendage, great cardiac vein and posterior vein of the left ventricle in anatomic route and it was best visualized on axial images at the level of the lateral wall of the left ventricle as a round structure with variable density [12]. In the present study, it was difficult to identify the pericardiophrenic bundle in the spicular or triangular structure, because of insufficient spacial resolution of CT images and motion artifact adjacent to the heart and great vessels. Based on the previous studies mentioned above, however, this structure most likely represents the pericardiophrenic bundles accompanied by a fold of the parietal pleura adjacent to the mediastinum.

There were two limitations in this study. First, chest radiograph was obtained in upright position while CT scan was performed in spine position. In addition, the subject raised both arms above head on CT examination. Precise comparison between the two modalities may not always be feasible. Second, radiograph and CT were not obtained on

exactly the same day. In 25 cases on the right side and 18 cases on the left side, the causes of cardiovascular border obliteration could not be explained by the phrenic nerve, pericardial fat pad, intra-fissure fat or overlapping pulmonary vessels, most frequently seen at the segment of the hilum. In these cases, the border obliteration may be associated with the contour of the cardiovascular margin, which is not tangential to the X-ray beam. However it was difficult to prove this relationship because of two limitations as mentioned before. There may be some other reasons for cardiovascular border obliteration, which cannot be determined on CT.

In conclusion, the phrenic nerve with accompanying vessels often forms a prominent fold of the parietal pleura and appears as a spicular or triangular structure adjacent to the mediastinum on CT. These structures can cause obliteration of the cardiovascular border on otherwise normal chest radiograph. If the cardiac border is unclear at the level of hilum or below the hilum without any abnormal findings in the lung field, the presence of phrenic nerve with accompanying vessels should be considered as a cause for it. Knowledge of the fact that the phrenic nerve with accompanying vessels can cause obliteration of the cardiovascular border on normal chest radiograph could be useful to avoid further examination.

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Table 1: Frequency of cardiac border obliteration on chest radiograph

	Right	Left
Absent	54	39
Present	46	61
Probably present	29	40
Definitely present	24	22
Total	100	100

Table 2: Number of cardiovascular border obliteration on chest radiograph in 100 subjects

	Right	Left
Above hilum	14	0
Hilum	25	35
Below hilum	21	13
Above the diaphragm	16	28
Total	76	76

Table 3: Number of phrenic nerve, fatty or vascular structures on CT images as possible causes of the cardiovascular border obliteration on chest radiograph in 100 subjects

	Right		Left	
	Number	Causes	Number	Causes
Above hilum	15	Phrenic nerve (n= 15)	2	Phrenic nerve (n= 2)
Hilum	18	Phrenic nerve (n= 18)	28	Phrenic nerve (n= 28)
Below hilum	30	Phrenic nerve (n= 23) Intra-fissure fat (n= 4) Overlapping pulmonary vessel (n= 3)	21	Phrenic nerve (n= 19) Intra-fissure fat (n= 1) Overlapping pulmonary vessel (n= 1)
Above the diaphragm	48	Intra-fissure fat (n= 25) Pericardial fat pad (n=23)	54	Intra-fissure fat (n= 7) Pericardial fat pad (n=47)

Table 4: Causes of cardiovascular border obliteration on chest radiograph analyzed by comparison with CT images

Cause	Above hilum		Hilum		Below hilum		Above diaphragm		Total	
	R	L	R	L	R	L	R	L	R	L
Pericardial fat pad	0	0	0	0	0	0	8	26	3/5	8/18
Phrenic nerve	8	0	11	20	15	9	0	0	15/19	10/19
Intra-fissure fat	0	0	0	0	1	1	6	2	0/7	2/1
Overlapping pulmonary vessel	0	0	0	0	2	0	0	0	2/0	0/0
Unknown	6	0	14	15	3	3	2	0	10/15	4/14

* (definitely obliterated / probably obliterated)

Figure Legends:

Fig. 1: Schematic diagram showing pathway of the phrenic nerve.
RPN: right phrenic nerve, RSV; right subclavian vein, RBCV: right brachiocephalic vein, SVC: superior vena cava, RA: right atrium, LPN: left phrenic nerve, LSV: left subclavian vein, LBCV: left brachiocephalic vein, AA: arch of aorta, LA: left atrium, LV: left ventricle

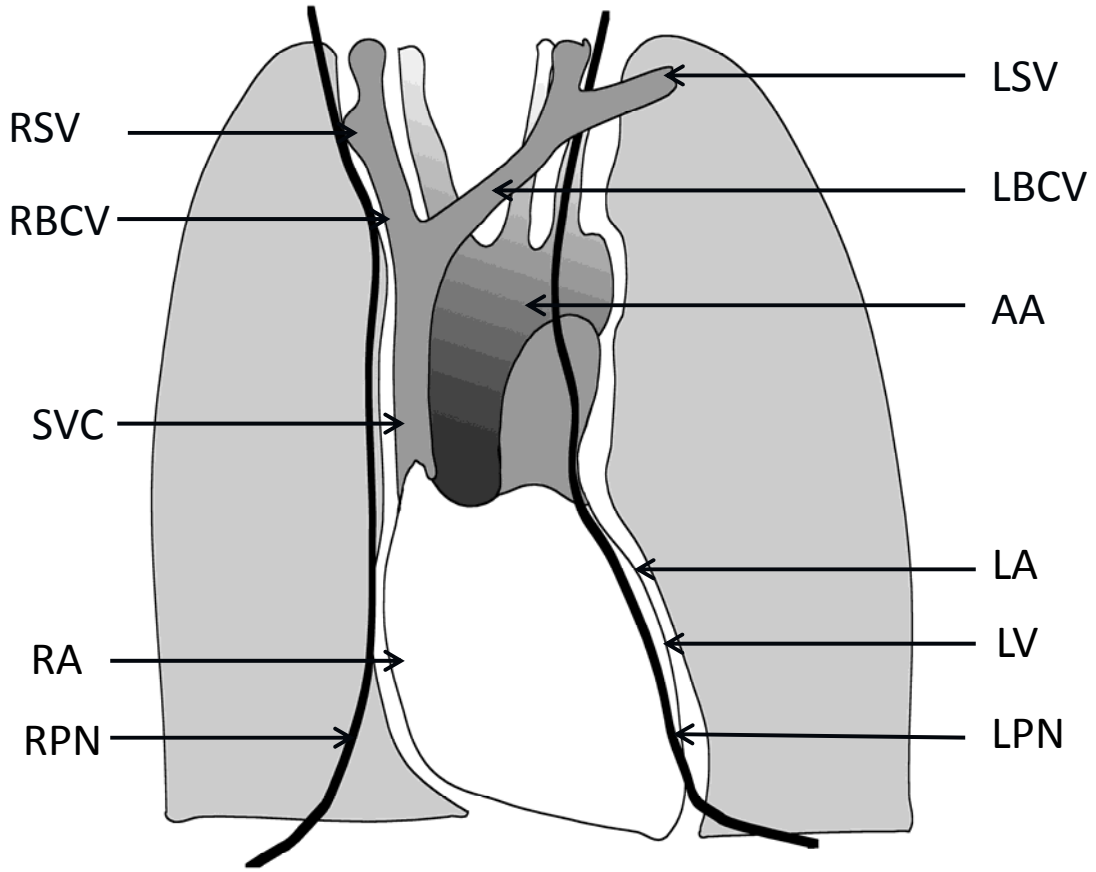
Fig. 2: Schematic diagram of the axial images of CT at three different levels (**a-c**) showing a triangular or spicular structure (arrows) corresponding to the course of phrenic nerve.

Fig. 3: **a** Cardiac CT image shows a triangular structure (arrow) below the hilum on the left side. **b** 3-D volume rendering image shows the left pericardiophrenic bundle passes (arrows) lateral to the fibrous pericardium covering the left surface of the left ventricle, which corresponds to the triangular structure on an axial CT image (**a**).

Fig. 4: Schematic diagram of frontal chest radiograph showing the four segments on both sides. 1= above the hilum, 2= hilum, 3= below the hilum, 4= above the diaphragm.

Fig. 5: **a** Frontal chest radiograph of a 19-year-old woman with no pathological finding shows cardiovascular border obliteration at the segments of above hilum, hilum and below the hilum on the right side and at the segment of hilum on left side (arrows).

b-d On axial CT images, obtained after 15 days, there are triangular structures (circles) in all mentioned segments of cardiovascular border obliteration on chest radiograph and it is confirmed as the phrenic nerve.



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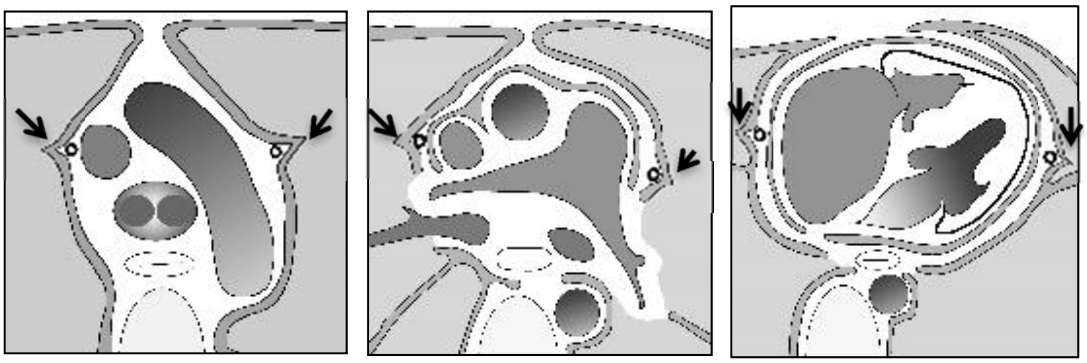

A B C

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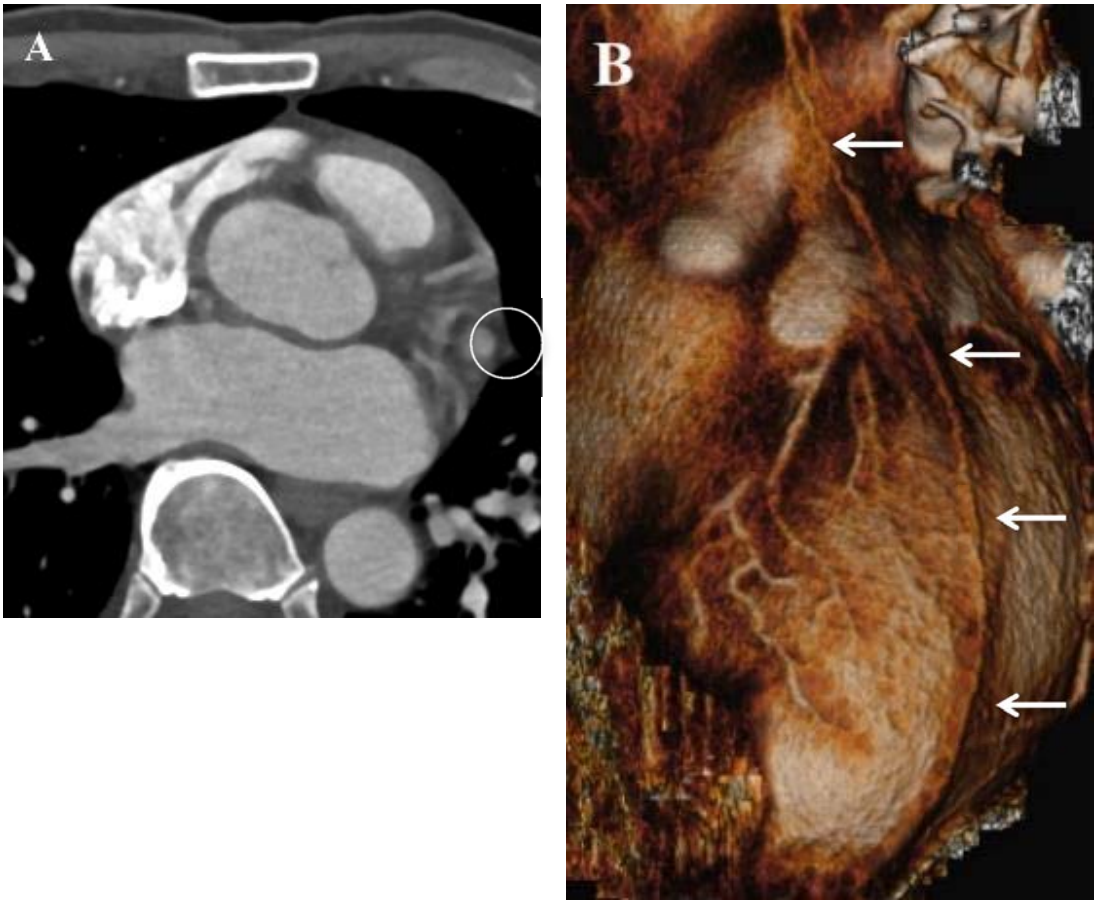

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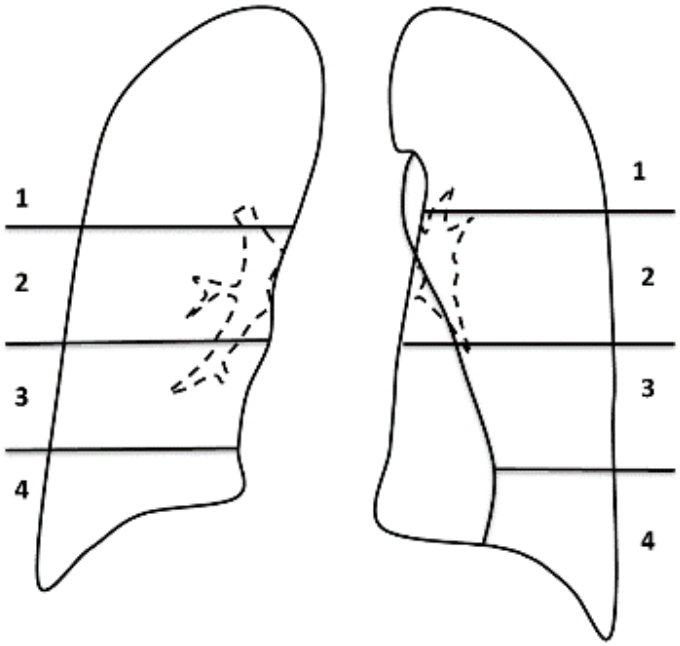

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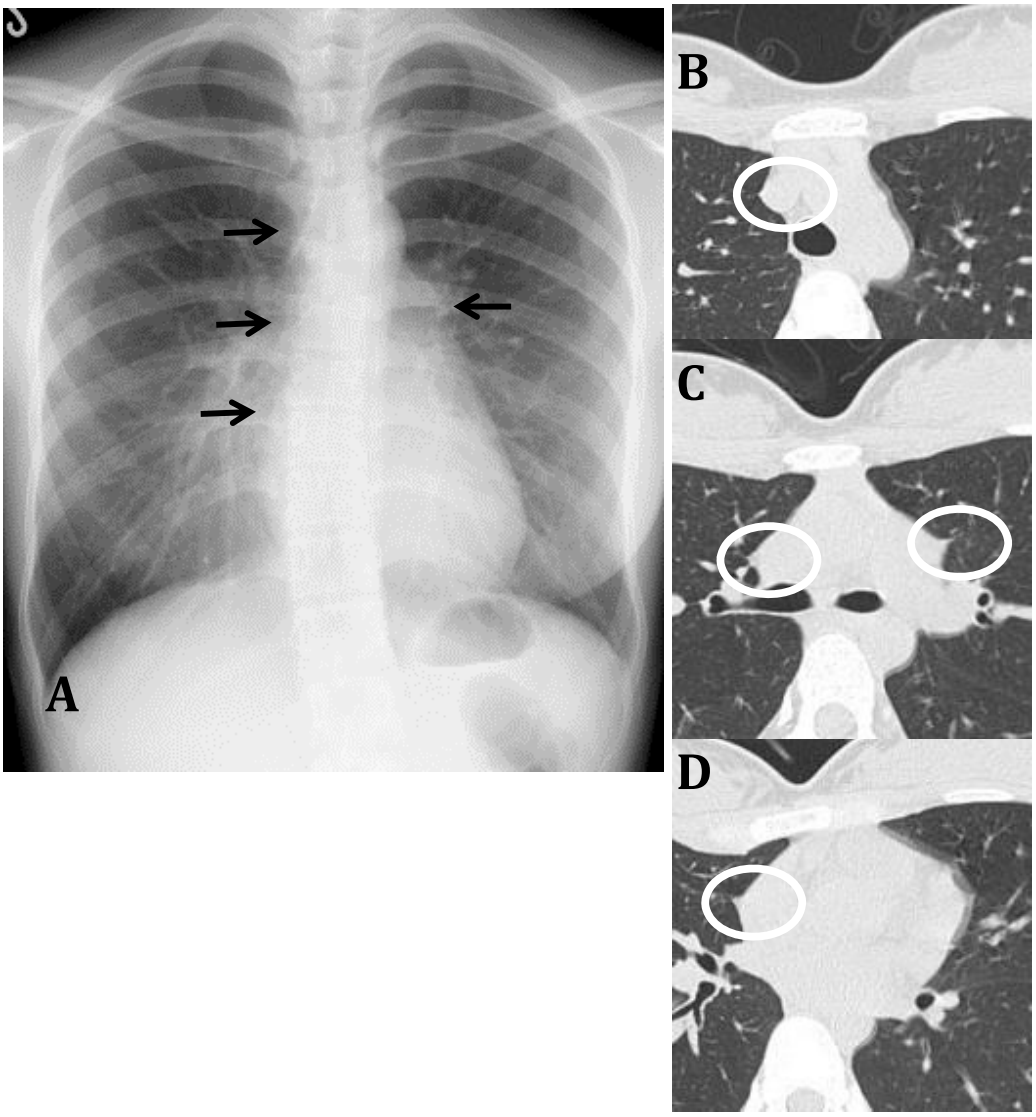

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b-d On axial CT images, obtained after 15 days, there are triangular structures (circles) in all mentioned segments of cardiovascular border obliteration on chest radiograph and it is confirmed as the phrenic nerve.