The Right Mediastinal Border and Central Venous Anatomy on Frontal Chest Radiograph—Direct CT Correlation

Peter T. Verhey, M.D., M.S., Marc V. Gosselin, M.D., Steven L. Primack, M.D., Paul L. Blackburn, R.N., M.N.A., Alexander C. Kraemer, B.S., M.E.

Abstract

We describe a direct and accurate method for defining chest radiographic anatomy and use this method to delineate the anatomic composition of the right mediastinal border in an adult population. Intravenous contrast-enhanced computed tomographic scans of the chest and accompanying scout tomograms from 99 adults without previously known or detected cardiopulmonary disease that could potentially distort mediastinal, cardiac, or pulmonary anatomy were retrospectively evaluated. Transverse CT images through the mediastinum were directly referenced to the respective acquisition location on the scout tomogram via the acquisition reference line. The anatomic composition of the right mediastinal border on the scout tomogram was determined by drawing a vertical line tangential to the most lateral right mediastinal structure in each transverse CT image. The lengths and relationships of these structures were tabulated. These results will help to create a consensus among radiologists and other clinicians regarding radiographic anatomy, allowing improved localization of mediastinal pathology and enabling more optimal positioning of vascular and cardiac support devices.

Introduction

The mediastinal borders on conventional frontal chest radiography are thought to be well-defined and understood. However, there is a surprising lack of literature definitively establishing the anatomic composition of these borders. Numerous publications address chest radiographic anatomy, but the actual anatomic composition of the radiographic mediastinum is indirectly inferred from cadaveric/surgical studies and cross-sectional imaging (Aslamy, Dewald, & Heffner, 1998; Chukwuemeka, Currie & Ellis, 1997; McComb, 2001; Procacci, Andreis, Caudana, Zonta, Martini, Graziani, et al., 1987; Proto, 1984; Proto, 1987). A detailed understanding of the composition of radiographic mediastinal borders is extremely important for detection and evaluation of pulmonary, mediastinal, and cardiac pathology. Additionally, a thorough knowledge of the chest radiographic appearance and location of central venous structures is important for the accurate localization and appropriate placement of medical support devices. We describe a direct and accurate method for defining frontal chest radiographic mediastinal anatomy and use this method to evaluate the composition of the right mediastinal border in an adult population.

Materials and Methods

Ninety-nine adults (≥ 18 years) in whom intravenous contrast-enhanced computed tomographic scans of the thorax and accompanying AP scout tomograms were obtained between 2004 and 2006 were retrospectively evaluated by the primary author (P.V.). The mean age of the study population was 48 years (range, 18—93 years); there were 43 males and 56 females. Inclusion criteria were all adult patients with intravenous contrast-enhanced CT scans and accompanying scout tomograms. Exclusion criteria were previously known or detected cardiopulmonary diseases, which could potentially distort mediastinal, cardiac, or pulmonary anatomy.

CT scans were performed with 16 and 64 detector scanners using 5-mm slice thickness and an average of 120 ml intravenous contrast. CT scans were performed during inspiratory breath-hold, with patients in the supine position and arms overhead. Transverse CT images through the mediastinum were directly referenced to the respective acquisition location on the scout tomogram via the acquisition reference line (Fig. 1A-C). The anatomic composition of the right mediastinal border on the scout tomogram was determined by drawing a line parallel...
to the CT table and then drawing a perpendicular line, tangential to the most lateral right mediastinal structure in each transverse CT image (Fig. 2A,B).

Using the transverse CT images, the following measurements were obtained in each patient: 1) length of the superior vena cava (SVC) (origin defined by the inferior margin of brachiocephalic vein (BCV) confluence where the SVC becomes cylindrical (Fig. 3A,B,E); SVC termination (i.e. cavoatrial junction, CAJ) defined by entry of the SVC into the right atrium (RA), where the cylindrical SVC flares into the RA chamber and the crista terminalis tissue no longer separates the anterior wall of the SVC and the posterior wall of the right atrial appendage (RAA) (Fig. 3C-E)); 2) origin and termination of the SVC relative to overlying anterior intercostal spaces (ICS); 3) origin and termination of the SVC relative to the carina; 4) position of the azygos-superior vena cava junction (defined by inferior margin of azygos vein entry into posterior wall of SVC) relative to superior vena cava origin and CAJ; and 5) relationship of SVC-superior right cardiac border junction to CAJ. These data were tabulated and analyzed using (Minitek® Statistical Software R14, PA).

Results

The right superior mediastinal border (from approximately 1 cm above the azygos vein to the right superior cardiac border) was almost always formed exclusively by the lateral border of the SVC. Infrequently, minor components of the border were formed by a mildly tortuous or dilated ascending aorta and/or the lateral wall of the azygos arch (Fig. 1A and Fig. 2A,B).

Mediastinal composition more than 1 cm cephalad to the azygos vein is variable and may consist of SVC, right BCV, and/or innominate artery. No anomalous vessels were detected in our study population. The average length of the SVC was 7.6 cm (range, 5.0—10.5 cm, S.D. ± 1.2 cm).

The most superior right cardiac border-forming structure on scout tomograms was the right atrial appendage (RAA) in 100% of patients (Fig. 4A & 4B). The junction between the vertically-oriented lateral border of the lower SVC and the convexity of the right cardiac border can therefore be referred to as the SVC-RAA junction (Fig. 5). The average distance from the SVC-RAA junction to the CAJ was 1.8 cm (range, 1.0—3.0 cm, S.D. ± 0.5 cm).

The remainder of the right cardio-mediastinal border below the RAA was formed by the right atrium (RA) in 100% of patients. The average distance from the carina to the CAJ was 4.7 cm (range, 2.5—7.2 cm, S.D. ± 1.1 cm). The average azygos vein-SVC junction was 1.3 cm (range, 0—3.0 cm, S.D. ± 0.74 cm) below the SVC origin and 6.2 cm (range, 4.0—9.5 cm, S.D. ± 1.1 cm) above the CAJ. The most cephalad aspect of the azygos vein seen on scout tomogram was never seen above the SVC origin. The 1st and 2nd ICS most commonly overlie the origin of the SVC (45% 1st and 55% 2nd, average, 1.4 ICS) and the 3rd and 4th ICS most commonly overlie the CAJ (39% 3rd and 52% 4th, average, 3.5 ICS).

No significant gender variation was observed in any of the cited measurements.

Discussion

To our knowledge, this is the first study using a direct method to characterize the radiographic composition of the right mediastinal border. Previous studies investigating the potential radiographic composition of the mediastinum indirectly determined mediastinal composition from cadaveric/surgical anatomy or cross-sectional images (Aslamy et al., 1998; Chukuwuemeka et al., 1997; McComb, 2001; Procacci et al., 1987; Proto, 1984; Proto, 1987). The direct characterization of the radiographic anatomy in this study limits inherent errors of inference, permitting accurate determination of radiographic structures and their inter-relationships.

A thorough understanding of the composition of the radiographic mediastinal border is extremely important for evaluation of potential thoracic pathology, as well as for accurate localization of medical support devices, particularly central venous catheters. Numerous publications and clinical practice guidelines indicate the importance of accurate positioning of central venous catheters to minimize catheter-related complications, such as malposition, occlusion, thrombophlebitis, and
vascular/cardiac mechanical injury. In fact, peripherally-inserted central venous catheters (PICC) are specifically recommended to be positioned in the lower SVC-CAJ region by numerous vascular access societies (Vesely, 2003). PICC’s in this position optimize the basic principles of appropriate catheter placement, including high-blood flow location, catheter lying parallel to the vessel wall, and catheter-tip motion from cardiac pulsatility and blood turbulence. PICC positioning within the lower SVC-CAJ region leads to fewer subsequent malpositions, decreased rates of catheter and venous thrombosis and infection, and better overall catheter performance (Vesely, 2003). Additionally, recent advances in PICC technology have enabled central venous pressure monitoring, providing another reason for accurate and optimal catheter positioning. Consequently, radiographic evaluation of central venous catheter location to determine potential associated complications following catheter placement is considered an integral component of the procedure.

Numerous studies attempt to define radiographic landmarks for optimally localizing PICCs (Vesely, 2003). However, most of these studies use non-vascular structures such as vertebral bodies, clavicles, carina, and right tracheobronchial angle, as anatomic reference guidelines for vascular structures, potentially creating inaccuracy due to parallax and rotation. As demonstrated in our study, the frontal chest radiograph can almost always directly visualize central venous anatomy and accurately determine the location of catheters and other medical support devices.

Dr. Aslamy and colleagues (1998) used coronal MRI to characterize the central venous anatomy and to evaluate other structures that could reduce potential catheter localization inaccuracies encountered with non-vascular landmarks. In their study, they inferred radiographic mediastinal anatomy from cross-sectional data, creating a source of inherent inaccuracy. They concluded that the left atrium comprised the radiographic right superior cardiac silhouette in 38% of patients and that the cephalad aspect of the azygos arch was cephalad to the SVC in 19% of patients. In contrast, we found that the right superior cardiac border was formed by the right atrial appendage in all of our patients. Additionally, the caudal margin of the azygos vein was found to be an excellent landmark for defining the cephalad origin of the SVC. The caudal margin of the azygos arch on scout tomogram was never above the caudal margin of the BCV confluence. Finally, in our adult patient population, the actual entry point of the SVC into the RA (i.e. CAJ) was always located between 1 and 2 cm below the SVC-RAA junction on scout tomogram.

Therefore, catheters (i.e. PICCs) that are recommended to be positioned in the region of the cavoatrial junction to minimize complications and maximize performance should be located 1-2 cm below the SVC-RAA junction on chest radiographs in adult patients.

Study limitations include use of the scout tomogram as representative of the conventional AP/PA chest radiograph, because the radiographic technique used to acquire the scout tomogram is slightly different than conventional chest radiography (supine positioning and arms overhead for scout tomogram acquisition). In addition, the exclusion of patients with known or detected cardiopulmonary disease with the potential for altering mediastinal anatomy limits the generalizability of our results.

Study strengths include the large patient population size evaluated and the accuracy and reproducibility of the described method to directly delineate radiographic mediastinal structures. In this study, no indirect inference from cross-sectional imaging or cadaveric/surgical dissection was required to characterize the composition of mediastinal structures on chest radiograph.

These results will allow consensus among radiologists and other clinicians regarding radiographic right mediastinal anatomy, enabling improved localization of mediastinal pathology.
and better positioning of vascular and cardiac support devices. Importantly, standardized reporting of catheter locations within venous structures should be possible. For example, terminology such as “projecting over the SVC” should not be necessary, unless the catheter follows an atypical course or a catheter placement complication has developed. Alternatively, with a better understanding of radiographic mediastinal anatomy and the clinical importance of catheter location, a catheter positioned 1 cm cephalad to the SVC-RAA junction on frontal chest radiograph could be interpreted as “catheter tip located within the lower SVC, approximately 3 cm above the CAJ.”

Possible future research using the described methods will include determination of the structures comprising the chest radiographic left mediastinal border in normal adult patients, the chest radiographic mediastinal borders in the pediatric population, and finally, the evaluation of radiographic mediastinal borders in various pathologic states.

**Acknowledgments**

Dr. Verhey receives financial support from Bard® Access Systems, Inc. This support poses no conflict of interest in relation to this article.

**References**


McComb, B.L. (2001). Reflecting upon the left superior mediastinum. *Journal of Thoracic Imaging* 16(1), 56-64.


---

**Fig. 5**—Frontal chest radiograph demonstrating the right lateral wall of the superior vena cava (open arrow) and the junction of the lower SVC with the superior convexity of the right cardiac border (SVC-RAA junction) (closed arrow). The cavoatrial junction (*) lies approximately 1-2 cm below SVC-RAA junction in adults.