The Correlation of Subcarinal Density Visualized on Plain Chest Roentgenograms with Computed Tomographic Scans

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A prospective evaluation of 212 paired chest roentgenograms and computed tomographic (CT) scans was performed to determine the predictive value of detecting subcarinal adenopathy by finding increased subcarinal density on routine roentgenograms. Based on CT criteria for subcarinal lymphadenopathy, 37 true-positive and 124 true-negative cases of subcarinal adenopathy were found in 161 patients. Evaluation of density in the subcarinal area on the routine posterior-anterior (PA) chest roentgenograms in these patients demonstrated a sensitivity of 72 percent and specificity of 96 percent for the detection of adenopathy when compared with established CT criteria. False-positive and false-negative appraisals of central mediastinal density on routine roentgenograms appear to be due to the superimposition of other masses, bullae, or lack of appropriate roentgenographic contrast. The accuracy of predicting the presence or absence of subcarinal adenopathy from routine chest roentgenograms suggests that this observation is clinically useful and should be routinely evaluated.

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The detection of adenopathy within the central mediastinum remains a difficult task. Prior to modern scanning techniques barium esophagel studies and planar chest tomography were commonly relied on to detect adenopathy in this region. As these indirect methods have become supplanted by computed tomography (CT) and magnetic resonance imaging (MRI), the process of nodal evaluation has become greatly refined. Specific nodal regions have been partitioned and thresholds have been set for defining abnormal nodal enlargement. Still, the sheer economics and time constraints of scanning every patient for the possibility of adenopathy limits the application of these newer methods to those candidates preselected by the detection of abnormalities on standard chest roentgenograms or those considered to be at exceptional risk. Over the last four years, to gauge mediastinal adenopathy, we have used a comparison of central roentgenographic density in the subcarinal region with the density of nearby mediastinal areas. We have found this technique useful for the evaluation of routine roentgenograms prior to bronchoscopy and to predict the presence of nodes prior to using other imaging modalities. At the behest of our colleagues we engaged in the following prospective study to assess the validity of routinely evaluating chest roentgenograms for the presence or absence of increased subcarinal density.

METHODS AND MATERIALS

Adult patients with paired single-view posterior-anterior (PA) chest roentgenograms and CT chest studies were identified through bronchoscopy and CT logs at both the University of Michigan Medical Center (UMMC) and the Ann Arbor Veterans Administration Medical Center (VAMC). The PA chest roentgenogram with the best mediastinal contrast within three weeks of the CT examination was chosen for close evaluation. Prior to the determination of central density, the three authors graded each single PA view chest x-ray film in terms of exposure quality to assure an adequate range of mediastinal contrast. This grading was based on the number of vertebral bodies visible through the lower cardiac silhouette (categorized as underexposed, adequate exposure, or excellent exposure: 0 to 1, 2 to 3, and 4 or more visible vertebral bodies, respectively). The normally lucent subcarinal region bordered to the top and right by the right mainstem bronchus and by the left mainstem and descending aortic shadows was then evaluated. Subcarinal density was determined in a qualitative fashion relative to the central mediastinal areas immediately above the carina (discounting for tracheal luency) and from 4 to 6 cm below the carina through the cardiovascular silhouette (see comparison regions of Fig 1 and 2). The presence or absence of increased subcarinal density was then rated on a five-point scale: 1. completely empty (lucent); 2, doubtful; 3, indeterminate; 4, probable; and 5, clearly filled (dense). Subcarinal ratings of 1 and 2 and those of 3, 4, and 5 were combined as negative and positive groups. Examples of these are provided in Figures 3 and 4.

Computed tomographic scans were evaluated in a blinded random sequence for the presence of adenopathy and mediastinal abnormality. Nodes were measured over their maximal long axis, short axis, and in terms of their longitudinal extent through contiguous 10-mm CT slices. On the basis of published studies thresholds of 1 cm short axis, 1.5 cm long axis, or appearance in two successive 1-cm CT slices were used to determine nodal enlargement. The overall volume of tissue in the subcarinal space was calculated to incorporate each threshold limit and reduce the reliance on single

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measurements. Determination of this subcarinal volume was based on the formula for an elliptical cone (volume = π/3 a b h/3). A volume of 0.8 cu cm was used to indicate significant subcarinal adenopathy (1 × 1.5 × 2 cm pyramidal shaped nodal collection). This calculation compensates for any angulation of nodes and provides a quick means for searching the patient database.

Roentgenographic and CT data from each case were collated and entered into the study in a serial fashion. Because assessing the subcarinal area requires that adequate gray scale contrast exists over the mediastinum, any study pair with inadequate roentgenographic exposure (underexposed) independently rated by two or more observers was eliminated from further consideration. This was done by sifting the overall computerized database by the radiologic criteria of readability alone without knowledge of positive or negative nodal status. This decision preserved a minimum of two observations on each x-ray film. Using standard statistical analyses, mean, standard deviation, and frequency statistics were calculated for each observer's scores. True and false, positive and negative cases were determined on the basis of CT nodal volume. Values for test sensitivity and specificity were derived from these tables.

**Roentgenographic Technique**

Standard PA chest roentgenograms were produced at a distance of 72 inches with exposures of 120-125 kV and 2 to 5 milliamperes seconds (MAS). Dupont Cronex 10/250 cassette and Kodak OC/Lanex medium 400 ASA film/screen combinations were used. Thoracic CT scanning was done with 2-s scans by either a GE 9800 series scanner (UMMC), typically at 120 kV 140 MAS with a focal diameter of 34 to 48 cm, or a Picker 1200SX scanner (VA) at 130 kV 95 MAS and a focal diameter of 42 cm.

**Figure 1.** Displayed are superior and inferior regions of interest to be used in comparison with the middle subcarinal zone. Regions are compared in terms of relative central density over the spine, immediately above and below that of the subcarinal area.

**Figure 2.** Idealized representation of the increased central mediastinal density occurring as a result of enlarged subcarinal nodes.

**Figure 3.** Negative case. This is the posteroanterior chest roentgenogram of a 60-year-old man being evaluated for deep central chest pain. Exposure contrast is good with vertebral bodies easily visible through the lower cardiovascular silhouette. Note the lack of central mediastinal density with similar appearance of areas immediately above and below the subcarinal region. The thin overlying oblong density is due to the anterior pleural reflection between the right and left lungs (arrowsheads) and should be disregarded during this type of density comparison.

**Figure 4.** Positive case. This is the initial posteroanterior chest roentgenogram of a 61-year-old man undergoing evaluation for a persistent cough. Note the enhanced density of the subcarinal region compared with immediately above and below this area. No evidence of expanded mediastinal contours is present in either the right paracardial, aorto-pulmonary window, or subcarinal region. Subsequent computed tomographic scan revealed a 2.5 × 3 cm subcarinal node extending through three successive slices.

Correlation of Subcarinal Density with CT Scans (Hammersley, Grum, Green)
RESULTS

Two hundred twelve adult patient examination pairs were prospectively evaluated. Of these, 51 chest roentgenograms were independently determined by two or more readers to be underpenetrated and were therefore dropped from analysis. The discarded cases had a similar rate of positive nodes as the remaining cases (29 percent vs 23 percent). Of the 161 remaining cases, 35 were females and 123 were males. Based on CT criteria, 37 patients were found to have significant adenopathy in the subcarinal area, with no significant subcarinal adenopathy in the remaining 124. Individual observer and mean results for subcarinal scoring are listed in Table 1. On average, 21 of the 37 true-positive cases were judged positive on the chest roentgenogram with an observer range of 9 to 28 and a mean of five false-positives per reader. On average each observer rated 14 cases (9 percent) as indeterminate, indicating that they could not reliably judge the subcarinal area. One hundred twenty-six cases were considered negative. These included 111 of the 124 true-negative cases and 15 false-negatives. The calculated sensitivity of finding increased subcarinal density is therefore 72 percent and the specificity of this sign is 96 percent. Two other indices are pertinent for studies of this kind. The usefulness or predictive value of a positive or negative test depends on the prevalence of the disease, in this case adenopathy, in the population under study. If the prevalence rate of this population undergoing CT examination is used (0.23, 37 positive cases of 161), the predictive value of finding increased subcarinal density with the actual presence of adenopathy ranges from 82 to 95 percent. The predictive value of finding subcarinal lucency with true absence of adenopathy ranges from 95 to 97 percent due to the skewing effect of a large number of true-negative cases.

Cases falsely read as having subcarinal adenopathy, especially when missed by two or more observers, typically had increased subcarinal density due to a superimposed secondary density. Causes for falsely predicting subcarinal adenopathy included an anterior mediastinal mass, a posterior esophageal mass, a densely sclerotic spine, and a very large left atrium. The large number of false-negatives were believed to have been caused by overpenetrated radiologic technique that limited central mediastinal contrast. Only patients with “underexposed” roentgenograms were eliminated prior to analysis, as potentially overexposed x-ray films did not have a specific prospective standard for detection. Additional errors appear to have been caused by the loss of normal adjacent areas for comparison to the subcarinal region. Large bullae, mediastinal shifts off the spinal column, and in two cases, tumor extension both above and below the subcarinal region obscured any relative density differences within the region of interest.

DISCUSSION

While determination of the presence of mediastinal adenopathy is of primary concern in the staging of lung cancer, the presence of even transitory nodal enlargement in the subcarinal area is also of interest in the course of granulomatous and other nonmalignant diseases. At present, with all imaging techniques, assessment of nodal abnormality depends primarily on measurements of physical size. The evaluation of normal ranges for nodal dimensions throughout the mediastinum has been significantly enhanced by the American Thoracic Society regional mapping system. Using this nodal classification schema, a series of studies have demonstrated significant differences in the size of histologically normal nodes from different regions. Our present study used these published upper limits to provide a single volume measurement capable of detecting nodal enlargement. Alterations in tissue density within the subcarinal area and its anteroposterior thickness combine to produce the radiologic density of this space on routine frontal roentgenograms. Partial or total calcification of subcarinal nodes will therefore enhance the net visibility of this area. In contrast, several anatomic variants have the potential to effect radiologic density with and without obliteration of local contrast differences. Extensive fat surrounding subcarinal nodes may eliminate local density differences and fill mediastinal recesses without contributing to a major increase in subcarinal density. In a similar fashion anterior and posterior masses may alter the visible degree of density in this area by providing additional absorption of x-rays in the overlying tissue and yet leave air/tissue interfaces intact. Effective overall central mediastinal density

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In 1985 Muller et al. described the detectability of subcarinal adenopathy in terms of the loss of visibility of the medial right main bronchial wall. While not their major consideration, the sensitivity of observing subcarinal opacity in their cases can be calculated as 40 percent, primarily due to a 60 percent false-negative rate. The specificity of their observation of subcarinal density was 93 percent, similar to ours. These results may exhibit less accuracy than our study due to a lack of correction for roentgenographic technique. Both the study of Muller et al. and our own emphasize that specific observation for subcarinal density must be made relative to adjacent regions. Care must therefore be taken to preserve gray scale contrast over the central mediastinum in roentgenograms undergoing this form of evaluation. Exposure technique that emphasizes display of the medial border of the right mainstem bronchus will likely be overpenetrated relative to the preservation of appropriate central gray scale. Legmann and Grenier, in a study of 300 normal subjects, noted the obvious presence of subcarinal lucency in 83 percent of normal subjects but found that display of the right medial bronchial wall was inconsistent. In 30 cases with subcarinal pathology, they commented that the observation of increased central density was highly suggestive of subcarinal abnormality.

In our study of 161 cases, examination for increased central mediastinal density alone was made relative to surrounding areas without specific attention paid to the presence or absence of tissue/air interfaces. While this differs from the data of Muller et al., it supports and significantly extends the work of Legmann and Grenier. The asymmetry in our numbers of true-false and true-negative cases is proportionally similar to both of these studies and cannot alone account for the improved outcome in our investigation. Our results indicate that with experience multiple readers can achieve individual accuracy from 82 to 95 percent in properly suspecting adenopathy and 95 to 97 percent in accurately predicting its absence. We believe that these results are also not significantly influenced by knowledge of other thoracic abnormalities. Our previous experience with this sign indicates that there is poor correlation between enlargement in individual nodal areas and the presence of masses or local collapse. The current study therefore did not eliminate such possible influences, as the entire PA roentgenogram was viewed in an effort to judge overall exposure contrast, not just the mediastinal area. We believe that our restriction of analyzed cases to those x-ray films with proper exposure technique played the greatest role in improving our results over those previously obtained.

The results of these previous studies and our current investigation strongly support the validity of examining chest roentgenograms for increases in subcarinal density and associated loss of air/tissue interface lines. The predictive ability of this subcarinal sign suggests that it should be used more widely. We believe this sign also to be of value when an old CT scan is unavailable for comparison of mediastinal structures but a well-exposed chest roentgenogram is. In practice we do not advocate the use of this sign to abrogate choosing advanced scanning modalities when their use is indicated or strongly desired, but instead we advocate its use to help determine the need for scanning in low-yield situations and to aid retrospective review of a patient's course. Explicit evaluation of the subcarinal region can be of great value on all chest examinations and should be routinely employed.

REFERENCES

5. Genereux GP, Howe JL. Normal mediastinal lymph node size and number: CT and anatomic study. AJR 1984; 142:1095-100