Computed tomography of the thorax[1]

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This article reviews the impact of computed tomography (CT) on the recognition and diagnosis of diseases of the thorax. Topics discussed include the chest wall, pleura, and fissures; chest trauma; mediastinal masses; the thoracic aorta; other vascular applications; metastatic disease; solitary pulmonary nodules; interventional techniques; and bronchogenic carcinoma. CT can greatly enhance the ability of the radiologist to identify disease, define its extent, and, in some cases, aid in the guidance of an interventional procedure. The major advantages of the modality are related to the axial anatomic display and its superior density discrimination capabilities.

Index term: Thorax, computed tomography

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In the 1970s, the coupling of computer technology with imaging techniques provided a new method of visualizing anatomic detail in the axial plane. This new medical technology, computed tomography (CT), excited tremendous interest and controversy. Research led to the rapid development of four generations of CT scanners within a decade, each generation providing higher quality images in a shorter period of time. Scan time, resolution, and patient throughput have now reached practical end points and will probably only benefit from modest refinements in the future. Major limitations at present are related to x-ray tube design and practical limitations of exposure dose. This article reviews the areas within the thorax where CT imaging has made a useful contribution.

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A

B

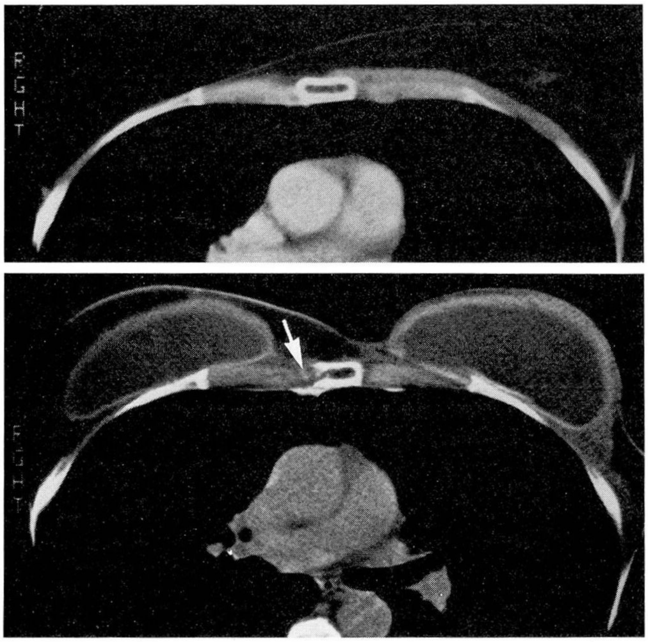


Fig. 1. **A.** High-resolution CT scan of the anterior chest wall after right mastectomy for breast carcinoma.

B. CT scan of the anterior chest wall obtained 9 months subsequent to **A** demonstrates the presence of bilateral breast prostheses. Note a mild alteration in density of the right parasternal chest wall tissues with associated sternal destruction (arrow) on the right lateral margin secondary to recurrent breast carcinoma in the anterior chest wall.

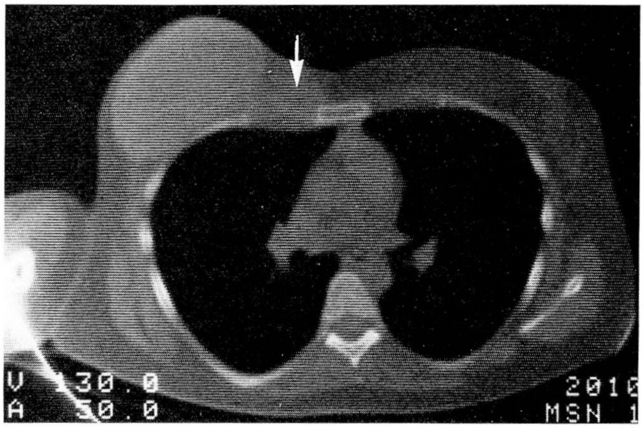


Fig. 2. CT scan demonstrates a parasternal soft-tissue mass on the right side (arrows). Note the right breast implant, which was performed subsequent to mastectomy for carcinoma. A CT-guided biopsy of this lesion showed recurrent breast carcinoma.

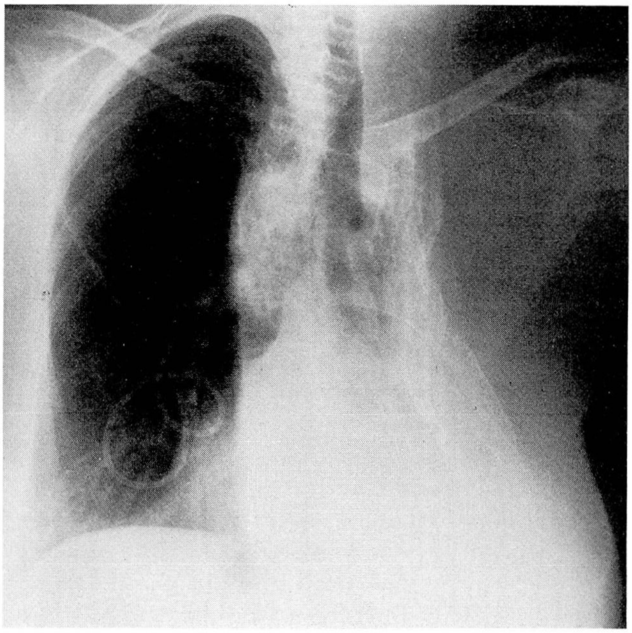
Chest wall, pleura, and fissures

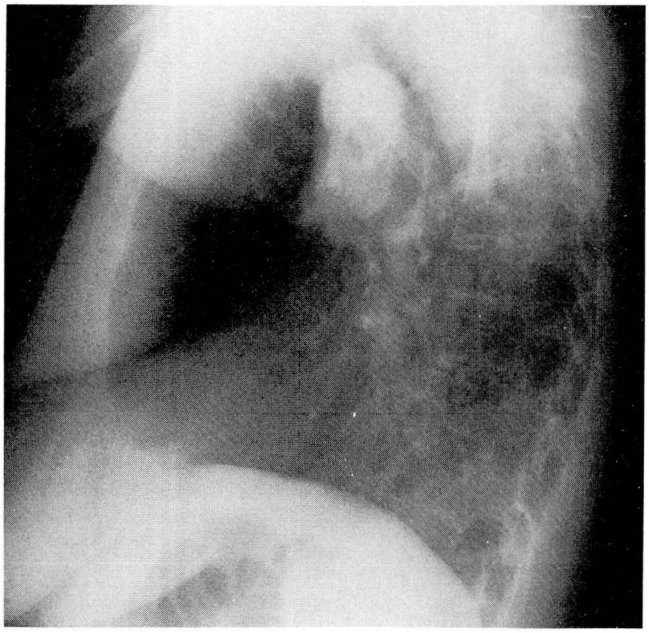
Because of the advantages of the transverse plane, CT can play a unique role in the assessment of chest wall thickness, alteration of soft-tissue structures, and the rib cage. In patients with primary or secondary tumors involving the chest wall, demonstration by CT of the total extent of disease can affect the choice between radical surgery or radiotherapy as palliative treatment. We have found this imaging modality to be extremely useful in the evaluation of the anterior thoracic wall in patients being considered for reconstructive surgery following mastectomy. The modality has also been found useful in the evaluation of the chest wall subsequent to breast reconstruction (*Figs. 1* and *2*). Recurrent disease arising in the muscles of the anterior thoracic wall is readily displayed in the axial plane.[1] Tumors located in the upper inner quadrant of the breast often metastasize to the internal thoracic lymph nodes. Minimal lymphadenopathy involving this group of nodes is more readily appreciated on axial CT sections than on conventional lateral radiographs of the thorax.

Primary and secondary pleural tumors are well evaluated by CT. In the case of malignant mesothelioma, this modality depicts the rind of tumor encasing the lung and allows appreciation of invasion of the pericardium, mediastinum, diaphragm, and contralateral hemithorax. In a report of the CT findings in nine patients with this disease,[2] five were found to have unsuspected abdominal extension of tumor. Serial scans during treatment provide objective evidence of tumor growth or regression.

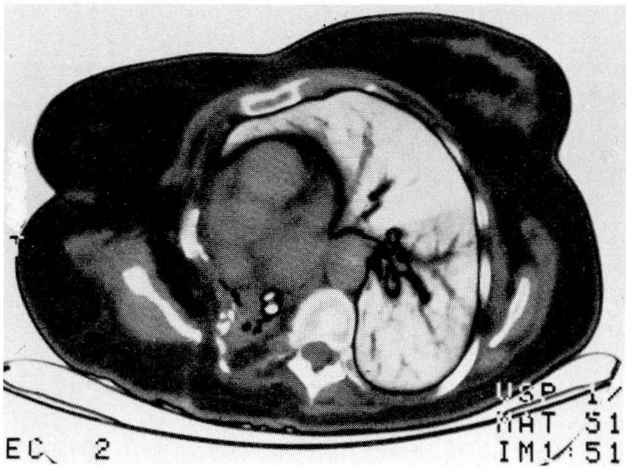
Shuman and Libshitz,[3] in a review of 71 cases of lymphoma, found 31% demonstrated solid pleural manifestations of lymphoma. Pleural-based lymphoma represented either a site of recurrence or an additional intrathoracic site of presentation. In no case did it represent the solitary initial manifestation of disease. CT imaging is uniquely sensitive to the presence of abnormalities involving the pleura.

Proto and Ball,[4] in an excellent article, reviewed their experience concerning identification of the major and minor fissures. They point out that identification of the fissures on computed tomograms may be useful in localizing and analyzing pulmonary processes. The major fissure may appear as a lucent band, a line, or, less





A,B



C

Fig. 3. Conventional chest radiographs (**A** and **B**) after thoracoplasty for treatment of left upper lobe tuberculosis. Distortion of the left hemithorax precludes radiologic appraisal of the left lung. The patient had a fever of unknown origin. The CT scan (**C**) reveals the presence of an infiltrate in the posterior portion of the surgically deformed left hemithorax.

frequently, as a dense band. The distribution of the minor fissure is visualized as a lucent area on CT scans of the thorax. Portions of the major fissures are identified on approximately 85% of CT scans of the thorax. The superior portions of the major fissures are more frequently visualized than the inferior portions.

In the evaluation of 75 patients with complex pleural and parenchymal disease, Pugatch et al[5] found CT provided information not otherwise available in one-third of their patients. CT was found to be particularly useful in the definition of diseases involving the pleura and extrapleural space and their separation from underlying parenchymal abnormalities. An example of the usefulness of this application is shown in *Figure 3.*

Chest trauma

The cross-sectional anatomic display afforded by CT facilitates rapid recognition of the consequences of thoracic trauma. Injuries to the thorax play a major role in one-third to one-half of all fatalities related to traffic accidents. Accurate assessment of these injuries is of paramount importance in planning therapy. In a retrospective study reported by Toombs et al,[6] CT and conventional radiography were used to study 20 patients with chest injuries. CT revealed a total

Fig. 4. CT scan demonstrates the presence of a soft-tissue mass posterior to the tracheal air column within the superior mediastinum. The axial anatomic display and superior density discrimination of CT allow identification of both calcification (arrowhead) and a colloid cyst (arrow) within the goiter. These findings were not seen on conventional plain radiographs.

of 50 traumatic lesions ranging from pericardial fluid collections to diaphragmatic rupture. Only 12 of these were detected on plain radiographs.

Mediastinal masses

CT allows excellent visualization, anatomic assessment, and characterization of mediastinal masses. Because of the uniform low attenuation coefficient of adipose tissue on computed tomograms, this modality facilitates such diagnoses as mediastinal lipomatosis and discrete mediastinal lipomas. It provides information pertaining to the boundaries and to the consistency of mediastinal masses (*Fig. 4*). In the majority of cases, it will allow differentiation of cystic from solid masses within the mediastinum. A recent report by Mendelson et al[7] dealt with four cases of bronchogenic cysts that showed unusually high attenuation values, suggesting that they represented solid lesions. The authors suggested that the high readings were due to the turbid contents of the cyst and that the diagnosis of bronchogenic cyst cannot be excluded on the basis of a high CT number.

CT may be useful in the evaluation of the thymus gland. Its usefulness, however, may depend on the state of the normal thymus. The normal thymus has a bilobed, arrow-shaped cross-section at all ages with gradual focal or diffuse fatty infiltration of the parenchyma usually occurring between 20 and 40 years of age.[8] Mink et al[9] describe the CT appearance of the anterior mediastinum in patients with myasthenia gravis and suspected thymoma. Sweeney and O'Donovan[10] suggest that the presence of a thymoma is extremely unlikely in the presence of an anterior junction line on a high-quality posteroanterior radiograph of the chest plus a negative antistriational antibody test.

Kirks et al[11] have reported the usefulness of CT in the evaluation of middle mediastinal masses in the pediatric population. They comment that thoracic CT not only demonstrates the presence of extrinsic airway compression in pediatric patients with mediastinal masses, but also is capable of providing precise measurement of the degree of luminal compromise present. The method thereby may be used to identify children at potential risk for respiratory compromise. Shurin et al[12] report the usefulness in the pediatric age group of CT in differentiating primary parenchymal masses from those arising within the mediastinum.

Thoracic aorta

Conventional CT with intravenous contrast material injection effectively demonstrates the features of aneurysms of the thoracic area (dilatation, calcification, intramural thrombus, and displacement and erosion of adjacent structures). In aortic dissection, CT can establish the diagnosis by demonstrating either a double lumen with an intimal flap or displaced intimal calcification separating a patent lumen from the lower-attenuation area characteristic of a thrombosed lumen. Dynamic CT following a contrast material bolus shows the relative rate of filling of the true and false channels when both are patent and demonstrates the intimal flap with optimal clarity. CT is noninvasive and can be easily repeated to assess progress. Although aortography is still required prior to surgery in some cases, CT is a safe screening procedure that may replace invasive angiographic procedures in some cases.

Dissection is the most common acute catastrophe involving the aorta. Prognosis depends upon early diagnosis, correct classification, and management. Conventional chest radiographs may reveal characteristic signs such as a widening of the aorta, displacement of intimal calcifications, and mediastinal or pleural hematoma, any or all of which require immediate confirmation or exclusion by aortography. Other noninvasive methods such as echocardiography (including two-

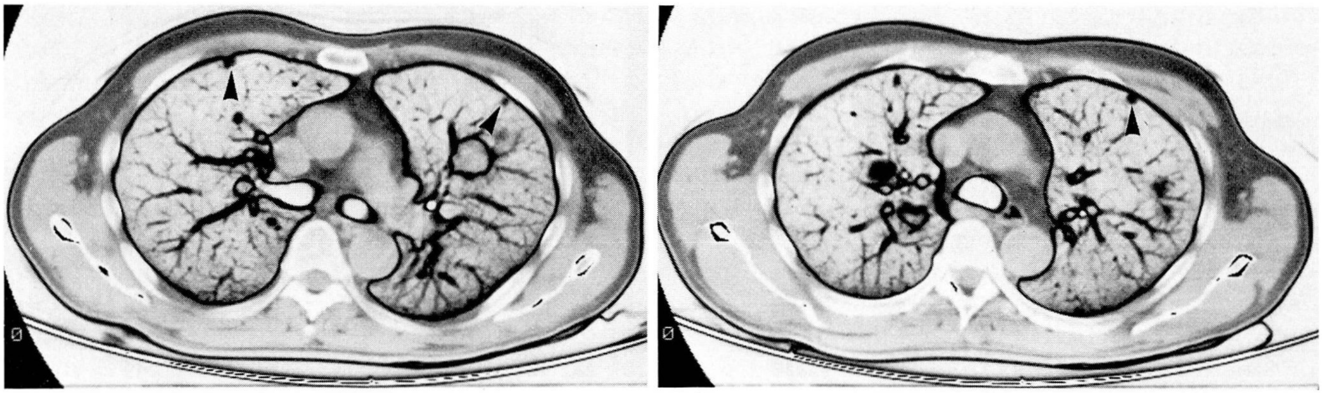


Fig. 5. This patient underwent both conventional tomography and computed tomography of the chest to assess the extent of metastatic thoracic disease. Although the larger parenchymal nodules, identified in the left lung on **A** and in the right lung on **B**, were seen on conventional tomograms, the small pleural-based metastatic lesions in the anterior thorax (arrowheads) were not visualized on conventional linear tomography of the chest.

dimensional studies) have major limitations, including difficulties in imaging the entire thoracic aorta; CT is a reliable method of evaluation, potentially allowing identification of the site and extent of dissection.

Saccular and fusiform aneurysms are more common than dissections in the thoracic aorta, although acute rupture of an aneurysm occurs less frequently than acute dissection.[13,14] False aneurysm of the ascending aorta is not commonly encountered but may be seen following an aortic valve replacement, coronary artery bypass, or cardiopulmonary bypass. The diagnosis should be considered in patients in whom an anterior mediastinal mass develops subsequent to the above-mentioned surgical procedures. Cases associated with local infection are somewhat more common and tend to present sooner after surgery than their counterparts without known infection, possibly indicating failure of proper healing at the suture line rather than subsequent breakdown. Moore et al[15] suggest that CT with contrast enhancement should be performed preoperatively in this group of patients to prevent inadvertent rupture of the aneurysm sac at median sternotomy.

Possible sequelae in patients who have had surgical or medical treatment of an aortic dissection include redissection, extension of dissection, formation of aneurysms, and rupture. CT with contrast enhancement provides a convenient noninvasive method for follow-up in these patients. Godwin et al[16] used CT for follow-up in 12 patients with known aortic dissections. The advantages of CT in relation to aortography are that it is noninvasive and can be performed as an outpatient procedure. There is considerably less radiation exposure associated with a CT scan of the chest, and the acute risk in both cases is limited to the remote possibility of an adverse reaction to contrast material. For these reasons, CT is an acceptable method for the examination of asymptomatic patients. Its ability to detect intimal flaps in the aorta probably exceeds that of aortography,[17] and it is more sensitive in detecting intimal calcifications and in establishing displacement from the rest of the aortic wall.

Other vascular applications

CT has been used in assessing patency of aortocoronary bypass grafts. Moncada et al[18] used third and fourth-generation scanners and contrast material to study 33 grafts in 18 patients. Although 10 of 11 occluded grafts were correctly judged occluded by CT, angiography revealed 22 of 23 grafts thought to be patent on CT images were patent but two had 90% stenosis and one had 60% stenosis. We do not use this method to evaluate aortocoronary bypass grafts because although the method may allow diagnosis of complete occlusion of the graft, assessment of the degree of patency is not possible.

A pulmonary varix, an aneurysmal dilatation of the pulmonary vein, is relatively rare. Plain radiographic examination of the chest demonstrates a smooth-margined, well-defined, often lobulated opacity occurring most often in the right lower lobe, then the left upper lobe, then the lingula.[19] While angiography can establish its vascular nature, CT is a less invasive method to demonstrate this benign entity.[20]

Obstruction of the superior vena cava or its major tributaries usually is suspected clinically and verified by venography. Venous obstruction can also be diagnosed by chest CT performed during intravenous infusion of contrast material.[21,22] Engel et al[23] reported their experience with CT of mediastinal and thoracic inlet venous obstruction in 50 consecutive cases. They found that although CT was inferior to venography in opacifying peripheral collateral veins and determining the degree of obstruction, the information provided by CT obviated venography in most patients in the series. CT may be the initial procedure of choice in suspected mediastinal venous obstruction.

Metastatic disease

Conventional linear tomography of the thorax has proved to be a sensitive screening study for the detection of metastatic disease in the presence of a normal chest radiograph. This is important because aggressive surgical treatment of metastatic carcinomatous and sarcomatous pulmonary nodules has yielded a 30–35% five-year survival rate.[24,25] Correlation of operative findings with those of conventional tomography indicates the number of nodules to be underestimated using this modality in 30–50% of cases.[26] A prospective study undertaken by Chang et al[27] revealed that CT of the thorax demonstrated more nodules than conventional tomography in 13 of 27 cases with thoracotomy (48%) (*Fig. 5*). Heaston et al[28] evaluated a group of 42 patients with known malignant melanoma and a high propensity for metastases due to advanced local or regional disease. Each patient was initially evaluated by high-kV chest radiography. Chest CT and conventional tomography were performed on the same day. Of the 42 patients, 22 showed no evidence of metastasis on the basis of the combined imaging methods and clinical follow-up. Definite pulmonary nodules were shown by chest radiography in 11 cases, conventional tomography in 16, and CT in 20 cases.

In both of the above-mentioned studies, nodules detected only by CT were small and usually occurred in apical, diaphragmatic pleural, or subpleural sites. In the study of Chang et al[27], conventional tomography proved more specific. Approximately 66% of lesions identified using conventional tomography were metastatic, compared with 50% of lesions identified using CT.

The study by Chang et al[27] defines the lower limit of reliable detectability of parenchymal nodules by conventional linear tomography to be 6 mm, compared with 3 mm using CT. Neither method is tissue-specific in the absence of a nidus of calcification. Sixty percent of nodules measuring 3–6 mm in diameter and detected only by CT proved to be benign at thoracotomy. CT, however, was able to define bilateral involvement missed by conventional tomography and provided an accurate method of assessing growth on sequential examinations. In the absence of greater tissue specificity, the superior sensitivity of CT in nodule detection may not justify its substitution as a screening test for pulmonary metastasis.

Solitary pulmonary nodules

Management of the solitary pulmonary nodule identified on posteroanterior and lateral chest radiographs is a problem with which pulmonologists and radiologists alike are familiar. In a compilation of five large series comprising 1,711 resected solitary pulmonary nodules, the commonest specific diagnoses were: granuloma 54%, bronchogenic carcinoma 28%, hamartoma 6.6%, metastasis 3.5%, and bronchial adenoma 2%.[29] In 1980, Siegelman et al[30] described the technique to assess the solitary pulmonary nodule by CT. The main thrust of this technique lies in the fact that a significant percentage of diffusely dense nodules that cannot be assessed as calcified by conventional linear tomography can be characterized as benign by CT. The method described has been reproduced with varying degrees of success in other institutions since the original publication. In a more recent report, Siegelman et al[31] indicated that between March 1978 and June 1982 a large group of patients examined by CT had pulmonary nodules assessed as benign; 178 of these patients had been followed up for at least 18 months and no case had proved to be malignant. A nodule phantom used in the analysis of such lesions has now been standardized for use with all CT scanners. Use of this phantom in the CT analysis of solitary pulmonary nodules removes the necessity for thoracotomy in some patients whose nodules cannot be characterized as benign on conventional linear tomography.

Interventional techniques

Fluoroscopically guided percutaneous needle aspiration of pulmonary lesions is a well-established diagnostic procedure. Biplane or C-arm fluoroscopy is considered the optimal guidance mechanism for thoracic biopsy. In the experience of this author, a nodule identified on conventional radiographs of the chest very rarely will not be discernible at fluoroscopy. In such cases, CT-guided needle aspiration has proved useful. Gobien et al[32] reported their experience with thin-needle aspiration biopsy of 23 mediastinal and 27 other thoracic masses performed in 40 patients over a two-year period. A specific diagnosis was obtained in 34 cases for an overall diagnostic yield of 85%. In this series, the major advantage of CT guidance was that it allowed an extrapleural needle trajectory in 23 patients. Five of the remaining 17 patients sustained pneumothorax, for which two required tube thoracostomy. The two major indications for CT-guided percutaneous thin-needle aspiration are the inability to visualize the lesion using fluorscopy or, in the case of mediastinal lesions, the ability to use an extrapleural approach to the lesion.

Empyema is a common problem, occurring most frequently after surgery, trauma, or infection. Standard therapeutic options include antibiotics, thoracentesis, drainage *via* a thoracostomy tube, excision of a rib for open drainage, and open thoracostomy. When the first three methods fail, operation is necessary and usually proves successful; however, in an unstable patient, general anesthesia and major surgery may result in prolonged morbidity.[33] Failure of the thoracostomy tube treatment is the result of a poorly positioned or nonfunctioning tube. Van Sonnenburg et al[34] reported a total of 17 patients who underwent placement of percutaneous catheters for empyema drainage, guided by ultrasound and fluoroscopy in seven and CT in 10. Fifteen patients (82.2%) were treated successfully, averting surgery or further drainage, and bacteremia in one patient was the only complication. They point out that previously unrecognized communications with the bronchi, esophagus, and subphrenic space were demonstrated, and intracavitary tumor biopsy and instillation of a sclerosing agent were performed in several patients. Compared with the tubes used to drain abdominal abscesses, empyema catheters need less irrigation; Dionosil (propyliodone oil suspension) is often the preferred contrast agent, the catheter can be withdrawn in one step, and the residual fibrotic or tumor cavity may persist after pus has been evacuated.

Bronchogenic carcinoma

The use of CT in the preoperative evaluation of patients with bronchogenic carcinoma has received much attention in the literature. Many reports attest to the ability of CT to image lymphadenopathy accurately within the mediastinum. However, the demonstration of mediastinal lymphadenopathy does not prove malignant involvement of those nodes. The diagnosis of hilar or mediastinal lymphadenopathy, by any means, can only suggest to the thoracic surgeon that mediastinoscopy or mediastinotomy should be performed to assess operability prior to embarking upon thoracotomy.[35]

We have found CT to be useful in patients with normal conventional chest radiographs but highly suspected to have bronchogenic carcinoma, due to the presence of a paraneoplastic syndrome such as inappropriate antidiuretic hormone secretion. Similarly, in patients with sputum-positive cytologic findings and normal chest radiographs, CT may be helpful in determining the site of abnormality. Also in cases where plain radiographs suggest chest wall or mediastinal invasion, the axial display of anatomy afforded by CT may prove helpful. Vas et al[36] recommended abdominal CT as part of the staging process in patients with small-cell carcinoma of the lung, since the extent of disease is relevant to the prognosis. They found evidence of intra-abdominal metastases in 37% of 65 patients with biopsy-proved but untreated small-cell carcinoma of the lung. The majority of the metastases were located in the liver and the adrenal glands. Finally, Glazer et al[37] demonstrated the usefulness of CT in the detection of recurrent bronchogenic carcinoma subsequent to pneumonectomy.

Conclusion

CT does not represent a panacea in the diagnosis of thoracic disease. The efficacious application of this technology, however, can greatly enhance the ability of the radiologist to identify disease, define its extent, and, in some cases, aid in the guidance of an interventional procedure.

The major advantages of the modality are related to the axial anatomic display and its superior density discrimination capabilities.

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References

1. Gouliamos AD, Carter BL, Emami B. Computed tomography of the chest wall. Radiology 1980; **134:**433–436.
2. Mirvis S, Dutcher JP, Haney PJ, Whitley NO, Aisner J. CT of malignant pleural mesothelioma. AJR 1983; **140:**665–670.
3. Shuman LS, Libshitz HI. Solid pleural manifestations of lymphoma. AJR 1984; **142:**269–273.
4. Proto AV, Ball JB. Computed tomography of the major and minor fissures. AJR 1983; **140:**439–448.
5. Pugatch RD, Faling LJ, Robbins AH, Snider GL. Differentiation of pleural and pulmonary lesions using computed tomography. J Comput Assist Tomog 1978; **2:**601–606.
6. Toombs BD, Sandler CM, Lester RG. Computed tomography of chest trauma. Radiology 1981; **140:**733–738.
7. Mendelson DS, Rose JS, Efremidis SC, Kirschner PA, Cohen BA. Bronchogenic cysts with high CT numbers. AJR 1983; **140:**463–465.
8. Moore AV, Korobkin M, Olanow W, et al. Age-related changes in the thymus gland: CT-pathologic correlation. AJR 1983; **141:**241–246.
9. Mink JH, Bein ME, Sukov R, et al. Computed tomography of the anterior mediastinum in patients with myasthenia gravis and suspected thymoma. AJR 1978; **130:**239–246.
10. Sweeney PJ, O'Donovan PB. Myasthenia, thymoma and the anterior junction line. Abstract. Canadian Journal of Neurological Sciences 1984; **11:**335.
11. Kirks DR, Fram EK, Vock P, Effmann EL. Tracheal compression by mediastinal masses in children: CT evaluation. AJR 1983; **141:**647–651.
12. Shurin SB, Haaga JR, Wood RE, Ittleman FP. Computed tomography for the evaluation of thoracic masses in children. JAMA 1981; **246:**65–67.
13. Crisler C, Bahnson HT. Aneurysms of the aorta. Curr Prob Surg Dec 1972:1–64.
14. Wheat MW, Palmer RF. Dissecting aneurysms of the aorta. Curr Prob Surg Jul 1971:1–43.
15. Moore EH, Farmer DW, Geller SC, Golden JA, Gamsu G. Computed tomography in the diagnosis of iatrogenic false aneurysms of the ascending aorta. AJR 1984; **142:**1117–1118.
16. Godwin JD, Turley K, Herfkens RJ, Lipton MJ. Computed tomography for follow-up of chronic aortic dissections. Radiology 1981; **139:**655–660.
17. Godwin JD, Herfkens RL, Skiöldebrand CG, Federle MP, Lipton MJ. Evaluation of dissections and aneurysms of the thoracic aorta by conventional and dynamic CT scanning. Radiology 1980; **136:**125–133.
18. Moncada R, Salinas M, Churchill R, et al. Patency of saphenous aortocoronary-bypass grafts demonstrated by computed tomography. N Engl J Med 1980; **303:**503–505.
19. Bartram C, Strickland B. Pulmonary varices. Brit J Radiol 1971; **44:**927–935.
20. Borkowski GP, O'Donovan PB, Troup BR. Pulmonary varix: CT findings. J Comput Assist Tomog 1981; **5:**827–829.
21. Zerhouni EA, Barth KH, Siegelman SS. Demonstration of venous thrombosis by computed tomography. AJR 1980; **134:**753–758.
22. Hidalgo H, Korobkin M, Breiman RS, Heaston DK, Moore AV, Ram PC. CT demonstration of subcutaneous venous collaterals. J Comput Assist Tomog 1982; **6:**514–518.
23. Engel IA, Auh YH, Rubenstein WA, Sniderman K, Whalen JP, Kazam E. CT diagnosis of mediastinal and thoracic inlet venous obstruction. AJR 1983; **141:**521–526.
24. Choksi LB, Takita H, Vincent RG. The surgical management of solitary pulmonary metastasis. Surg Gynecol Obstet 1972; **134:**479–482.
25. Thomford NR, Woolner LB, Clagett OT. The surgical treatment of metastatic tumors in the lungs. J Thorac Cardiovasc Surg 1965; **49:**357–363.
26. Neifeld JP, Michaelis LL, Doppman JL. Suspected pulmonary metastases: correlation of chest x-ray, whole lung tomograms, and operative findings. Cancer 1977; **39:**383–387.
27. Chang AE, Schaner EG, Conkle DM, Flye MW, Doppman JL, Rosenberg SA. Evaluation of computed tomography in the detection of pulmonary metastases: a prospective study. Cancer 1979; **43:**913–916.
28. Heaston DK, Putman CE, Rodan BA, et al. Solitary pulmonary metastases in high-risk melanoma patients: A prospective comparison of conventional and computed tomography. AJR 1983; **141:**169–174.
29. Siegelman SS, Stitik FP, Summer WR. Management of the patient with a localized pulmonary lesion. [In] Siegelman SS, Stitik FP, Summer WR, eds. Practical Approaches to Pulmonary Diagnosis. New York, Grune & Stratton, 1979, pp 339–358.
30. Siegelman SS, Zerhouni EA, Leo FP, Khouri NF, Stitik FP. CT of the solitary pulmonary nodule. AJR 1980; **135:**1–13.
31. Siegelman SS, Khouri NF, Scott WW, Leo FP, Zerhouni EA. Computed tomography of the solitary pulmonary nodule. Semin Roentgenol 1984; **19:**165–172.
32. Gobien RP, Stanley JH, Vujic I, Gobien BS. Thoracic biopsy: CT guidance of thin-needle aspiration. AJR 1984; **142:**827–830.
33. Davis WC, Johnson LF. Adult thoracic empyema revisited. Ann Surg 1978; **44:**362–368.
34. van Sonnenburg E, Nakamoto SK, Mueller PR, et al. CT- and ultrasound-guided catheter drainage of empyemas after chest-tube failure. Radiology 1984; **151:**349–353.
35. Center S. Does computed tomography aid in the staging of lung cancer? J Thorac Cardiovasc Surg 1981; **82:**334.
36. Vas W, Zylak CJ, Mather D, Figueredo A. The value of abdominal computed tomography in the pre-treatment assessment of small cell carcinoma of the lung. Radiology 1981; **138:**417–418.
37. Glazer HS, Aronberg DJ, Sagel SS, Emami B. Utility of CT in detecting postpneumonectomy carcinoma recurrence. AJR 1984; **142:**487–494.