# COMPUTED TOMOGRAPHY OF THE CHEST

J. DAVID GODWIN

# Tomography of the Chest

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# Preface

In the last 2 years, computed tomography (CT) has established its place among imaging techniques for the thorax. The literature on thoracic CT has grown to the point that a summary in the form of a book has become appropriate and necessary. Our goal in producing this book has been to provide a compact overview of thoracic CT, suitable for radiology residents and practitioners, as well as for internists and surgeons interested in chest imaging.

We are fortunate to have, in a single department, radiologists who have already published on all the major aspects of thoracic CT. We have organized this book so that each author could write about his particular interests. In any book drawing from several contributors, some overlap of topics is unavoidable. We have found it desirable to tolerate a small amount of repetition in order that each individual chapter could be complete in itself. Otherwise, references to other sections would be excessive.

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# OVERVIEW

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Computed tomography (CT) has developed rapidly since its introduction in about 1973. Early scanners, suitable only for the head, revolutionized neuroradiology. Later, faster machines made whole body scanning possible.

At first, chest CT developed more slowly than did abdominal CT, partly because plain radiographs and conventional tomograms are highly effective for the chest, whereas no comparable screening examination exists for the abdomen. Despite its early lag, chest CT has now established itself, and its strengths, indications, and weaknesses have been defined. In our own practice of CT, chest examinations have increased to about 40% of the case load, and in the literature on body CT about one fourth of all citations deal with the chest.[1]

The particular advantages of CT in imaging in the thorax are its cross-sectional image format, superior density resolution, and wide dynamic range. The cross-sectional format clearly separates structures that are superimposed on conventional radiographs. The high degree of density resolution reveals the individual structures of the mediastinum and chest wall within their surrounding fat. The wide dynamic range encompasses the whole spectrum of tissue density in the thorax. No other radiographic technique captures lung, soft tissue, and bone detail simultaneously with a single exposure.

## INDICATIONS AND LIMITATIONS

The unique features of CT determine its applications in thoracic imaging.[2-4] CT's high degree of density resolution makes it the preferred technique for imaging the soft tissue compartments of the chest—the mediastinum and chest wall. Since fat gives characteristically low CT numbers, CT can distinguish fat from other causes of mediastinal widening or masses. Fatty masses include mediastinal lipomatosis, pericardial fat pad, and herniated omental fat. CT's cross-sectional image format makes it the preferred technique for detecting pulmonary metastases, since they tend to occur in areas obscured by overlying structures on conventional projection radiographs—adjacent to the pleura, behind the mediastinum, and deep in the costophrenic sulci. Both cross-sectional format and high-density resolution make

CT useful in evaluating pleural disease complicated by adjacent lung or chest wall disease or bronchopleural fistula. A more detailed list of indications for chest CT appears below.

**INDICATIONS FOR COMPUTED TOMOGRAPHY OF THE CHEST**

**Lung**

Detection of metastatic pulmonary nodules
Detection of lesions hidden by mediastinum or diaphragm
Detection of occult primary carcinoma (positive cytology but negative bronchoscopy)
Staging of lung carcinoma
Evaluation of the lung in the presence of pleural disease
Evaluation of pulmonary nodules for calcification (controversial)
Evaluation of lung density or early interstitial disease (experimental)

**Mediastinum**

Evaluation of abnormal or questionably abnormal contour
Identification of specific benign lesions
- Fatty masses—lipomatosis, pericardial fat pad, herniated omentum
- Pericardial cyst (water density)
- Aberrant or anomalous vessels

Diagnosis and assessment of aortic aneurysm or dissection
Diagnosis and assessment of mediastinitis and mediastinal abscess
Detection of thymoma in myasthenia gravis
Detection of parathyroid adenoma following neck dissection
Detection and evaluation of other mediastinal masses—goiter, bronchogenic cyst, neural tumor, lymphoma, metastasis, adenopathy
Evaluation of the rectrocrural space or paraspinal widening—fat, aneurysm, neoplasm, infection, adenopathy, herniation, hematoma, extramedullary hematopoiesis
Evaluation of pericardial thickening or loculated pericardial effusion (when echocardiography is unsatisfactory)
Evaluation of position and size of intrapericardial portions of pulmonary artery and aorta
Detection of intracardiac masses—thrombi or tumor (when echocardiography is unsatisfactory)
Evaluation of patency of coronary bypass grafts

**Hilum**

Distinguishing vessels from adenopathy (oblique tomography preferred by many)

**Pleura**

Evaluation of extent of tumor metastasis, mesothelioma, lymphoma
Distinguishing empyema or bronchopleural fistula from lung abscess
Evaluation of postpneumonectomy space for tumor recurrence or infection

(Continued)

**Chest Wall**

Evaluation of spread of cancer or infection from pleura or lung
Evaluation of axilla for adenopathy
Evaluation of brachial plexus
Evaluation of muscle for infection, tumor, trauma
Evaluation of sternum and sternoclavicular joint for dislocation, infection, neoplasm, arthropathy

**Other**

Radiation treatment planning for bronchogenic carcinoma, lymphoma, metastatic neoplasm
Evaluation of thoracic inlet

(Modified from Heitzman ER: Computed tomography of the thorax: Current perspectives. AJR 136:2–12, 1981; Jost RG, Sagel SS, Stanley RJ, Levitt RG: Computed tomography of the thorax. Radiology 126:125–136, 1978; Pugatch RD, Faling LJ: Computed tomography of the thorax: A status report. Chest 80:618–626, 1981)

On the other hand, CT's cross-sectional format shows only a small part of the thorax on each slice. Cross-sectional images are thus disadvantageous for displaying longitudinal structures such as the esophagus or aorta. They are also unsuitable for evaluating structures in the same plane as the scan, such as the diaphragm. CT's low spatial resolution makes it unsuitable for evaluating the esophageal mucosa, plaques in the coronary arteries, or thrombi in subsegmental pulmonary arteries. Long scanning times relative to the cardiac cycle result in degradation of images by heart motion. All these factors—cross-sectional format, low spatial resolution, and low temporal resolution with blurring—combine to make it difficult to evaluate the hila for lymphadenopathy. Limitations are summarized below.

**LIMITATIONS OF CT**

Low spatial resolution (especially in longitudinal axis)
Low temporal resolution and long scan times
  Results in blurring by cardiac and respiratory motion
  Requires cooperative patient
  Prevents assessment of cardiac dynamics
  Induces streak artifacts
Limited accuracy and reproducibility of CT numbers
Lack of tissue specificity—prevents distinguishing benign from malignant tumors or adenopathy, preventing accurate cancer staging
Inability to reproduce lung volumes for sequential scans causes risk of missed areas between slices in search for metastasis
Limited field of view—requires several slices to cover the thorax
Inability to alter plane of image—transverse plane unsatisfactory for dome of diaphragm, aortopulmonary window, esophagus, airway, hila
Narrow gantry aperture—prevents imaging obese patients or patients with extensive life-support equipment

## DOSE

The dose of radiation to the patient depends on the chosen technique, the condition of the x-ray tube, the centering of the patient in the gantry aperture, and the spacing of slices.[5] In one study using typical technique factors, doses to an anthropomorphic chest phantom ranged from 2 to 5 rad at the surface and up to 1 rad at the center. Making contiguous scans increased the dose to the center by three to five times. This increase is the result of divergence and scatter of the fan beam in the longitudinal axis.[5] Contiguous slices with narrower collimation would increase the dose even further.

## CHARGES

Charges for body CT examinations were compiled for 146 departments in 1981.[6] The charges for body CT were $309 for examinations performed without administration of intravenous contrast agent and $396 for examinations with contrast. Most examinations were of the abdomen and pelvis, and only 12% were of the chest. An average of 21 images were made for each body scan. No separate figures were given for thoracic CT, but costs should be comparable to abdominal scans adjusted for the number of slices.

Despite decreasing charges from 1976 to 1978, charges began to rise at about 9% per year in 1979 through 1981, an increase below the rate of inflation.

## EFFICACY

Only a few studies have attempted to assess the efficacy of CT of the chest. The components of efficacy include accuracy, ability to add information over other diagnostic tests, and ability to substitute for other more expensive or more invasive diagnostic methods.[7] Carrying the analysis beyond diagnosis to the impact of CT on the course of the disease involves so many other variables that the connection between the CT scan and the outcome of the disease becomes tenuous. For example, in a case in which CT is the only diagnostic technique to detect metastasis to the lung, it is certainly efficacious for diagnosis. If however, there is no effective therapy, the patient will not benefit from this added information, and CT will not have been efficacious in terms of improving the patient's survival.

Because of the difficulty in defining efficacy, studies that emphasize CT's contribution to diagnosis and immediate management, rather than to eventual outcome of the disease, are more convincing. One such study retrospectively evaluated 101 chest CT cases examined with a 2-second scanner.[8] The efficacy of chest CT had improved since an earlier study at the same institution with a 2½-minute scanner.[9] In 39% of cases CT had a significant impact—it provided unique information not otherwise available from any other test at the time of the scan, and this information altered diagnosis, prognosis, management, or therapy. In another 44% of cases, CT provided unique information that was without significant impact, even though clinical confidence was enhanced. In only 17% of cases did CT provide no new information.

Because of chest CT results, planned surgery was modified or canceled in 11 cases and radiation portals were modified in several patients. Fewer conventional tomograms and fluoroscopic examinations were performed, although there was no change in the use of thoracic angiography.

The authors attributed the improved percentage of examinations having significant clinical impact (rising from 15% in the earlier study to 39% in the later) to four factors: technical improvements in images; improved diagnostic skill of the radiologists through greater personal experience and growth of the CT literature; acceptance of CT by radiologists and clinicians so that both positive and negative CT results were trusted and not subjected to verification by other radiologic tests or invasive procedures; better selection of patients for study by CT based on better understanding of CT's abilities and reduction of the number of scans unlikely to contribute to management decisions.

CT's clinical efficacy in this report was shown by its high degree of diagnostic accuracy, its diagnostic impact—causing a decline in the use of chest fluoroscopy and chest tomography—and its impact on radiation and surgical therapy planning, even sparing some patients the debilitation of unnecessary surgery.

An earlier study of efficacy evaluated 623 patients who had undergone body CT.[10] Of these, 35 had been scanned for the mediastinum and 35 for the lungs. CT made positive contributions to diagnosis in 66% of the mediastinum cases and 51% of the lung cases. Therapy was improved because of CT results in 20% and 14%, respectively, as indicated by changes in surgical approach or adjustments in medications. For body CT as a whole, CT caused a reduction in use of angiography and surgery, but results were not tabulated separately for the chest.

Another study attempted to include clinical outcome in the retrospective analysis of 302 thoracic surgical patients scanned with 5- to 10-second scanners.[11] Efficacy was scored on an 18-point scale. The largest groups of patients were scanned to evaluate lung lesions, hilar or mediastinal masses, and lung cancer for staging. Most scans were ordered to confirm or evaluate suspected or proven lesions on standard radiographs. Despite CT's high accuracy (93%), the overall score for efficacy indicated only marginal usefulness. Utility was greatest for diagnosing aortic aneurysms and dissections and for evaluating pleural fluid collections. Lung cancer staging was limited by the inability to determine malignant involvement of lymph nodes on the basis of nodal size, as has been reported by others.

The low efficacy for CT in this study occurred largely because additional information supplied by CT did not necessarily lead to a change in therapy or outcome, because indications for chest CT were still being refined, and because in many situations, such as lung cancer staging, there is simply no satisfactory noninvasive technique.

We conclude from the published studies and from our own experience that chest CT is efficacious for detecting disease, determining its extent and location, increasing the confidence of diagnosis, obviating some other diagnostic tests, and guiding biopsy or thoracotomy. However, a CT examination should not be undertaken when its results have no chance of influencing management. As greater experience with chest CT is accumulated, we can expect fewer noncontributory examinations and correspondingly higher efficacy.

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