Computed Tomography of the Gastrointestinal Tract

Megibow • Balthazar

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Indeed, if a little knowledge is dangerous,
where is the man who has so much as to be out of danger?

Thomas Huxley (1825-1895)

Collected Essays

PREFACE

The discovery and recent technological advances in computed tomography have substantially changed the practice of radiology, including that of abdominal imaging. While the clinical use of computed tomography in the diagnosis of diseases involving solid viscera (liver, pancreas, spleen) and retroperitoneal organs was established and accepted early, its use in the gastrointestinal tract lagged behind in development. This is explained mainly by the poor quality images obtained from second generation scanners and by a lack of unified technique and coordinated effort to evaluate primary gastrointestinal lesions. The ability of the newer generation scanners to accurately assess the thickness of the bowel wall and to determine the existence and degree of extramural involvement has added a totally new dimension to our diagnostic proficiency.

As gastrointestinal radiologists by training and experience, we became interested in the appearances of gastrointestinal pathology on computed tomography and since 1980 started to rapidly accumulate material. In the summer of 1983, Dr. Elias A. Zerhouni, then of the De Paul Hospital in Norfolk, Virginia, introduced us to his work with air distention of the colon and gas insufflation of the stomach. This technique provides a uniform, simple, and reliable methodology to examine the stomach and colon. Aside from an accurate, reproducible method for examining the wall of the alimentary tract, improved contrast resolution provides a better appreciation of subtle findings in the perivisceral fat.

We like to underline however, that in spite of the high-quality images obtained today, computed tomography should be considered complimentary to conventional contrast examinations. It opens a totally new horizon and gives access to important clinical data inaccessible to conventional barium studies. Although confusion and controversy still exist in regard to the place of computed tomography in evaluating primary gastrointestinal lesions, a continuously enlarging body of evidence attests to its undeniable importance. We have attempted to allow the reader to form his or her own conclusions by providing correlations between barium images and computed tomograms.

Our intention in writing this book is to present in a comprehensive volume an up-to-date evaluation of the role, significance, indications, and limitations of computed tomography of the gastrointestinal tract. The first chapter on technique outlines our schedules for oral contrast administration as well as maneuvers utilized to optimize air contrast techniques. In the following chapters the computed tomographic findings of a large variety of gastrointestinal lesions, including their complications, are described and illustrated. In addition, a close correlation with barium studies and a complete review of the literature is provided. A chapter on percutaneous abscess drainage has been included to give the reader precise technical information and data base for referral of patients for this important procedure. Finally an atlas of radiographic-gross pathologic and microscopic correlations is provided to aid the reader in understanding the pathologic basis of radiographic abnormalities seen by CT. Most of our illustrations were made from images obtained on GE 9800 and 8800 scanners and selected from pathology material seen in our institution. They reflect the experience at NYU Medical Center in our extensive use of computed tomography in the evaluation of the gastrointestinal tract.

We believe that this book can be used effectively by the student in radiology, by the clinical radiologist, and by the gastroenterologist, general practitioner and general surgeon interested in selecting the most helpful and cost effective radiologic examination for the patient. Finally, we like to gratefully acknowledge the enthusiastic cooperation of our contributors, all of whom are very experienced in the field of abdominal CT.

Alec J. Megibow
Emil J. Balthazar

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CONTENTS

Chapter One

TECHNIQUES OF GASTROINTESTINAL COMPUTED TOMOGRAPHY

CLASSICAL TECHNIQUES

Alec J. Megibow

Successful interpretation of all computerized tomographic examinations requires accurate identification of normal anatomic structures enabling the confident recognition of pathological processes and masses. This principle applies to any computer tomography (CT) examination of the abdomen, regardless of indication. The sensitivity of CT diagnosis of gastrointestinal pathology is directly proportional to bowel opacification and distention. When a portion of the alimentary tube is adequately distended, the intestinal wall may be accurately assessed.

In 1978 Kressel outlined the advantages CT has over traditional imaging modalities for evaluation of the gastrointestinal tract. These include: (1) sharp, transverse tomographic images show the relationship of organs to the alimentary tube; (2) vessels, ducts, nodes, masses, cysts, ascites, blood, and hemorrhages can be seen rather than presenting as nonspecific displacements; (3) mesenteric fat can be easily imaged; and (4) the bowel wall itself can be seen.[1] These same advantages apply today. However, improved equipment, particularly the use of higher reconstruction matrices and fast scan times, has significantly improved spatial resolution to the point where these advantages can be more routinely realized.

Because thickening of the intestinal wall is the basic radiopathologic finding signifying disease, it is of the utmost importance to ensure that the apparently thickened portion of the bowel is in fact distended. This chapter focuses on the various oral contrast agents available to the radiologist for computed body tomography and schedules that will result in uniform, homogeneous bowel opacification. We consider special problems of opacifying each level of the alimentary tube. Finally we attempt to categorize special indications requiring modified oral contrast administration.

Oral contrast agents

Routine use of oral contrast agents was realized to be a necessary adjunct to all body CT examinations early in clinical experience with this method.[2,3,4] The ideal contrast agent has the capacity to accurately identify a given loop of bowel, be palatable and nontoxic, not produce artifacts, and should distribute evenly through the gut. In the segments in which it is not present as a bolus, it is hoped enough contrast agent residue would be present to identify the loop.

Two positive contrast agents are available; solutions of water-soluble, iodinated compounds or suspensions of barium sulfate. Both agents must be significantly diluted to prevent the production of streak artifacts. Commercial barium preparations are available in weights ranging from 1.2% to 2.0%.* Iodinated, water-soluble solutions are used at 2% to 3% concentrations in water. Early experience with USP barium sulfate at low concentrations was unsuccessful because of difficulties in maintaining the barium in suspension; therefore commercial preparations for CT scanning contain suspending agents that avoid flocculation and ensure homogeneous distribution in the bowel. When barium suspensions were initially developed

*E-Z CAT, Redi-CAT, manufactured by E-Z-EM Company, Westbury, New York; Tomo-CAT, manufactured by Lafayette Company, Indianapolis, Indiana; Baro-CAT, manufactured by Mallinkrodt, Inc., St. Louis, Missouri.

for CT, it was hoped that they would coat the intestinal mucosa thus being able to identify a bowel loop after the bolus had traversed that segment of the intestine. This hope has yet to be realized.[5,6] Thus relatively large amounts must be consumed before the examination to ensure that the loops are filled when scanned.

In our practice we routinely use barium sulfate suspensions in *all* routine CT scanning procedures. We favor barium sulfate because it is palatable, unabsorbed by the intestine, and does not have the irritant properties of water-soluble solutions, which may increase peristalsis leading to motion-induced image degredation. Barium has an added advantage in patients undergoing systemic chemotherapy in whom the nausea may limit the amount of contrast tolerable. Ball et al. recently have shown image-degrading percipitation of water-soluble contrast solutions in the stomach. The percipitate generates streak artifacts. Elimination requires buffering of the oral contrast agent.[6a]

There are specific instances when water-soluble contrast agents are indicated. These include scans performed for blunt abdominal trauma; scans of immediate preoperative or postoperative patients; scans performed for suspected gastrointestinal perforation; and as a bowel marker for any CT interventional procedure. The major factor underlying all of these indications is the possibility of an occult gastrointestinal perforation. Federle et al. have shown a higher incidence of bowel perforation occurring in patients with blunt trauma to the abdomen than has been clinically apparent.[7] CT

A

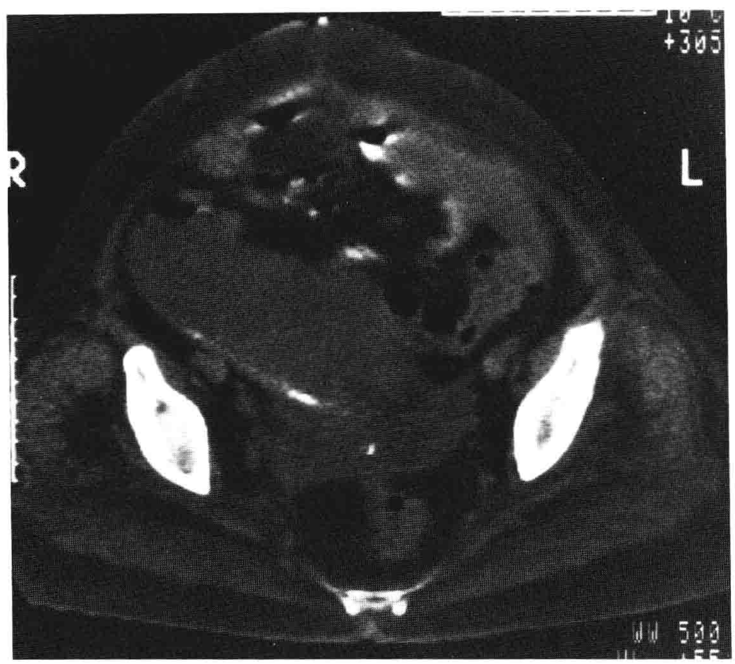

Fig. 1-1. Unsuspected ileal perforation with pelvic abscess. **A,** CT scans of the midpelvis in a patient who developed a fever 5 days following aortic aneurysm surgery. There is an amophous fluid collection. A small area of increased density represents extravasated oral contrast.

may visualize this abnormality in two ways. First, small amounts of free air may be seen particularly near the falciform ligament; secondly, oral contrast material may be seen in the peritoneal cavity.[8] Obviously in these cases water-soluble contrast agents are preferred because of the potential complications resulting from barium entering the peritoneal cavity[9] (Fig. 1-1). We have recently been requested to scan patients immediately before operative procedures, sometimes within 1 hour of induction of general anesthesia. Although these cases were not emergencies, increasing government restrictions on hospital stays are forcing a more telescoped work up. These patients are given water-soluble agents. Postoperative patients, particularly those having undergone resection of bowel or those with a fresh anastomosis, should also be given water-soluble contrast agents, especially when an abscess or leak is suspected.

Factors involved in contrast distribution

Uniform bowel opacification is critical to successful CT interpretation. Uniformity is based on intestinal transit time and the status of the luminal content of the bowel. Transit time is controlled by many endogenous and exogenous factors. These factors should be considered when administering oral contrast material.

Endogenous factors include interplay of diverse controls such as cortical hunger centers, autonomic nervous system, gastrointestinal hormones, prostaglandins, and thyroid hormones. Exogenous factors such as drug therapy, narcotic intake, or recent surgery diminish intestinal motility.[10]

B

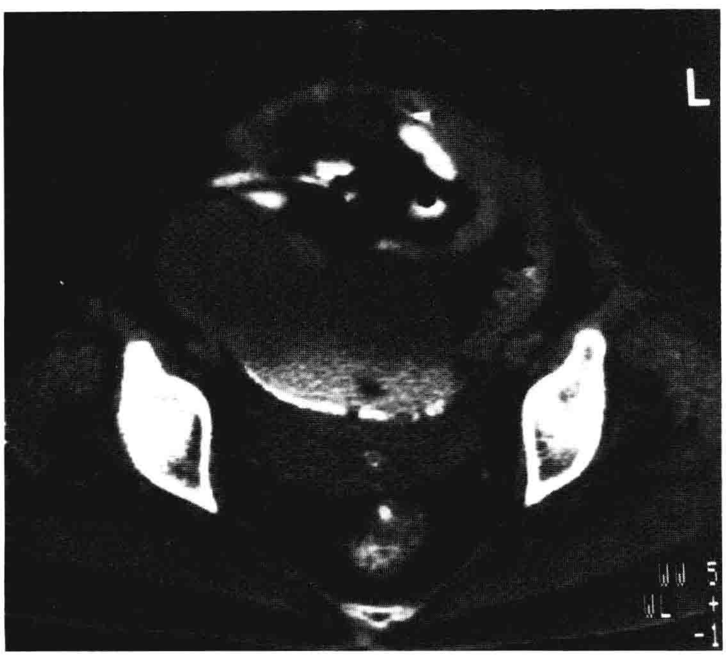

Fig. 1-1, cont'd. B, CT scan of same patient approximately 30 minutes later shows increasing amounts of oral contrast medium collecting in the fluid, indicating communication with the bowel. At surgery a loop of ileum was perforated, communicating with a large pelvic abscess. Water-soluble contrast material was used in this case because of a history of fever in postoperative patients.

In our experience complete opacification of the small bowel can be achieved within 45 minutes of ingestion of the contrast material in most *ambulatory* patients. Patients who are not ambulatory may require a longer prescan contrast administration time because of the imbalance of factors outlined earlier. Complete opacification can generally be achieved by consumption of 500 to 600 ml (15 to 18 ounces of oral contrast material). As stated previously, this amount should be consumed 30 to 45 minutes before the beginning of the examination. Optimally the contrast material should be consumed steadily, approximately one 6 ounce cup each 10 minutes over the waiting period. This ensures uniform distribution. Utilizing this schedule of contrast administration we routinely achieve opacified ileal loops and right colonic opacification in over 95% of patients. Colonic visualization beyond the proximal ascending colon is not routinely achieved by this method. Best results are obtained when patients are kept NPO. Outpatients are usually restricted from between 3 to 5 hours (the meal before) the examination. This is an added safety measure because an empty stomach is preferred when intravenous contrast agents are administered.

Visualization of the proximal bowel

Visualization of distal small bowel loops is easily achieved given sufficient time and volume of oral agent. Adequate opacification and distention of the stomach, duodenum, and proximal jejunum is more difficult. In the duodenum, the largest flux of water into the lumen of the intestine occurs. Receptors in the duodenum that are sensitive to pH, fats, and osmotic pressures slow gastric emptying and promote large amounts of pancreatic and mucous secretions—all of which serve to dilute the gastric contents and maintain an isosmotic solution when compared to blood.[11] The duodenum is also a site of vigorous peristalsis, making this segment of the intestine and the proximal jejunum difficult to opacify uniformly.[12] In order to overcome the dilutional effects of the duodenum, the patient must consume *additional* contrast material in order to have this portion of the gastrointestinal tract filled during the time of the scan. Thus immediately before the scan begins, as the patient lies on the scan couch, he or she is given one additional cup of oral contrast material. This distends the stomach, fills the duodenum and proximal jejunum, and overcompensates for the dilutional activity within the duodenum. Regardless of how much contrast material the patient has consumed prior to entering the scan room, this additional cup of contrast material is *essential* and must not be neglected in any CT examination regardless of the indication (Fig. 1-2). This step must also be performed when patients undergo CT scans of both the chest and the abdomen. If the chest is scanned first, the additional cup of contrast material should be administered when the diaphragm is reached and before proceeding to obtain sections in the abdomen.

Controversy has arisen concerning differences in transit time between water-soluble contrast agents and barium sulfate suspensions. Hyperosmotic solutions of water-soluble iodinated products tend to shift the gradient of water transport from the blood to the lumen because the unabsorbed molecules must be maintained in isotonic solutions. This accounts for the cathartic, "irritant" properties of these compounds. This irritant property is thought to stimulate peristaltic activity.[11] Whether the irritation actually occurs at the concentration utilized in CT scanning (2% to 4% solution) is questionable. A commercial barium preparation has added osmotically active agents to speed the passage of the bolus to the small bowel.* This suspension works best at slightly higher concentrations (2.0% weight:weight) than routine barium suspensions because the osmotically active additives draw water into the proximal intestinal lumen thus reducing visibility.

*Redi-CAT, manufactured by E-Z-EM Company, Westbury, New York.

A

B

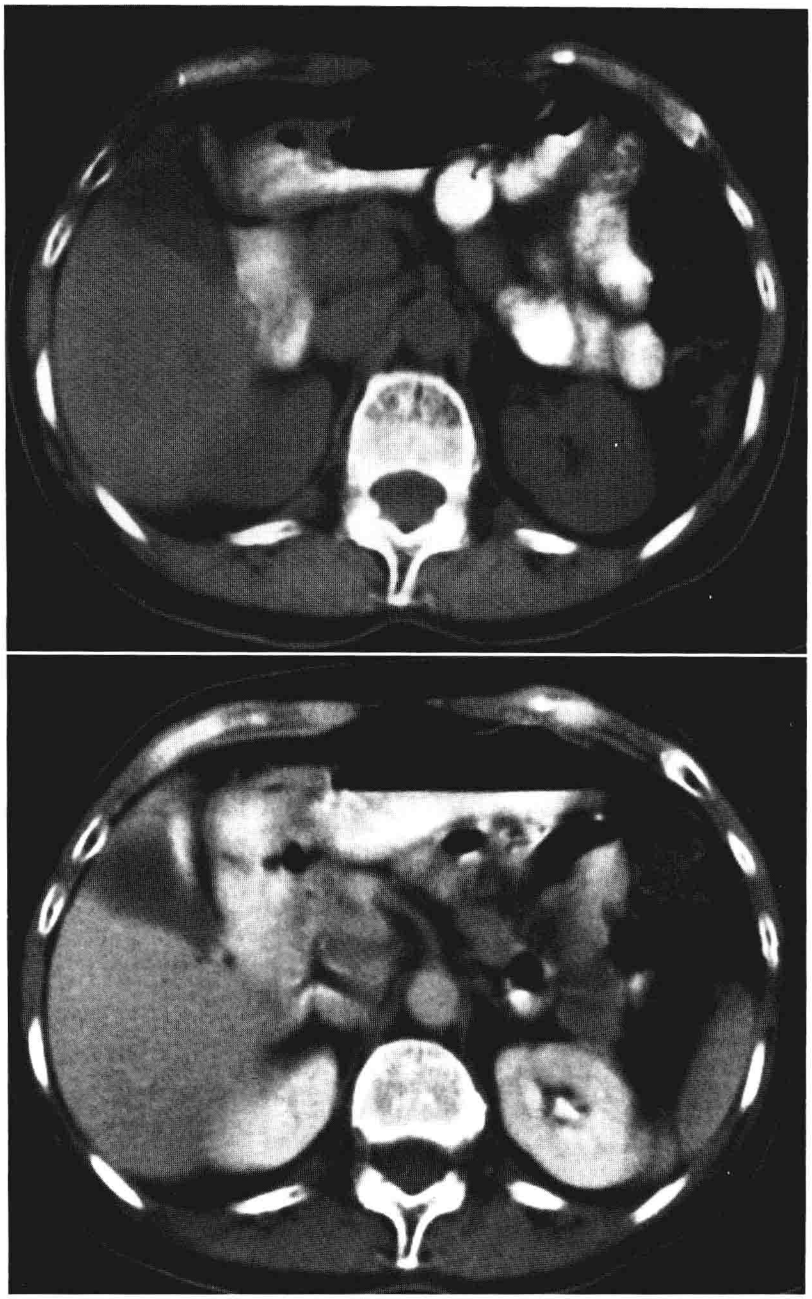

Fig. 1-2. Dilution of contrast in duodenum. **A,** Non-contrast images with excellent opacification of the duodenum and proximal jejunum. **B,** Scan at same level 10 minutes later, following administration of intravenous contrast material. Although some oral contrast material is still present, it is markedly diluted by influx of fluid into the duodenal lumen and proximal jejunum. If the upper abdomen is rescanned, additional oral contrast material should be administered to overcome this effect.

Glucagon

Glucagon was recommended as a routine adjunct to abdominal CT early in CT experience because 18 second scan times were routine and the streak artifacts generated from peristaltic activity produced severe image degredation, often resulting in nondiagnostic examinations.[13,14] As faster scan times became more routine, glucagon was no longer recommended.[15]

We routinely use intravenous glucagon in all CT examinations.* Even with 2 second scan times, bowel relaxation and hypotonia induced by glucagon provides scans of superior resolution to those performed without it. We administer 0.1 mg intravenously immediately following the administration of the final cup of contrast material. These doses have proved effective in inducing hypotonia for upper gastrointestinal examinations.[16,17] Glucagon can be administered with the intravenous contrast bolus. Hypotonia occurs within 1 minute and lasts from 9 to 17 minutes. The site and mechanism of action on the gastrointestinal tract is unknown. A 1 mg dose vial can provide enough glucagon for ten CT examinations. In New York City, this increases the cost of the CT examination by $1.80. Glucagon is particularly helpful in paralyzing the duodenum, which is useful in the examination of the pancreas. It must be remembered that glucagon causes contraction of the pyloric sphincter, therefore oral contrast material given to visualize the duodenum should be administered *prior to* the injection of glucagon. Contraindications to its use are insulinoma and pheochromocytoma. Although the drug is safe for most diabetic patients, we do not administer it to brittle patients on insulin therapy.

*Glucagon USP for injection manufactured by Eli Lilly Company, Indianapolis, Indiana.

SPECIALIZED TECHNIQUES FOR LEVELS OF THE GASTROINTESTINAL TRACT

Esophagus

The peristaltic activity of the normal esophagus results from sequential activation of muscles dependent on efferent nerve impulses from higher centers. The primary peristaltic wave sweeps from the cricopharyngeus muscle to the lower esophageal sphincter and can push a bolus of water through its length within 1 second. Coupled with momentum generated from hypopharyngeal muscle contraction water moves faster than the primary wave even in the horizontal position. Any material remaining within the esophagus will be swept through by secondary contractions. This results in our inability to opacify the normal esophagus for the length of time necessary for CT examinations. Because the esophagus is fixed in its mediastinal location, it is generally not difficult to recognize during thoracic CT examinations. Oral contrast material helps to differentiate the convex border of the esophagus from adjacent mediastinal adenopathy. Furthermore, if the esophagus appears thick-walled, a contrast agent should be available to distend this portion of the alimentary tube. In these cases we administer a pastelike suspension of barium sulfate.* This material clings to the esophageal wall and is not efficiently cleared by normal peristaltic activity. We use the contrast agent in the evaluation of intraluminal esophageal masses because it allows a more precise delineation of the borders of the lesion. Its most common use is to correlate an impression seen on a routine esophagram, ensuring that the area of the impression is in fact scanned during the esophageal CT (see Chapter Two for further details).

*Esopho-CAT manufactured by E-Z-EM Company, Westbury, New York.

Stomach

Gastric opacification is necessary not only to evaluate the stomach but also to accurately outline the extent of pathological processes in the upper abdomen. This is routinely achieved by ensuring that the patient consumes at least 6 ounces (180 ml) of oral contrast medium immediately before commencement of scanning as discussed previously. This additional contrast material should be administered regardless of how much the patient has previously consumed. In our practice, this is routinely administered after the patient has come to the scanner just before lying on the scan couch. Consumption in the sitting position provides more uniform distribution, prevents pooling of contrast material in the dependent gastric fundus, and leads to reliable gastric distention. This helps avoid false-positive diagnoses related to the inability to evaluate segments of normal wall thickening, particularly in the region of the esophagogastric junction and the pylorus. Apparent masses in the left adrenal gland, retroperitoneum, and pancreatic tail have been mistakenly diagnosed only to turn out to be a partially opacified gastric fundus.[18,19] We have seen several cases in which the splenic vessels can be seen to traverse the posterior aspect of the gastric fundus, showing portions of the stomach actually posterior to this vascular axis (Fig. 1-3). Inadequate opacification would surely result in mistaking this segment for a retroperitoneal, particularly adrenal, mass. When pathologic processes involving the stomach are suspected, alterations in patient positioning may be necessary to ensure that the portion of the stomach is maximally distended. Thus antral processes may be studied with the patient in a right-side-down decubitus position and fundal pathology may be studied with the patient in a left-side-down decubitus position. The prone position may help distend the fundus in thin patients in whom there is a suspicion of a left adrenal mass. Other agents have been used to visualize the stomach. These include water, mineral oil, and air.[20,21] These agents provide negative contrast, allowing identification of the viscus as well as evaluation of the wall. We describe our experience with air contrast techniques subsequently. At times one may want no gastric opacification. One may not wish to administer gastric contrast in scans directed at evaluation of liver metastases.[22] This eliminates streak artifacts generated from the air contrast level in the stomach. With present day equipment, algorithms eliminate the objectionable streaking and we therefore use oral contrast in every case.

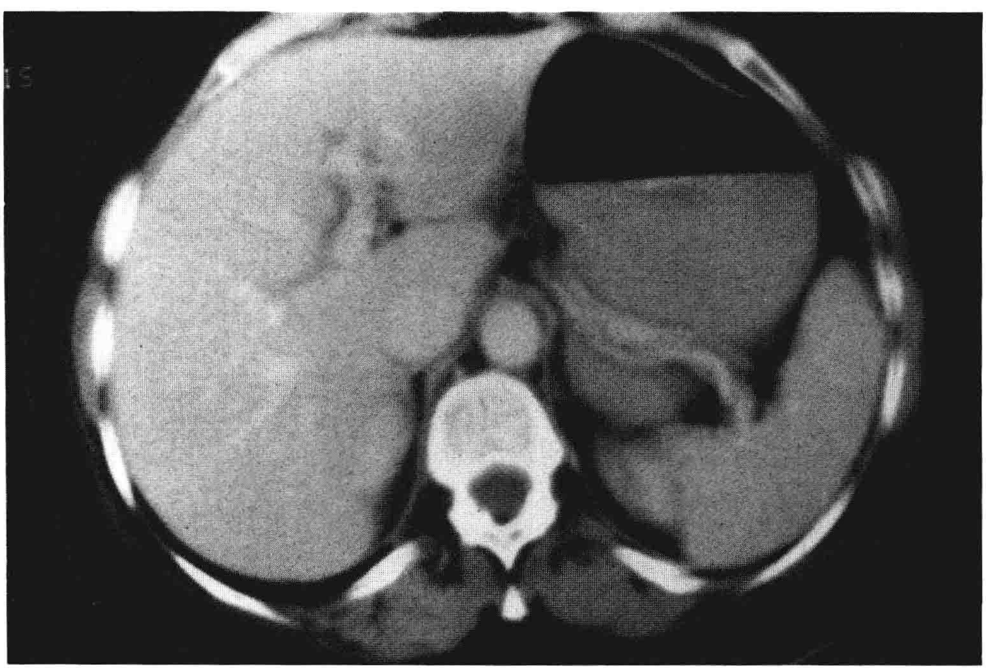

Fig. 1-3. Gastric fundus posterior to splenic vessels. A portion of the gastric fundus can be seen posterior to the splenic artery and vein. Poor filling of the stomach can lead to the false diagnosis of a left adrenal mass.

Duodenum

The duodenum is the most difficult segment of the abdominal gastrointestinal tract to reliably opacify. The motility in the duodenum is greater than the motility in any other segment of the small bowel and is particularly active when the stomach is stretched as with large volumes of oral contrast material.[11,12] Because of its close anatomic relationship to so many important structures, the segment becomes critical to visualize (Fig. 1-4). Routine administration of 0.1 mg of glucagon intravenously *following* a 6 ounce cup of oral contrast material generally produces sufficient hypotonia to reliably opacify the duodenal sweep. Haaga et al. have used the right-side-down decubitus position to routinely visualize the segment, particularly in cases in which pathologic processes in the pancreatic head were suspected.[23] Alternative air contrast techniques are discussed subsequently.

Small bowel

Filling of the small bowel is generally achievable by the schedules described previously. With the advent of faster scanners providing improved spatial resolution, unfilled bowel loops are less difficult to recognize. The problem patient is the cachectic individual who has no fat separating structures. Therefore particular effort must be directed at ensuring adequate contrast consumption.

If a "mass" is encountered and an unfilled bowel is thought to be the cause, a repeat cut obtained over the region may show the loop to be filled with contrast material. The physician monitoring the patient is responsible for this determination, and in optimal practice, a physician should view the scans before the patient is "off the table."

Another aid in recognition of a bowel loop is gained by attempting to track mesentery or mesenteric vessels associated with the loops. This is particularly useful in postoperative patients, especially those having undergone retroperitoneal surgery. Because of the recent postoperative status, they may not be able to drink sufficient amounts of contrast material and varying degrees of postoperative ileus may render optimal bowel opacification difficult. Furthermore, because unopacified fluid-filled bowel may simulate an abscess collection, it is important to look for the mesenteric attachments. The mesenteric axis appears as a central fat density surrounded by a fluid-filled loop. Occasionally a vessel may be seen within the mesenteric fat (Fig. 1-5). Another finding that may be of occasional use is to obtain a thin (less than or equal to 5 mm) cut over the region of question. The improved spatial resolution obtained when using a thin cut may show valvulae conniventes, thus identifying the "mass" as a loop of bowel.

A

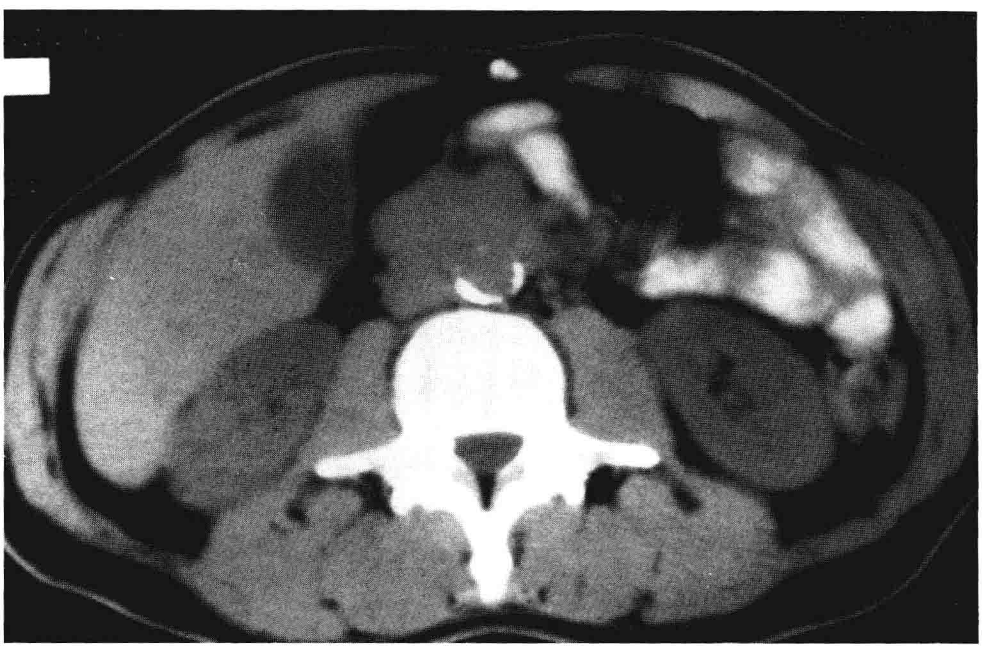

Fig. 1-4. Unopacified duodenum simulating peripancreatic nodes. **A,** CT scan in a patient with gastric carcinoma suggests the presence of peripancreatic lymphadenopathy appearing as lobulated densities deforming the contour of the pancreatic head.

B

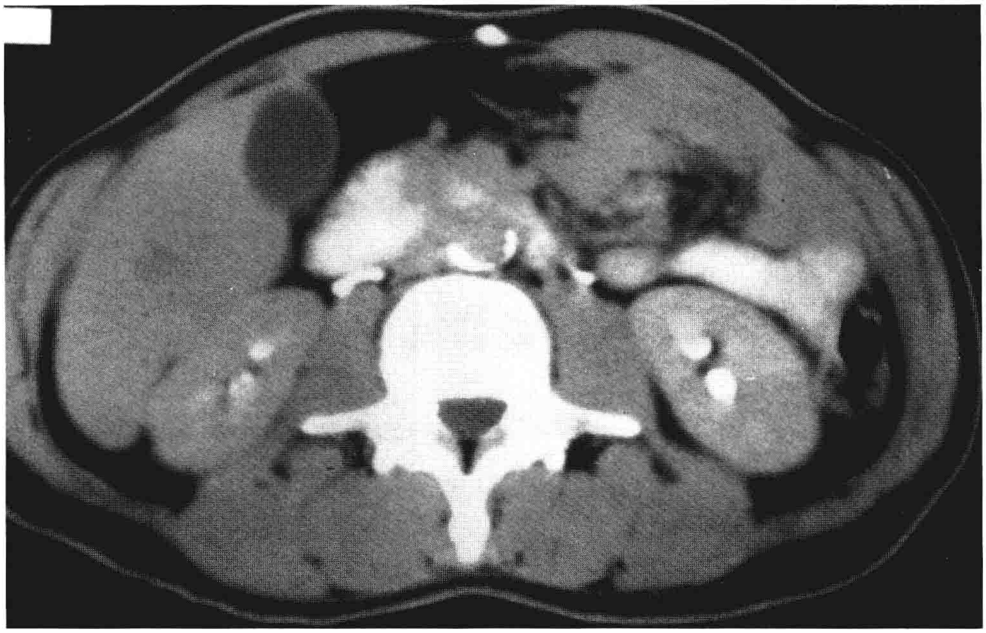

Fig. 1-4, cont'd. B, Repeat scan following ingestion of 6 ounces of additional oral contrast material. Enhanced scan clearly shows the "mass" accounted for by an unfilled duodenal sweep.

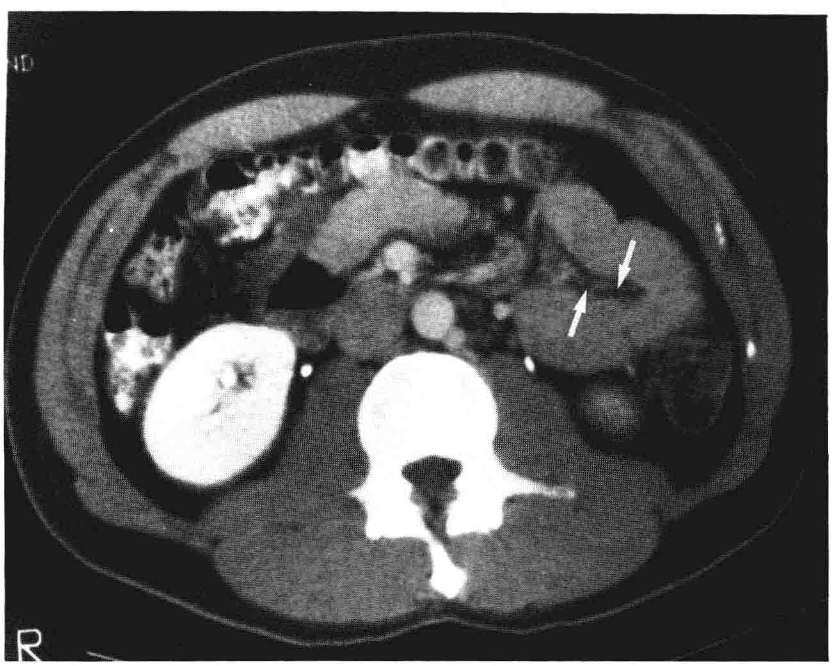

Fig. 1-5. Mesentery identifying loop of small bowel. Poor contrast opacification is present in the jejunum. Notice the fat and vessels in the central mesentary subtending this loop of bowel *(arrows)*.