

Detectability of Choledocholithiasis on CT: The Effect of Positive Intraduodenal Enteric Contrast on Portovenous Contrast-enhanced Studies

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ABSTRACT

Background/Aim: To retrospectively assess the accuracy of intravenous (IV) contrast-enhanced multidetector CT (MDCT) in choledocholithiasis detectability, in the presence and absence of positive intraduodenal contrast. **Patients and Methods:** Over a 3-year period, patients in whom endoscopic retrograde cholangiopancreatography (ERCP) was performed within a week from a portovenous (PV)-enhanced abdominal CT were identified. The final cohort consisted of 48 CT studies in which the entire common bile duct (CBD) length was visualized (19 males, 29 females; mean age, 68 years). We identified two groups according to the absence ($n = 31$) or presence ($n = 17$) of positive intraduodenal contrast. CT section thickness ranged from 1.25 to 5 mm. Two radiologists, blinded to clinical information and ERCP results, independently evaluated the CT images. Direct CBD stone visualization was assessed according to previously predefined criteria, correlating with original electronic CT reports and using ERCP findings as the reference standard. A third reader retrospectively reviewed all discordant results. The diagnostic performances of both observers and interobserver agreement were calculated for both groups. **Results:** 77%–88% sensitivity, 50%–71% specificity, and 71%–74% accuracy were obtained in the group without positive intraduodenal contrast, versus 50%–80% sensitivity, 57%–71% specificity, and 59%–71% accuracy in the group with positive intraduodenal contrast. With the exception of the positive predictive value (PPV), all diagnostic performance parameters decreased in the positive intraduodenal contrast group, mostly affecting the negative predictive value (NPV) (71%–78% vs 50%–67%). **Conclusion:** PV-enhanced MDCT has moderate diagnostic performance in choledocholithiasis detection. A trend of decreasing accuracy was noted in the presence of positive intraduodenal contrast.

Key Words: Common bile duct, choledocholithiasis, computed tomography, CT, multidetector CT, portovenous, stone

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Endoscopic retrograde cholangiopancreatography (ERCP) is considered the reference standard for choledocholithiasis detection. However, during the past decade, the role of ERCP has shifted increasingly from a diagnostic to a therapeutic one.^[1] Magnetic resonance cholangiopancreatography (MRCP),^[2,3]

transabdominal ultrasound (US),^[4,5] and endoscopic ultrasound (EUS)^[6] are all acceptable and less-invasive tools in the diagnosis of choledocholithiasis.

The estimated incidence rate for gallstones is 10%–20% in the United States and probably higher worldwide.^[7] About 10%–15% of these cases are associated with choledocholithiasis.^[7] Knowing that computed tomography (CT) has replaced many investigative methods in the initial workup of patients with abdominal complaints in both the elective and emergency settings, it is not surprising that a significant number of common bile duct (CBD) stones are first encountered on such examinations.

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A large number of abdominal CT scans are performed using multidetector CT (MDCT) scanners with intravenous (IV) contrast administration. The accuracy of portovenous (PV) phase-enhanced MDCT for the detection of choledocholithiasis has not been extensively evaluated in the literature. In addition, to our knowledge, the effect of administering positive enteric contrast on the accuracy of choledocholithiasis detection has not been independently assessed. Thus, the purpose of this study is to assess the ability of PV-enhanced MDCT, with and without intraduodenal positive contrast filling, in direct choledocholithiasis visualization, using ERCP as the reference standard.

PATIENTS AND METHODS

Subjects

The institutional Department of Professional Services' permission was obtained to review the patients' medical records; informed consent was waived. Reports of 1580 ERCP studies performed at two tertiary care centers from January 2005 to July 2007 were reviewed. All PV-enhanced 4- and 64-MDCT examinations performed within seven days prior to the ERCP studies were selected, resulting in 129 patients. Strict exclusion criteria were applied to ensure visualization of the whole CBD length on the selected MDCT studies. These included obscuration by intraluminal stents, by surrounding biliary leaks, by large compressive or infiltrative masses, or from hepatobiliary surgical-related changes. All patients who underwent biliary-related procedures in the interval from the time of having the CT to the time of performing the ERCP were also excluded. This yielded 48 patients (19 men, 29 women; mean age, 68 years) for the final study group. Regardless of the type of oral contrast given, the final patient population was stratified into two groups according to the absence ($n = 31$) or presence ($n = 17$) of positive enteric contrast in the duodenal lumen. Only patients with total or near-total intraduodenal positive contrast opacification were considered in the latter group.

The clinical indications for the CT studies were as follows: Jaundice ($n = 15$), pancreatitis ($n = 14$), abnormal liver function tests ($n = 3$), abdominal pain ($n = 3$), pancreatic tumor ($n = 2$), liver mass ($n = 2$), and others ($n = 9$). The clinical indications for the ERCP studies were as follows: Suspicion of a CBD stone on CT ($n = 16$), jaundice ($n = 9$), pancreatitis ($n = 7$), cholangitis ($n = 4$), abdominal pain ($n = 2$), and others ($n = 10$). The mean CT-ERCP time interval was 3 days (range of 0–7 days).

CT technique

Only PV phase MDCT studies were selected for analysis even if the patient had other acquisitions in the same study. All CT examinations were performed on two scanners. The first, a 4

detector CT (Lightspeed QXI, GE Healthcare, Milwaukee, WI, USA) with the following parameters: A slice thickness of 2.5–5 mm, a reconstruction interval of 2.5–5 mm, and a pitch of 0.75–1.5:1. The second, a 64 detector CT (Lightspeed VCT, GE Healthcare, Milwaukee, WI, USA) with the following parameters: A slice thickness of 1.25–2.5 mm, a reconstruction interval of 0.9–2.5 mm, and a pitch of 0.984:1. All scans were performed in a craniocaudal direction, with 120 kVp and 250–350 mAs.

All patients received IV contrast material consisting of 100 mL iohexol (omnipaque, 300 mg/mL; GE Healthcare, Milwaukee, WI, USA) power injected at a rate of 2–3 mL/s via a hand or antecubital vein. A bolus tracking technique was used to detect maximal aortic contrast attenuation and the PV acquisition started approximately 70–80 s from the time of injection.

The patients were given positive oral contrast ($n = 24$), negative oral contrast ($n = 14$), or both ($n = 10$); based on the decision of the radiologist in charge at the time of performing the exam. Nonallergic patients received 250 mL of 25 mL 9.17 g iodine (Gastrografin; Bracco Diagnostics, Princeton, NJ, USA) in 1 L of tap water. Iodine-allergic patients received 250 mL of 2% barium sulfate suspension (E-Z-CAT; Therapex, Montreal, QC, Canada) diluted in 750 mL of normal saline. For negative enteric contrast, patients received 250–300 mL of water. A number of patients received positive enteric contrast 2 h before the CT study, followed by negative enteric contrast immediately before the examination. Out of the 31 patients constituting the group with no intraduodenal positive contrast filling, seven received positive oral contrast, 14 received oral water, and 10 received both.

Image analysis

Two radiologists (observers 1 and 2) who were aware of the study aim, but blinded to the clinical presentations, original CT reports, and ERCP results, independently and retrospectively interpreted all selected studies randomly at picture archiving and communication systems workstations (Inteleviewer, software 3-4-1-P102; Intelrad Medical Systems, Montreal, QC, Canada). The observers had 13 and 18 years of experience in cross-sectional imaging, respectively. The use of different window settings, magnification or multiplanar reformatting was optional. A diagnosis of choledocholithiasis was made only when there was direct visualization of a stone using any of the following criteria: (1) Homogeneously calcified, (2) partially calcified, (3) rim calcified, (4) noncalcified central soft-tissue density, or (5) noncalcified ill-defined hyperattenuation within the CBD, surrounded by bile either completely (target sign) or incompletely (crescent or rim signs).^[1] Calcification was assessed on visual basis and not by measuring mean

Hounsfield units. To ensure pure direct visualization, ancillary or suggestive findings such as gallbladder stones, intrahepatic biliary stones, bile tree dilatation, abrupt biliary tree transition, or CBD mucosal enhancement were not used for diagnosing choledocholithiasis.

The findings of the original clinical CT reports were also evaluated. Twelve radiologists, with a 1–34 year range of experience, originally read the CT examinations. The standard of reference was the electronic reports of the ERCP examinations. The ERCP studies were initially performed by eight endoscopists and eventually interpreted by eight radiologists with experience ranging from 1 to 34 years. A third reader, with 34 years of experience in biliary-related imaging, evaluated any discordance between the retrospectively evaluated CT studies and the electronic ERCP reports and provided likely explanations for discordant results.

Statistical analysis

We performed separate analysis for the group without positive enteric duodenal contrast and the group with positive enteric duodenal contrast filling for the results of observer 1, observer 2, and original electronic CT reports. The following results were calculated: Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy. The kappa statistic was used to evaluate the agreement between the two observers and classified as follows: 0.00–0.20, poor; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, good; and 0.81–1.00, very good.

RESULTS

There were 27 (56%) stone-positive and 21 (44%) stone-negative cases based on the ERCP reports. Based on stones correctly detected on CT, the size range was 3–18.3 mm (mean = 11.2 mm). Each patient counted as a single positive result whether single or multiple stones were diagnosed. On CT, a stone was detected by at least one of the observers in 23 of 27 (85%) choledocholithiasis cases. In the correctly diagnosed 23 cases, there were 12 (51%) homogeneously calcified, 1 (4%) partially calcified, 1 (4%) rim-calcified, and 9 (39%) noncalcified stones.

Group A (PV-enhanced with no positive enteric duodenal contrast filling)

Seventeen of 31 (55%) patients in this group had choledocholithiasis on ERCP. Table 1 shows results of CT diagnosis of choledocholithiasis in this group for both observers.

A total of 11 false-positive results were made in 7 patients. Both observers made false-positive interpretations in 4 patients. In 2 patients with a negative ERCP performed 3 days after the CT, both observers detected a homogeneously

calcified distal CBD stone measuring 5 mm in 1 patient and 13 mm in the other [Figure 1]. The third observer retrospectively suspected passed stones in the interim. Both observers falsely diagnosed near-by pancreatic ductal calcification as a distal CBD stone in one patient and volume averaged enhancing ampulla in another patient. In the 3 remaining patients, a false-positive interpretation was made by only one of two observers. This was retrospectively explained by volume averaging from a stone in a redundant gallbladder fundus in 1 patient, ampulla of Vater in another patient, and a low inserting cystic duct–CBD confluence in the third patient [Figure 2].

An overall total of 6 false-negative results were made in 4 patients. Both observers made false-negative interpretation in 2 patients. Both observers failed to diagnose a patient with a 6 mm distal CBD stone, likely due to isoattenuation with bile. In another patient, they both failed to detect multiple stones measuring around 4 mm each. These stones were retrospectively seen on the patient's unenhanced CT acquisition [Figure 3]. Thus, this was likely due to surrounding soft tissue enhancement after IV-contrast administration, leading to stone obscuration. In the 2 remaining patients, a false-negative interpretation was made by only one of the two observers. One observer failed to detect 7 and 8 mm noncalcified distal CBD stones in 1 patient, likely due to their near-bile density. In another patient, one observer missed multiple middle and distal CBD calcified stones. Because these stones were retrospectively seen on the unenhanced CT acquisition, they were likely missed due to obscuration by surrounding enhancing soft tissues.

Group B (PV-enhanced with positive enteric duodenal contrast filling)

Ten of 17 (59%) patients in this group had choledocholithiasis on ERCP. Table 2 shows results of CT diagnosis of choledocholithiasis in this group for both observers.

Table 1: Results of PV-enhanced CT with no positive intraduodenal contrast filling (Group A)

Observer	True-positive	True-negative	False-positive	False-negative	Total
1	15	7	7	2	31
2	13	10	4	4	31

Values are numbers of patients

Table 2: Results of PV-enhanced CT with positive intraduodenal contrast filling (Group B)

Observer	True-positive	True-negative	False-positive	False-negative	Total
1	5	5	2	5	17
2	8	4	3	2	17

Values are numbers of patients

An overall total of 5 false-positive results were made in 3 patients. Both observers made false-positive interpretations in 2 patients. In one patient, they both interpreted a 7 mm homogeneously calcified distal CBD stone that was not seen on the ERCP performed 1 day after the CT [Figure 4]. The proposed explanation by the third observer was that this stone might have passed in the interval. In the other patient, the third observer postulated that both observers have likely misinterpreted volume averaged enhancing soft tissues as multiple CBD stones. In 1 patient, a false-positive result was made by one of two observers, where an intraluminal surgical clip at the distal CBD was misinterpreted as a 1 cm calcified stone.

An overall total of 7 false-negative results were made in 5 patients. Both observers made false-negative interpretations in 2 patients. In 1 patient, a 14 × 6 mm middle–distal CBD stone was missed by both observers and was not seen even on retrospective evaluation despite a large stone size [Figure 5]. The third observer postulated that this was likely a pure cholesterol stone leading to its isoattenuation with bile.

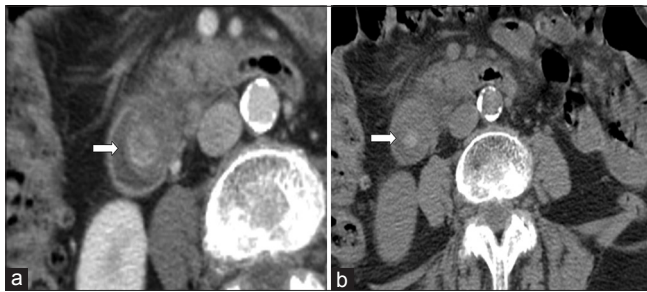


Figure 1: A 77-year-old woman having obstructive jaundice. (a) IV contrast-enhanced transverse MDCT with no positive intraduodenal contrast demonstrating a distally impacted rim-like calcified stone (straight arrow), which was detected by both observers. (b) The stone was seen on the transverse precontrast CT acquisition (straight arrow). The ERCP 3 days later showed no stones. The third reader concluded that this stone had likely passed in the interim

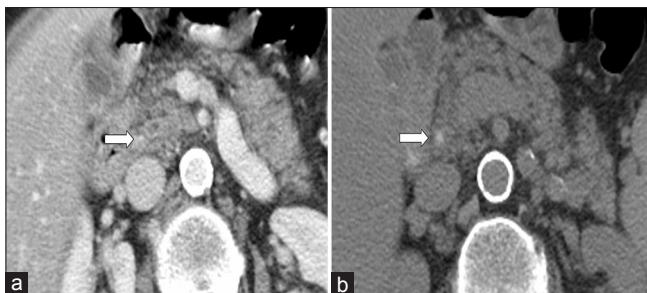


Figure 3: A 74-year-old woman presenting with acute pancreatitis. The images are of transverse MDCT with no positive intraduodenal contrast filling. (a) On this IV contrast-enhanced image, a stone was missed by both observers due to the relative isoattenuation with surrounding enhancing structures (straight arrow). (b) The stone was easily detected on the original clinical CT reading, since it was clearly seen on the unenhanced acquisition (straight arrow)

In the other patient, both readers missed multiple stones. This was also thought to be due to bile-isoattenuation. In the 3 remaining patients, a false-negative interpretation was made by only one of the two observers [Figure 6]. The third observer proposed that the small stone size and/or their isoattenuation with bile were the likely reasons for missing the stones in those patients.

Diagnostic performance and interobserver agreement

Table 3 shows the calculated diagnostic performance parameters for both observers and for the original reports. The kappa value for interobserver agreement was 0.66 (good) for the group where intraduodenal positive contrast was absent and 0.55 (moderate) for the group where intraduodenal positive contrast was present.



Figure 2: A 48-year-old woman with right upper abdominal pain. The images are of an IV contrast-enhanced transverse MDCT with no positive intraduodenal contrast filling. (a) One observer falsely described a distal CBD rim-like calcified stone (straight arrow). (b) Cranial images following the proximal CBD showed that this false-positive result was due to volume averaging of the enhancing mucosa at the confluence of a low inserting cystic duct (curved arrow) with the distal CBD (straight arrow)

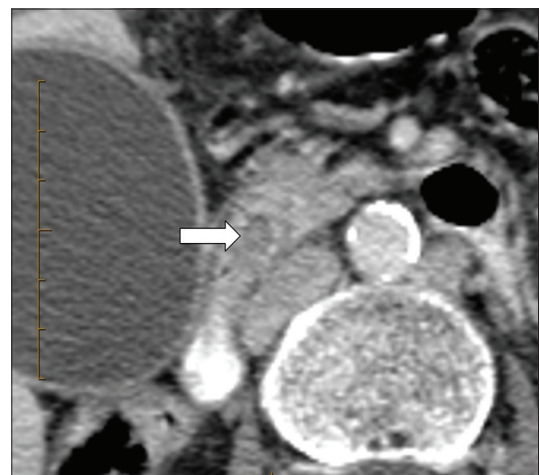


Figure 4: An 81-year-old woman with a clinical picture of obstructive jaundice. This is an IV contrast-enhanced transverse MDCT images with positive intraduodenal contrast filling. Both observers and the original CT reading described a crescent-like homogeneously calcified distal CBD stone (straight arrow). The ERCP performed one day after the CT showed no stones. The third reader concluded that this stone had likely passed in the interim

DISCUSSION

Due to variations in the study design and CT technique, the diagnostic performance of CT in detecting choledocholithiasis has been reported to have a 20%–90% sensitivity range.^[4,8-14] However, the sensitivity for direct CBD stone depiction has been reported to range between 69% and 88%.^[9,15] It has been proposed that administration of both or either IV and positive enteric contrast material would decrease CT detectability of CBD stones.^[15,16] In our study, the PV enhancement phase was chosen since this is the most commonly used type of acquisition in the evaluation of general abdominal complaints in daily practice. We also stratified our data according to the absence or presence of intraduodenal positive contrast material. To our knowledge, this form of stratification has not been performed in previous publications.

Biliary stones have variable compositions. About 20% of stones are purely composed of cholesterol. These stones are isoattenuated or minimally hypoattenuated when compared with surrounding bile, leading to a 20% sensitivity limit in choledocholithiasis detectability on CT.^[17-19] This latter fact is a potential reason for missing stones in our study in both of our groups. Additionally, the obscuration of calcified stones by adjacent enhancing soft tissues was another proposed reason for missing stones in our study. The stone

size is another known factor that affects CT detectability. However, the stone composition is a major determinant in its detectability on CT, regardless of the stone size being small or large. Stones containing calcium are substantially easier to identify.^[13] On unenhanced CT, it has been advocated to manipulate the window settings when a stone is not initially seen, to increase the chance of detecting stones that are isoattenuated to bile.^[9,15] In this current study, we noticed that this type of window setting adjustment was helpful in evaluating cases with positive duodenal enteric contrast filling as well.

The major reason for false-positive readings in our study was volume averaging with various enhancing surrounding structures. Encountering this well-known phenomenon is not surprising, given that our population was composed of IV-enhanced CT studies.^[20] Interestingly, we encountered one false-positive case due to volume averaging of enhancing mucosa at the confluence of CBD and a low-inserting cystic duct. This type of pitfall, to our knowledge, was not described in previous studies.

Our overall sensitivity was 50%–88%, which is roughly comparable to the previously stated sensitivities range of 70%–88% on unenhanced CT.^[9,15,21] The major differences were in both the specificity and accuracy. The former dropped from a published range of 92%–100% to 50%–71%, whereas

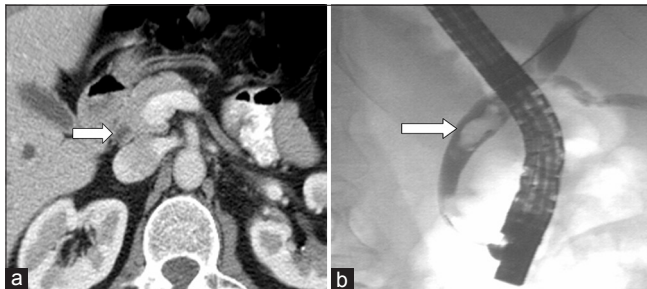


Figure 5: A 57-year-old man with fever and right upper quadrant pain. (a) IV contrast-enhanced MDCT transverse image with positive intraduodenal contrast filling. (b) Both observers failed to detect an ERCP-confirmed 14 × 6 mm mid-CBD stone (straight arrows). Despite its large size, this stone was likely missed due to isoattenuation to surrounding bile

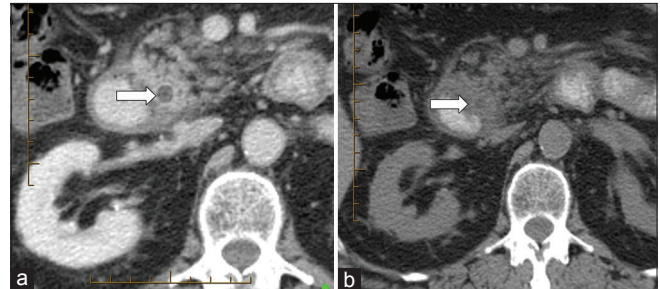


Figure 6: A 63-year-old man with acute pancreatitis. The images are of transverse MDCT with positive intraduodenal contrast filling. (a) On this IV contrast-enhanced acquisition, only one observer successfully detected an ERCP-proven distal CBD stone appearing as a rim-sign (straight arrow). (b) The stone was otherwise obscured on the unenhanced CT acquisition (straight arrow)

Table 3: Results of analysis by observer 1, observer 2, and original reports in both groups

Diagnostic performance (%)	Observer 1		Observer 2		Original report	
	Group A	Group B	Group A	Group B	Group A	Group B
Sensitivity	88	50	77	80	82	40
Specificity	50	71	71	57	79	71
PPV	68	71	77	73	82	67
NPV	78	50	71	67	79	46
Accuracy	71	59	74	71	81	53

Group A, PV-enhanced CT with no positive intraduodenal contrast filling; Group B, PV-enhanced CT with positive intraduodenal contrast filling, PPV: Positive predictive value, NPP: Negative predictive value

the latter dropped from a published range of 85%–94% to 59%–74%. This result suggests a better performance of unenhanced CT in detecting cholelithiasis, mainly due to volume averaging of IV-enhancing structures that surround the CBD. However, a recent study by Anderson *et al.* highlighted that this problem could be overcome by using uniformly thinner slice thicknesses and multiplanar reformatting.^[16] Of note, our sensitivity is also roughly comparable with that previously reported for IV-enhanced MDCT studies.^[15,16]

The accuracy achieved in our study is 59%–74% versus that of 84%–88% in a previous similarly designed study by Anderson *et al.*^[15] One possible reason for their superior results is that we included CT examinations with variable slice thicknesses, ranging from 1.25 to 5 mm, versus uniformly thinner slice thickness in Anderson *et al.*'s study.^[15] The accuracy dropped by 3%–12% when positive enteric contrast filled the duodenum. A 28% drop in accuracy was encountered in this group of positive intraduodenal contrast as well, when compared to that of our hospital's original electronic CT reports. This observation might concur with the general belief that more stones are missed due to obscuration by positive enteric duodenal contrast.^[15,16] Thus, when CBD stones are suspected clinically, obtaining thinner slice thicknesses in the presence of positive intraduodenal contrast might be worthwhile. Our NPV has dropped in the group of intraduodenal positive enteric contrast filling despite a relatively unchanged PPV, suggesting that excluding stones on IV- and oral-contrast enhanced MDCT is less than satisfying in the context of a normal-appearing CT examination.

We encountered a number of limitations. First, the lack of accurate documentation of stone size and number on the clinical ERCP report led to a smaller case number than originally desired (ie, each patient counted as one result whether single or multiple stones were present). Second, the retrospective nature of the study may have allowed interval passage of some stones from the time of obtaining the CT to the time of performing the ERCP (ie, yielding more false-positive results). Third, verification bias may have been encountered since a number of patients underwent ERCP due to the suspicion of cholelithiasis on the basis of CT.^[22] Fourth, the variable slice thicknesses used in our study might have affected our final results. However, this kind of variability mirrors daily routine acquisition in many other institutions and may reflect a practical reality. Finally, excluding clinical data and ancillary CT findings in diagnosing stones on CT could have affected our results, which may explain a few discrepancies between our retrospective results and those of the original electronic CT reports.

CONCLUSION

In conclusion, PV phase 4- and 64-MDCT has moderate diagnostic performance in cholelithiasis detection. A trend of decreasing accuracy was observed with positive intraduodenal contrast administration, suggesting that a normal-enhanced MDCT does not exclude the diagnosis in suspected cases. Introducing a precontrast scan or using negative enteric contrast material may be practically useful in such cases.

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