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Multiphase Computed Tomographic Enterography: Diagnostic Yield and Efficacy in Patients With Suspected Small Bowel Bleeding

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Abstract

Objective: To estimate the diagnostic yield and efficacy of multiphase computed tomographic enterography (mpCTE) for suspected small bowel bleeding in routine clinical practice.

Patients and Methods: All mpCTEs performed between January 1, 2006, and December 31, 2014, for suspected small bowel bleeding were included and classified by a gastroenterologist and an abdominal radiologist. The reference standard for a definitive diagnosis was balloon-assisted enteroscopic, angiographic, surgical, or pathologic results. Overall and lesion-specific diagnostic yield (DY), sensitivity, and positive predictive value were calculated. The relationship of mpCTE diagnosis and continued bleeding or iron supplementation was examined using logistic regression in patients with at least 1 year of follow-up.

Results: We identified 1087 patients who had an initial mpCTE indication of small bowel bleeding. The overall DY was 31.6% (344 of 1087 patients; 95% CI, 29.0%-35.0%), higher for an indication of small bowel bleeding that was overt or occult with heme-positive stool vs occult with only iron-deficiency anemia (DY, 35.0% [170 of 486] and 35.3% [66 of 187] vs 26.1% [108 of 414]; P=.004 and P=.02, respectively). The highest sensitivity and positive predictive value were for small bowel masses (90.2% [55 of 61] and 98.2% [55 of 56], respectively). Higher risk of future bleeding and iron supplementation was seen with a negative result on mpCTE (odds ratio [OR], 1.91; 95% CI, 1.28-2.86), lack of surgical intervention (OR, 4.37; 95% CI, 2.31-8.29), or discrepant balloon-assisted enteroscopic findings (OR, 2.50; 95% CI, 1.03-6.09).

Conclusion: Multiphase computed tomographic enterography has a higher rate of detection in patients with overt bleeding or heme-positive stool. The procedure provides actionable targets for further intervention and leads to substantially reduced rates of rebleeding in long-term follow-up.

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Small bowel bleeding is defined as chronic gastrointestinal (GI) blood loss in a patient who has had negative findings on upper and lower endoscopic evaluation.[1] It can be manifested by either visible bleeding (overt small bowel bleeding) or iron-deficiency anemia with or without heme-positive stools (occult small bowel bleeding). The current entity of small bowel bleeding was previously defined as obscure GI bleed.[2] Patients with small bowel bleeding

often require multiple blood or iron transfusions, hospitalizations, and procedures as well as extensive and expensive diagnostic work-up. Establishing etiologies of small bowel bleeding is challenging, largely owing to the intermittent nature of small bowel blood loss itself, coupled with the small size of bleeding vascular lesions, small bowel tumors, or inflammation.

Prior meta-analysis has suggested that routine computed tomographic enterography

(CTE) has an acceptable but lower yield with higher specificity in patients with small bowel bleeding, especially when compared with capsule endoscopy.[3] In patients with suspected small bowel bleeding, a 3-phase acquisition protocol (multiphase CTE [mpCTE]) is generally used to display the small bowel wall during multiple phases of enhancement (arterial, enteric, and delayed) at our institution.[4,5] It provides information regarding 3-dimensional morphology, temporal vascular evolution, and regional clues that often differentiate the different types of lesions, with an improved ability to display potential causes of small bowel bleeding as well as suggest specific etiologies.[5] In a retrospective and prospective study using the mpCTE protocol, the sensitivity of mpCTE rivaled that of capsule endoscopy for identifying causes of small bowel bleeding, with superior sensitivity for small bowel masses.[6,7] Given its ability to display the small bowel wall (rather than the mucosa), it may play a role complementary to capsule endoscopy.[1]

Consequently, our institution incorporated routine mpCTE as a complement to capsule endoscopy in the evaluation of patients with suspected small bowel bleeding. However, there have been no large-scale studies evaluating the effectiveness of mpCTE in routine clinical practice. Our purpose was to estimate the diagnostic yield (DY) and efficacy of mpCTE for patients with suspected small bowel bleeding in routine clinical practice.

PATIENTS AND METHODS

Study Population
In this institutional review board—approved, Health Insurance Portability and Accountability Act—compliant single-center retrospective study, we reviewed the medical records of consecutive patients who had undergone mpCTE at our institution from January 1, 2006, through December 31, 2014, and had provided research authorization. For this study, we included only patients who had mpCTE for an initial indication of suspected small bowel bleeding in the outpatient or inpatient setting and not in the emergency department. Patients who had imaging performed for other diagnoses such as hematologic disease, malabsorption, known cause of iron-deficiency anemia, or malignancy separate from the GI tract were excluded from analysis.

Multiphase CTE Protocol
The contrast-enhanced mpCTE in these patients was conducted with 1350 mL of neutral oral contrast medium (VoLumen, E-Z-EM, Inc) with the patient asked to continue drinking water as tolerated and scanned 60 minutes after beginning the oral contrast

Variable	Overt small bowel bleeding (N=486)	Occult small bowel bleeding with heme-positive stool (N=187)	Occult small bowel bleeding with iron-deficiency anemia (N=414)
TABLE 1. Baseline Characteristics of the Study Population, Stratified by Initial Indication for Multiphase Computed Tomographic Enterography[a]			
Age (y)	65 (54-76)	66 (57-73)	65 (55-73)
Female	228 (46.9)	111 (59.4)	230 (55.6)
Transfusions[b]	339 (69.8)	110 (58.8)	159 (38.4)
Prior endoscopic evaluation[c]	440 (90.5)	166 (88.8)	371 (89.6)
Further testing			
Surgery	57 (11.7)	22 (11.8)	29 (7.0)
Balloon-assisted enteroscopy	126 (25.9)	53 (28.3)	68 (16.4)
Capsule endoscopy	195 (40.1)	82 (43.9)	139 (33.6)
Angiography	25 (5.1)	3 (1.6)	3 (0.7)
Other	76 (15.6)	41 (21.9)	54 (13.0)

[a]Data are presented as median (interquartile range) or No. (percentage) of patients.
[b]Prior to multiphase computed tomographic enterography.
[c]Prior esophagogastroduodenoscopy and colonoscopy in the 24 months preceding multiphase computed tomographic enterography.

FIGURE 1. Study flowchart. CTE = computed tomographic enterography; GI = gastrointestinal.
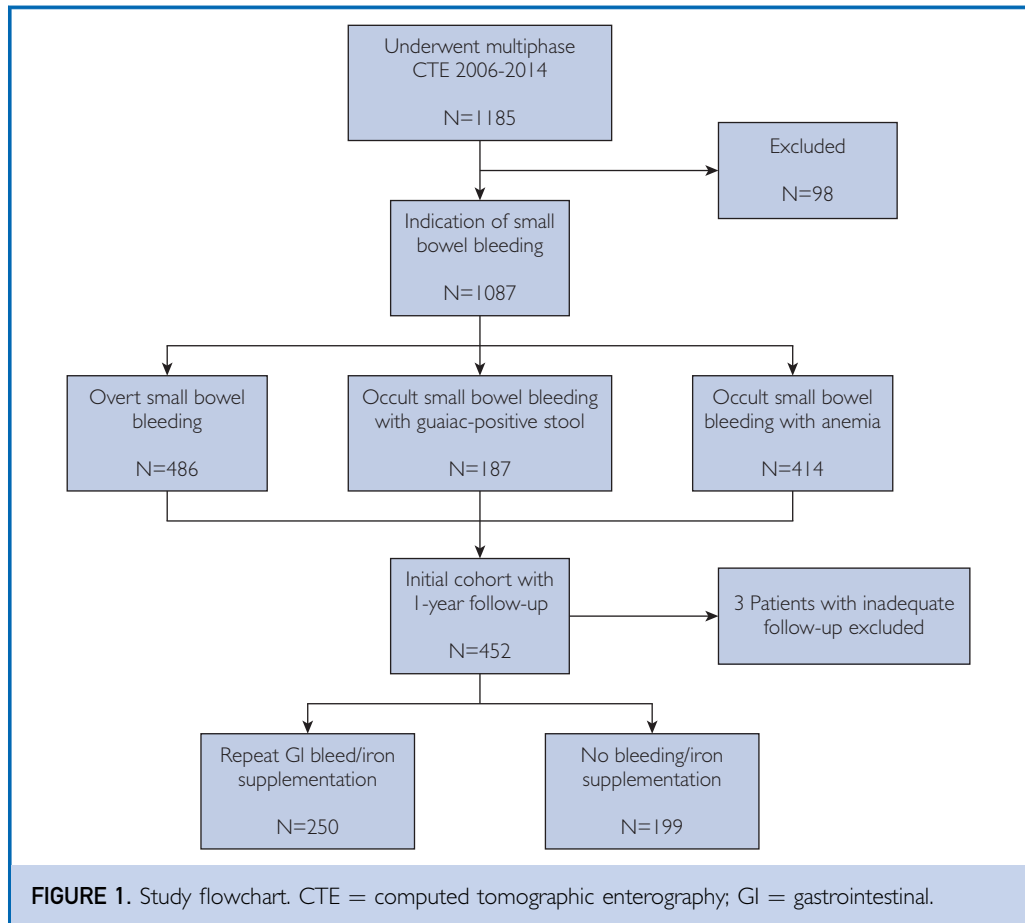
with images acquired in the arterial, enteric, and delayed phases of enhancement. The delayed phase allows temporal assessment of enhancement characteristics that may help improve characterization. It allows improved detection of certain abnormalities that may only be apparent on 1 or 2 phases and helps to differentiate true pathology from ingested high-attenuation material that can lead to false-positive interpretations. In our published prospective study, the 3-phase scan performed at least as well as, if not better than, wireless capsule endoscopy.[5]

Data Collection and Definitions

We reviewed medical records prior to mpCTE to determine the initial indication for mpCTE. If a patient had more than one mpCTE, the first was used as the index examination included in this study. For each patient, the original mpCTE images, GI procedures, surgical notes, and pathologic specimens were reviewed in consensus by a fellowship-trained abdominal radiologist and gastroenterologist and classified as definite positive (likely to cause blood loss), unclear (uncertain significance to blood loss), or negative (no cause for blood loss). Definite positive findings on mpCTE reports were recorded and further subclassified as being a small bowel mass, small bowel vascular lesion, small bowel inflammation, small bowel hemorrhage, or other pathologic process (which included non−small bowel lesions). The presence or absence of active bleeding during mpCTE was also noted, defined as extravasation of contrast medium into the lumen of the bowel with temporal change over the 3 phases.

Medical records were evaluated in consensus by a fellowship-trained abdominal radiologist and a gastroenterologist for all evaluations and interventions done in the form of

TABLE 2. Yield of Multiphase Computed Tomographic Enterography Stratified by Clinical Bleeding Pattern and Patient Age[a,b]

Yield	Overall (N=1087)	Subgrouped by clinical bleeding pattern			Subgrouped by age	
		Overt small bowel bleeding (n=486)	Occult small bowel bleeding with heme-positive stool (n=187)	Occult small bowel bleeding with iron-deficiency anemia (n=414)	<40 y (n=86)	≥40 y (n=1001)
All	344 (31.7)	170 (35.0)	66 (35.3)	108 (26.1)	26 (30.2)	318 (31.8)
SB inflammation	52 (15.1)	13 (7.7)	13 (19.7)	26 (24.1)	5 (19.2)	47 (14.8)
SB mass	72 (20.9)	40 (23.5)	14 (21.2)	18 (16.7)	6 (23.1)	66 (20.8)
SB vascular	124 (36.1)	64 (37.7)	23 (34.9)	37 (34.3)	11 (42.3)	113 (35.5)
SB hemorrhage	7 (2.0)	4 (2.4)	2 (3.0)	1 (0.9)	NA	7 (2.2)
Other lesions	89 (25.9)	49 (28.8)	14 (21.2)	26 (24.1)	4 (15.4)	85 (26.7)

[a]NA = not available; SB = small bowel.
[b]Data are presented as No. (percentage) of patients.

surgery, endoscopy, angiography, or further imaging in the subsequent 24 months. The reference standard for a definitive diagnosis of small bowel bleeding was defined as a finding on endoscopy, angiography, surgery, or pathology that could cause small bowel bleeding. Medical records were also reviewed to record prior iron or blood transfusions, as well as the number of upper and lower endoscopies conducted in the 24 months before the initial mpCTE. Furthermore, for patients who had clinical follow-up at least 1 year after the initial mpCTE, the medical records were evaluated for evidence of continued GI bleeding, which was defined as the occurrence of iron-deficiency anemia, overt small bowel bleeding, or need for continuing iron supplementation.
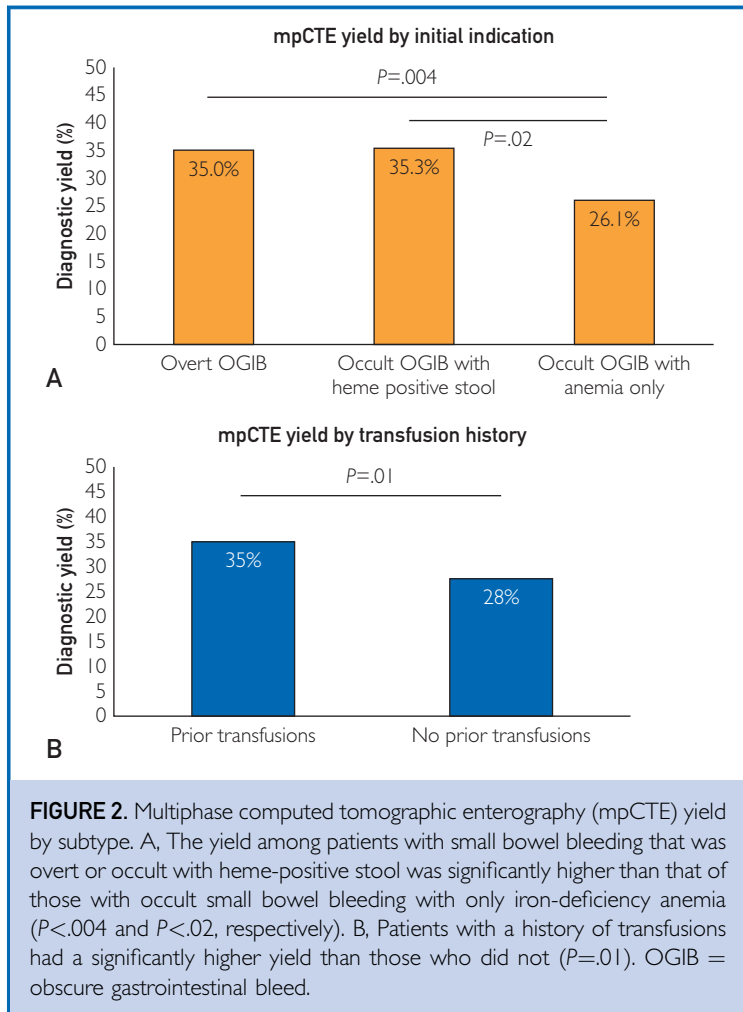
Statistical Analyses

Yield was calculated as the percentage of patients who had a definite positive finding on mpCTE. Yields between different subcategories of small bowel bleeding (eg, overt and obscure with or without heme-positive stool) were compared using a χ^2 test. In the subset of patients with a definitive diagnosis of small bowel bleeding confirmed by the reference standard tests, sensitivity was calculated as the proportion of all definitive diagnoses that were correctly identified by mpCTE. A true-positive diagnosis required a definitive diagnosis with the same type of lesion noted in the same region of the bowel during mpCTE based on review of endoscopy, imaging, operative notes, and pathology data and consensus between a fellowship-trained abdominal radiologist and a gastroenterologist. If there was

discordance in the type of lesion or the location of the lesion, it was deemed as "unclear" and was not counted as a true positive. Lesions identified by subsequent reference tests not seen on the initial mpCTE were noted as false-negatives. Positive predictive value (PPV) was calculated as the proportion of positive mpCTE findings that were confirmed by a subsequent definitive diagnosis. Specificity was not calculated because there is no combination of tests that can exclude the presence of pathologies causing small bowel bleeding. A χ^2 test was used to compare continued bleeding between patients with positive and negative findings on initial mpCTE who had subsequent evaluation (as defined previously) and 1 year of follow-up. Additionally, predictors of continued GI bleeding or iron supplementation during the first year of follow-up were assessed in patients who underwent mpCTE for small bowel bleeding and had follow-up for a duration of 1 year or greater, using logistic regression analysis with SAS statistical software, version 9.4 (SAS Institute). Multiple-comparison P values were corrected using the Bonferroni technique.

RESULTS

Of the 1185 patients who underwent mpCTE at our institution during the study period, 1087 underwent mpCTE with an initial indication of small bowel bleeding, with 486 patients (44.7%) having overt small bowel bleeding, 187 (17.2%) having occult small bowel bleeding with heme-positive stool, and 414 (38.1%) having occult small bowel bleeding with iron-deficiency anemia only.

FIGURE 2. Multiphase computed tomographic enterography (mpCTE) yield by subtype. A, The yield among patients with small bowel bleeding that was overt or occult with heme-positive stool was significantly higher than that of those with occult small bowel bleeding with only iron-deficiency anemia (*P*<.004 and *P*<.02, respectively). B, Patients with a history of transfusions had a significantly higher yield than those who did not (*P*=.01). OGIB = obscure gastrointestinal bleed.

included 124 small bowel vascular lesions, 72 small bowel masses, 52 cases of small bowel inflammation, 7 small bowel hemorrhages, and 89 other findings. The most commonly detected positive findings outside the small bowel on mpCTE included rectal and cecal vascular malformations (24), gastric lesions (12), colonic vascular malformations not in the rectum or cecum (7), and large hemorrhoids (6). The DY of mpCTE was subsequently examined for the different groups of patients with small bowel bleeding (Table 2). Notably, patients with an initial indication of overt small bowel bleeding (35.0% yield [170 of 486]) or occult small bowel bleeding with heme-positive stool (35.3% yield [66 of 187]) had a significantly higher yield than those whose initial indication was occult small bowel bleeding with only iron-deficiency anemia (26.1% yield [108 of 414]; *P*=.004 and *P*=.02, respectively). A history of transfusions (Figure 2) also significantly increased the DY of mpCTE from 28% without a history of transfusions to 35% with at least one prior iron therapy or blood transfusion (*P*=.01).

A definitive diagnosis of small bowel bleeding was established in 340 patients (31.3%) through surgical, endoscopic, angiographic, or pathologic findings. In this cohort, 165 patients had their definitive cause of small bowel bleeding identified on mpCTE, 56 had indeterminate findings, and 119 did not have the lesion identified at mpCTE, resulting in an overall sensitivity of 58.1% (165 of 284; 95% CI, 50.0%-66.0%). The sensitivity and PPV of mpCTE are estimated in Table 3. When considering specific types of lesions, the sensitivities were 55.4% (31 of 56) for small bowel inflammation, 80.0% (4 of 5) for small bowel hemorrhage, 90.2% (55 of 61) for small bowel masses (see examples of GI stromal tumors in Figure 3 and neuroendocrine tumors in Figure 4), 41.9% (44 of 105) for small bowel vascular lesions, and 54.4% (31 of 57) for other lesions (see examples of strictures from nonsteroidal anti-inflammatory drugs and radiation in Figure 5). For patients who had a positive finding on mpCTE as well as a definitive diagnosis, the overall PPV was 88.2% (165 of 187; 95% CI, 83.0%-92.0%). Lesion-specific PPVs were 93.9% (31 of 33) for small bowel inflammation, 98.2% (55 of 56) for small bowel masses, 83.0% (44 of 53) for small bowel vascular lesions, 100% (4 of 4) for

The baseline characteristics of the 3 groups of patients with small bowel bleeding are shown in Table 1. The study flow is depicted in Figure 1. Of the 1087 patients, 608 (55.9%) had received at least one transfusion of iron or blood prior to their mpCTE. Most of the patients had previous endoscopic evaluation in the 24 months before mpCTE; 95% of patients had a previous upper endoscopy, 92% had a previous colonoscopy, 89.9% had both, and only 3% had neither. Subsequent evaluation of these patients after mpCTE was available in the form of surgery (n=108), balloon-assisted endoscopy (n=247), capsule endoscopy (n=416), angiography (n=31), or other testing (n=171). The overall DY of definite positive findings for small bowel bleeding was 31.6% (344 of 1087; 95% CI, 29.0%-35.0%; Table 2). Positive examination results

small bowel hemorrhage, and 75.6% (31 of 41) for other lesions.

Of the 1087 study patients, 452 (41.6%) had clinical follow-up available at least 1 year after the initial mpCTE with a mean ± SD follow-up of 3.1±1.8 years, and 449 of the 452 (99.3%) had data available regarding continued bleeding or iron dependence. Among these patients, 250 (55.7%) had repeated bleeding or continued iron dependence. Risk factors for future bleeding or continued iron supplementation during the first year of follow-up were examined depending on the result of the mpCTE and other diagnostic strategies (Table 4). In differentiating by index mpCTE findings, those who had an initial positive mpCTE result had a 44.7% (63 of 141) rate of rebleeding or iron dependence compared with 60.7% (187 of 308) among those who had a negative mpCTE result. The risk of continued bleeding after a negative mpCTE result was significantly higher than the risk of continued bleeding after a positive mpCTE result (odds ratio [OR], 1.91; 95% CI, 1.28-2.86; P=.002). Among patients who had a capsule endoscopy (145 of 449 [32.3%]), we also found a trend toward an increased risk of bleeding or need for continued iron supplementation for patients with a positive result on capsule endoscopy compared with a negative result (69.8% [67 of 96] vs 55.1% [27 of 49]; OR, 1.88; 95% CI, 0.92-3.84). As expected, those who underwent surgery had a lower risk of rebleeding—presumably because the etiologic lesion was identified (25.5% [14 of 55] vs 59.9% [236 of 394]), so the risk of rebleeding is actually higher in those patients who do not undergo surgery (OR, 4.37; 95% CI, 2.31-8.29). Similarly, when balloon-assisted enteroscopy (BAE) findings were congruous with mpCTE findings, the risk of rebleeding was substantially lower (48.3% [14 of 29] vs 70.0% [49 of 70]), so patients with a BAE result that is normal or different from mpCTE findings are at increased risk of continued bleeding (OR, 2.50; 95% CI, 1.03-6.09).

DISCUSSION

In this study, we found that the overall DY of mpCTE was 31.7%, indicating that approximately 1 in 3 patients would have a positive finding capable of causing small bowel bleeding at mpCTE. This rate was higher in those with overt small bowel bleeding (35.0% yield) or

TABLE 3. Sensitivity and Positive Predictive Value for Lesion Detection Using Multiphase Computed Tomographic Enterography Among Patients With a Definitive Diagnosis of Small Bowel Bleeding[a,b]

| Type of lesion	Sensitivity	Positive predictive value
SB inflammation	55.4% (31/56)	93.9% (31/33)
SB mass	90.2% (55/61)	98.2% (55/56)
SB vascular	41.9% (44/105)	83.0% (44/53)
SB hemorrhage	80.0% (4/5)	100% (4/4)
Other lesions	54.4% (31/57)	75.6% (31/41)
Overall	58.1% (165/284)	88.2% (165/187)

[a]SB = small bowel.
[b]Reference standard is a definitive diagnosis of small bowel bleeding through surgical, endoscopic, angiographic, or pathologic findings.

occult small bowel bleeding with heme-positive stool (35.3% yield) compared with those with occult small bowel bleeding with iron-deficiency anemia (26.1% yield). This
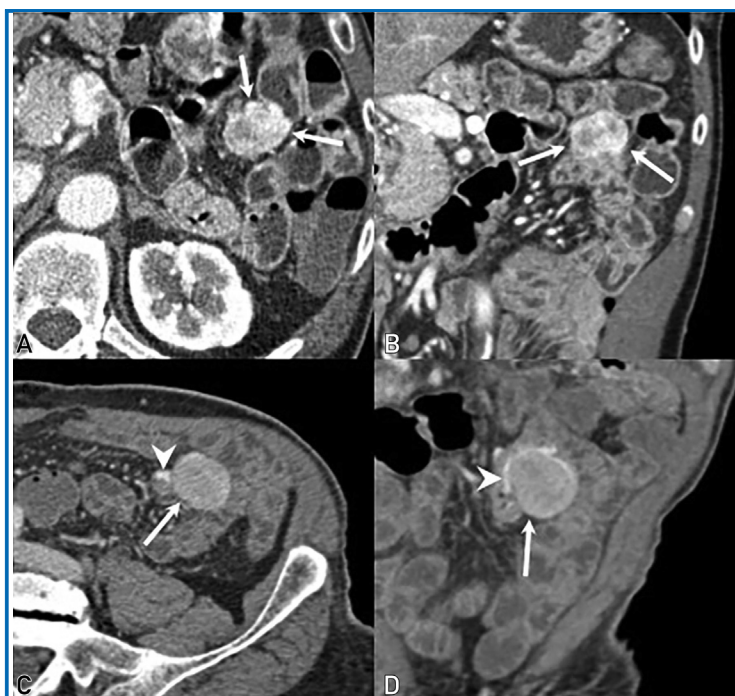
FIGURE 3. Images from 2 patients with gastrointestinal stromal tumors of the jejunum discovered on 3-phase computed tomographic enterography. A and B, Images from a 66-year-old man presenting with a 5-year history of iron-deficiency anemia being treated with iron therapy. Heterogeneously hyperenhancing mass arising from the proximal jejunum is clearly seen on enteric phase enterographic images (arrows). C and D, Images from a 75-year-old man presenting with melena. Note heterogeneously enhancing mass (arrows) arising from the jejunum with prominent varicosities (arrowheads) in the adjacent bowel wall.
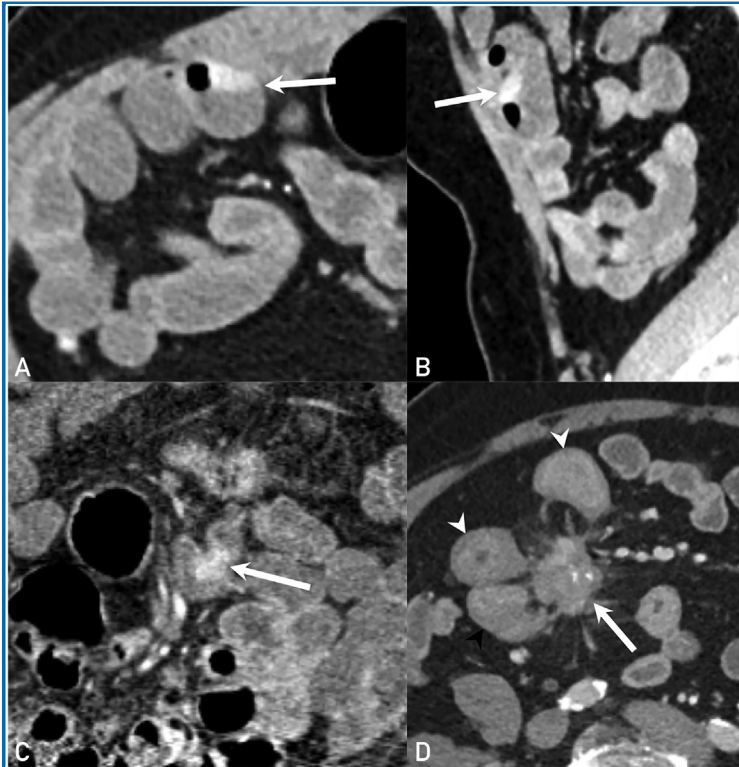
FIGURE 4. Images from patients with small bowel neuroendocrine tumors. A and B, Images from a 69-year-old patient presenting with melena. Axial (A) and sagittal (B) arterial phase images demonstrate a plaquelike hyperenhancing mass typical of a small bowel neuroendocrine tumor (arrows). C, Image from an 80-year-old woman receiving long-term anticoagulation for atrial fibrillation presenting to the emergency department with rectal passage of bright-red blood. Enteric phase computed tomographic enterographic image shows an enhancing plaquelike mass with typical serosal retraction or buckling of the small bowel wall caused by a small bowel neuroendocrine tumor (arrow). D, Image from a 77-year-old-man presenting with iron-deficiency anemia. Enteric phase computed tomographic enterographic image shows abnormal bowel wall edema (arrowheads) caused by a scirrhous mesenteric metastatic lesion with punctate calcifications (arrow) typical of a neuroendocrine tumor, which had obstructed the mesenteric veins.

finding is similar to that of a prior smaller study of 65 patients that reported that a history of massive bleeding was independently associated with a higher DY for CTE.[8] We additionally found that the sensitivity and PPV were highest for detection of small bowel masses.

Small bowel bleeding presents a diagnostic dilemma for physicians because further evaluation after negative results on upper and lower endoscopy can be invasive and challenging, and often unrewarding.[1] Although BAE can effectively evaluate the small intestine for

lesions, complete coverage of the small bowel may not be possible and often requires both anterograde and retrograde approaches.[9] Surgery and angiography are powerful tools, but the former is limited to evaluating previously identified abnormalities, while the latter is primarily useful in identifying vascular lesions or active bleeding. Subsequently, noninvasive approaches such as capsule endoscopy and mpCTE have been incorporated as visualization tools for small bowel assessment. Previous studies established the role of mpCTE as complementary to capsule endoscopy in finding a cause for small bowel bleeding, but this is the first study to systematically assess the DY and efficacy of mpCTE using a large cohort.[7]

The DY reported in this study was consistent with a previously reported pooled DY of 40% (95% CI, 33.0%-49.0%) in a prior meta-analysis of CTE performance in evaluating small bowel bleeding.[3] The findings of our study are especially important considering that only 31.3% of the patients in our cohort had an established definitive diagnosis of their small bowel bleeding. Although the presentations of patients with small bowel bleeding vary, we found that the yield on mpCTE was significantly higher for those patients who had a history of small bowel bleeding that is either overt bleeding or with heme-positive stools (P<.004 and P<.02, respectively). These patients likely had a higher volume of blood loss from larger or higher-flow lesions, which would be more easily detected on mpCTE. However, 1 in 4 patients who did not have these characteristics still had lesions identified on mpCTE, making mpCTE still a useful test for those patients with occult small bowel bleeding and iron-deficiency anemia without demonstrated blood loss. Moreover, approximately 7% had definite causes of small bowel bleeding outside the small bowel and elsewhere along the GI tract.

The estimated 58.1% sensitivity among subsequently identified causes of small bowel bleeding indicates that mpCTE can effectively detect a variety of lesions. As has been noted previously, identifying and characterizing small bowel masses is a strength of mpCTE because many small bowel tumors arise within the wall instead of the mucosa, with an estimated 90.2% sensitivity and 98.2% PPV in our study. Although the sensitivity for vascular
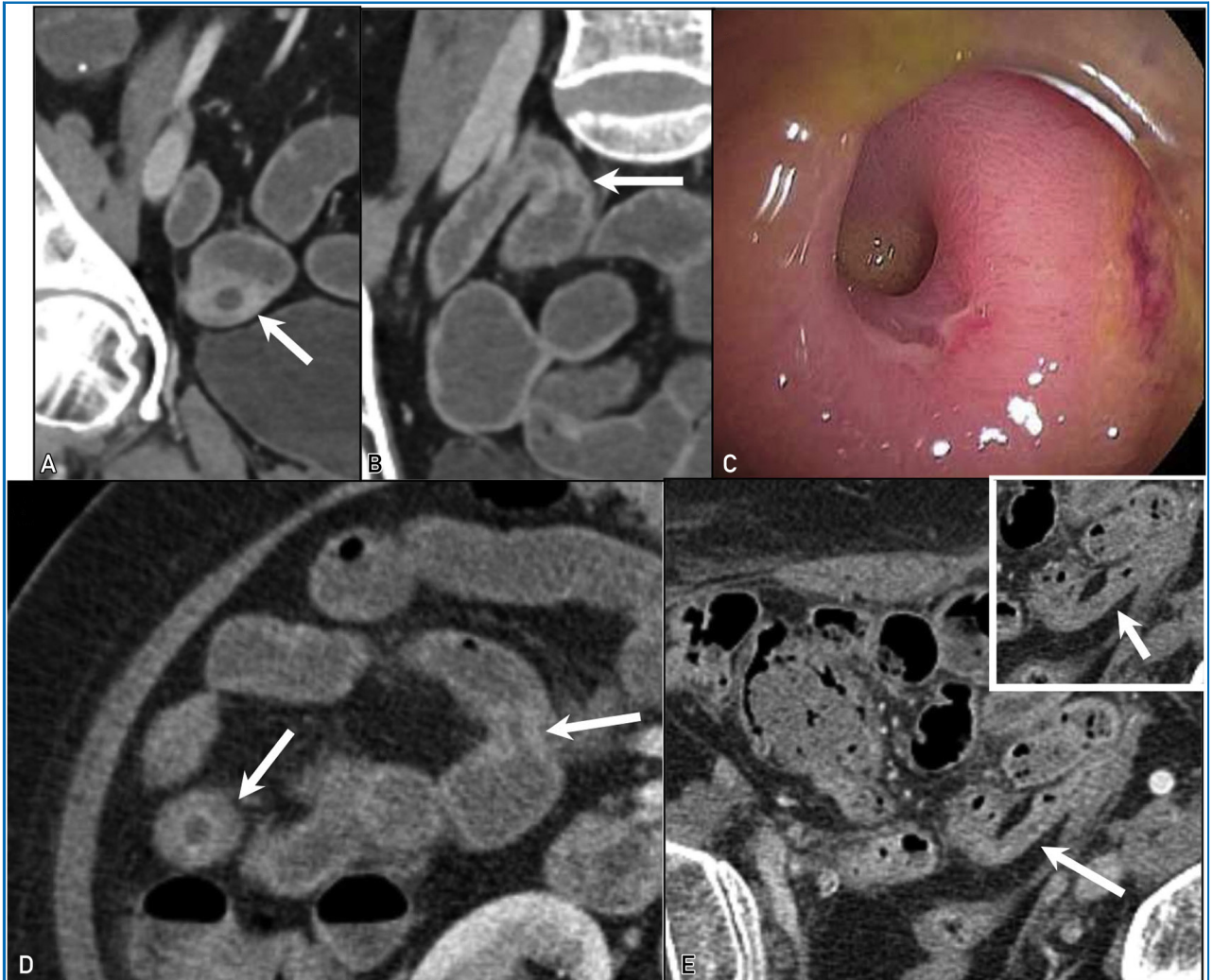
FIGURE 5. Images from patients with small bowel strictures. A-C, Images from a 69-year-old woman with chronic iron-deficiency anemia and negative findings on colonoscopy. Computed tomographic enterography revealed multiple short-segment ileal strictures (A and B, arrows) indicative of nonsteroidal anti-inflammatory drug (NSAID) enteropathy, with subsequent retrograde enteroscopy (C) confirming and dilating NSAID diaphragms. D, Computed tomographic enterographic image from a 49-year-old woman with transfusion-dependent iron-deficiency anemia demonstrating short-segment ileal strictures (arrows), thought to represent NSAID enteropathy or Crohn disease, with subsequent single balloon endoscopy confirming ileal strictures with ulcerations. E, Computed tomographic enterographic image from a 58-year-old woman with a history of radiation therapy for anal cancer and iron-deficiency anemia showing long-segment ileal strictures in multiple phases of enhancement (arrows) thought to represent radiation enteropathy. Subsequent abdominal exploration at another institution for retained capsule endoscopy demonstrated multiple adhesions and radiation enteritis.

lesions was lower at 41.9%, the 83.0% PPV indicates that these findings are consistently actionable and can provide appropriate targeting for BAE or angiography when present. A recent retrospective cohort study using a prospectively maintained database of 495 patients who underwent BAE for small bowel bleeding reported a numerically increased DY of BAE with preceding imaging (67.1%) compared to without preceding imaging (59.5%).[9] A similar pattern was observed relating to small bowel inflammation, reiterating the complementary nature of information obtained with mpCTE and capsule endoscopy. Overall, our combined PPV of 88.2% shows that mpCTE findings provide consistent targets for intervention, with less than in 1 in 8 lesions not identified at subsequent investigation.

TABLE 4. Risk Factors for Repeated Gastrointestinal Bleeding or Continued Iron Supplementation During the First Year of Follow-up After Multiphase Computed Tomographic Enterography and Other Strategies[a,b]

Procedure	Result	Future bleeding or iron supplementation	Odds ratio (95% CI)
mpCTE	Negative	187/308 (60.7)	**1.91 (1.28-2.86)** Positive mpCTE (Ref)
Capsule endoscopy	Positive	67/96 (69.8)	1.88 (0.92-3.84) Negative capsule endoscopy (Ref)
Surgery	Not done	236/394 (59.9)	**4.37 (2.31-8.29)** Surgery done (Ref)
BAE	Done	63/99 (63.6)	1.53 (0.96-2.42) BAE not performed (Ref)
BAE diagnosis	Negative or different from mpCTE	49/70 (70.0)	**2.50 (1.03-6.09)** BAE diagnosis same as mpCTE (Ref)
BAE treatment	Done	36/48 (75.0)	**2.67 (1.14-6.26)** BAE no treatment (Ref)

[a]BAE = balloon-assisted enteroscopy; mpCTE = multiphase computed tomographic enterography; Ref = reference.
[b]Data are presented as No. (percentage) of patients.

Although previous studies have also estimated the DY of mpCTE for small bowel bleeding,[10] we have assembled a large cohort to assess the DY of mpCTE, overall and by indication and type of detected lesion. The main strength of our study is the availability of follow-up data to determine the net effect of mpCTE on small bowel bleeding. This strength is best described by the observed outcome summarized by rates of continued bleeding or iron dependence in long-term clinical follow-up. In the 195 patients who had further investigation and 1-year follow-up, there was a profound reduction in rebleeding rates after a positive mpCTE result compared with a negative mpCTE result, as well as in those who underwent surgical intervention. This finding demonstrates how mpCTE results not only provided valuable targets for therapeutic intervention but also that many identified lesions truly were the underlying cause of small bowel bleeding.

Although the role of capsule endoscopy after a negative CTE result has been documented, especially in patients with overt bleeding, those with a history of bleeding, or patients who received large amounts of blood by transfusions, a CTE can identify causes of small bowel bleeding not identified at capsule endoscopy or in patients with indeterminate or equivocal findings at capsule endoscopy.[11,12] We additionally identified a 2.5-fold decrease in the risk of bleeding among those with correlative double balloon enteroscopy. The current study thus identifies a cohort that is at continued risk for rebleeding—those with negative CTE results, lack of actionable intervention, and BAE findings discrepant from those on mpCTE. A prior small study has similarly reported that a negative CTE result does not predict lower long-term risk of rebleeding and that such patients should have close clinical follow-up.[10]

The limitations of our study include the retrospective nature of the study with selection bias, a heterogeneous clinical population, and a heterogeneous reference standard. Because of the wide spectrum of diagnoses that cause GI bleeding, a single reference standard could not be used. Additionally, heme positivity of stools was also measured using varying techniques over the duration of the study period. Further, the original test interpretations were performed by multiple abdominal radiologists with varying experience, which may have affected the study results. Another potential limitation is verification bias, although it was minimized by using more than one method to verify mpCTE results such as information derived from surgical, endoscopic, angiographic, or pathologic data. Prior studies have reported higher DY with prospective compared with retrospective studies because clinical decision making cannot be fully accounted for in the retrospective analysis.[3] Despite that factor, the DY reported in this study

is similar to that reported in a meta-analysis on CTE performance for detecting small bowel bleeding.[3]

CONCLUSION

Multiphase CTE can play an important role in the diagnostic evaluation of small bowel bleeding, with a higher rate of detection in patients with increased blood loss. Although mpCTE was previously established as a modality for identifying small bowel masses, our results suggest that it is also a reliable screen for other causes of small bowel bleeding. Ultimately, mpCTE provides actionable targets for further intervention, leading to substantially reduced rates of rebleeding in long-term follow-up.

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