SHORT COMMUNICATION

Use of High-Density Oral Contrast in CT - Proof of Concept Phantom Study and Pictorial Review of Selected Clinical Cases

Najeeb Ahmed[1], Albertkeliang Ang[1*], Tim Wood[2], Hiten Joshi[1], Sharjeel Usmani[3] and Abdul Razack[1]

[1]*Department of Radiology, Hull University Teaching Hospitals NHS Trust, Hull, United Kingdom*
[2]*Department of Physics, Hull University Teaching Hospitals NHS Trust, Hull, United Kingdom*
[3]*Sultan Qaboos Comprehensive Cancer Care and Research Centre (University Medical City), Muscat, Oman*

ABSTRACT

With the advancements in computed tomography, there is improved abdominal imaging, minimizing concerns about high-density oral contrast media (HD-OCM) causing artifacts. This study evaluates the effectiveness of HD-OCM in detecting perforations and post-operative leaks using both older and newer MDCT scanners. Phantom experiments were conducted on two CT scanners to assess image noise and streak artifacts at different contrast concentrations. A retrospective review of clinical cases using HD-OCM for suspected perforations or leaks was also performed. Results showed that low concentrations (≤12.5%) of HD-OCM caused minimal image degradation, and clinical cases demonstrated improved detection of anastomotic leaks and bowel perforations. The study concludes that HD-OCM can enhance diagnostic accuracy in MDCT without significantly affecting image quality, even in older scanners. Its use in clinical practice should be considered to improve detection and reduce the need for repeat scans.

Keywords: *Multidetector computed tomography, oral contrast media, bowel perforation, anastomotic leak, postoperative complications.*

INTRODUCTION

Continuing advances in multidetector CT (MDCT) have vastly improved the ability of diagnostic abdominal imaging. The development of MDCT has allowed full coverage of the abdominopelvic region with a single breath hold and improved spatial and temporal resolution [1]. Shorter scan time reduces movement artefact from bowel peristalsis, allowing a more detailed assessment of bowel loops [2].

Abdominal MDCT generally involves the use of both intravenous contrast and positive oral contrast media (OCM), leading to improved delineation of individual bowel loops. In clinical practice, OCM is usually used in low concentration as traditionally high-density iodinated oral contrast media (HD-OCM) is thought to generate streak artefact and reduce the diagnostic quality of the study. Whilst this could have been true in early CT scanners, there is no definite evidence to preclude its use on modern MDCT scanners with advanced features such as CT Automatic Exposure Control (AEC) and iterative reconstruction (IR). This article aims to provide experimental as well as clinical proof-of-concept data to demonstrate that HD-OCM can be used without compromising image quality and can be beneficial in some clinical situations [3].

Oral Contrast Agents

Non-distended and non-opacified bowel loops can mask as well as mimic pathology. Oral contrast aids in bowel distention, gives the ability to exclude pathology, and often highlights existing pathology. OCM is available as either negative, neutral, or positive agents [2, 4].

Negative agents include air and carbon dioxide and are routinely used to aid bowel distension as part of CT-colonography [5].

Neutral OCM has characteristics similar to water (10-30 HU), with water itself being the most common neutral OCM agent used [6]. These agents are limited from the distal small bowel onwards due to rapid absorption [7, 8]. Additives can be used to slow down absorption [9, 10].

Positive OCMs are the most frequently used OCMs, usually contain iodine, and can be categorised into ionic or non-ionic compounds. Ionic compounds are associated with more adverse effects, and thus, non-ionic compounds are most frequently used.

Water-soluble positive OCMs are absorbed rapidly from the peritoneal cavity and have no known complications [11]. This feature makes them the primary choice in examining patients with suspected gastrointestinal tract leaks.

MATERIALS AND METHODS

Proof of Concept Physics Experiments

For validation in clinical use, phantom experiments were performed to assess how image noise and streak artefacts manifested for different contrast concentrations on two different CT scanners *i.e.* an older Philips Big Bore 16 slice scanner, manufactured in 2007 with limited CT AEC functionality and filtered back projection (FBP) only, and a newer Siemens Biograph

**Corresponding Author: Albertkeliang Ang, Department of Radiology, Hull University Teaching Hospitals NHS Trust, Hull, United Kingdom, E-mail: albertkeliang.ang@nhs.net*
Received: April 05, 2025; Revised: August 05, 2025; Accepted: August 25, 2025
DOI: https://doi.org/10.37184/nrjp.3007-5181.2.2

mCT Flow 128 slice scanner manufactured in 2014 with 4D CT AEC and Sinogram Affirmed Iterative Reconstruction (SAFIRE) (alongside standard FBP). For the Siemens scanner, the choice of reconstruction algorithm (IR *vs.* FBP) was also assessed.

Phantom Measurements

Objective measurements and subjective assessment of streaking artefacts were performed with the CT AEC phantom (Leeds Test Objects Ltd, Boroughbridge, UK), adapted to hold a central insert that was filled with varying concentrations of Omnipaque 300 mg I per ml contrast agent (GE Healthcare AS, Oslo, Norway). The elliptical uniform poly (methyl methacrylate) (PMMA) phantom was used to simulate patients of varying sizes. The central insert had an internal diameter of 49.5 mm and was initially filled with a 50% contrast/water mix. A typical adult abdomen/pelvis protocol was used to scan the phantom on both scanners, with scan parameters summarised in Table **1**. The CT automatic exposure control (AEC) system on each scanner was used for setting exposure factors throughout the scan, based on normal clinical requirements (CAREDose4D on the Siemens, DoseRight ACS with Z-DOM on the Philips).

The scans were repeated with the contrast insert diluted to nominally 25%, 12.5% and 6.75% contrast. Scans were also acquired with the insert consisting only of water (0%).

Table 1: Summary of exposure factors for the two systems used in this study.

Exposure Factors	Siemens Biograph mCT Flow	Philips Big Bore
kVp	100 kV	120 kV
Collimation	128 x 0.6 mm	16 x 1.5 mm
Image slice thickness	2 mm	2 mm
Pitch	0.6	0.813
Field of view	500 mm	500 mm
Iterative recon.	I30f, strength = 3	N/A
FBP recon.	B30f	Standard B

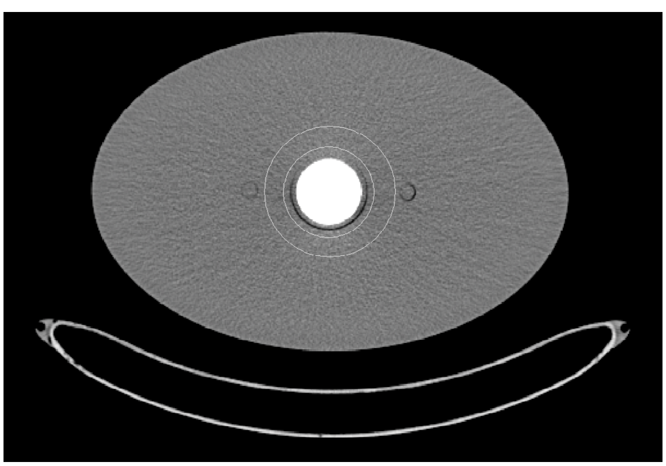

Fig. (1): Image of the CT AEC phantom with the contrast insert, and the region of interest (white circles) used in the objective analysis of image quality.

Quantitative measurements of CT number and image noise (standard deviation) were made using an annular region of interest in the PMMA around the contrast insert **(Fig. 1)**. CT number and image noise for the different concentrations and reconstruction techniques were plotted as a function of phantom width, and compared with the results for no contrast. Subjective image quality was assessed for artefacts by the senior authors.

Case Examples

We obtained 8 cases from our local institution where HD-OCM was used in clinical practice to better identify perforation or anastomotic leaks.

RESULTS AND DISCUSSION

Proof of Concept Physics Experiments

CT number as a function of phantom width is shown in Fig. **(2)** for the Siemens CT scanner; the results are shown for iterative reconstruction only, but no difference in the trend was noted for filtered back projection on either the Siemens or Philips scanner. Fig. **(2)** demonstrates that both scanners give elevated CT numbers in the area surrounding the insert when contrast is present, with this effect being small for smaller phantom sections (3-4 HU increase for 50% contrast mix), but getting worse for larger phantom sections (14-18 HU increase for 50% contrast mix). It is unlikely that such a small increase in CT number will have a significant impact on clinical interpretation.

Fig. **(3)** demonstrates the variation of image noise for the Siemens scanner with iterative reconstruction and varying contrast concentrations. The 50% contrast mix clearly demonstrates increased 'noise' due to the

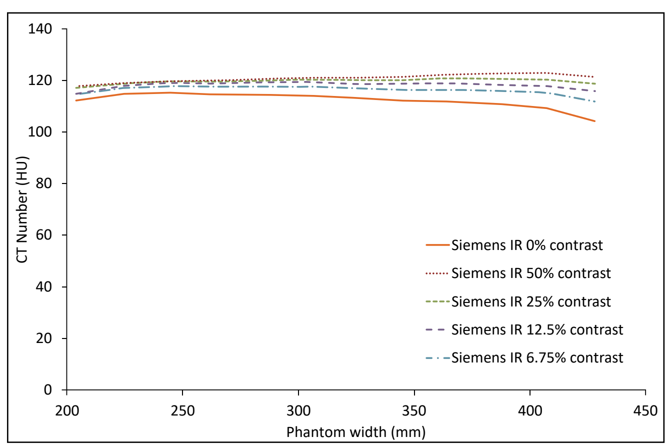

Fig. (2): CT number plotted against phantom width for the Siemens scanner with iterative reconstruction (SAFIRE, strength 3). Similar trends were noted with filtered back projection on the Siemens and Philips systems.

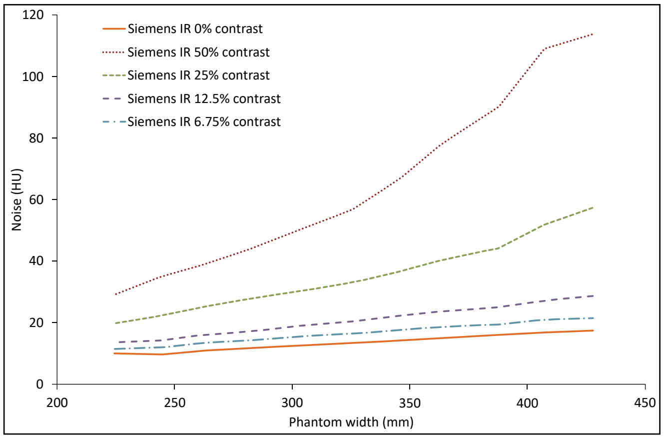

Fig. (3): Image noise plotted as a function of phantom size for the 5 different concentrations of contrast agent assessed in this study. Results are shown for the Siemens scanner with iterative reconstruction only.

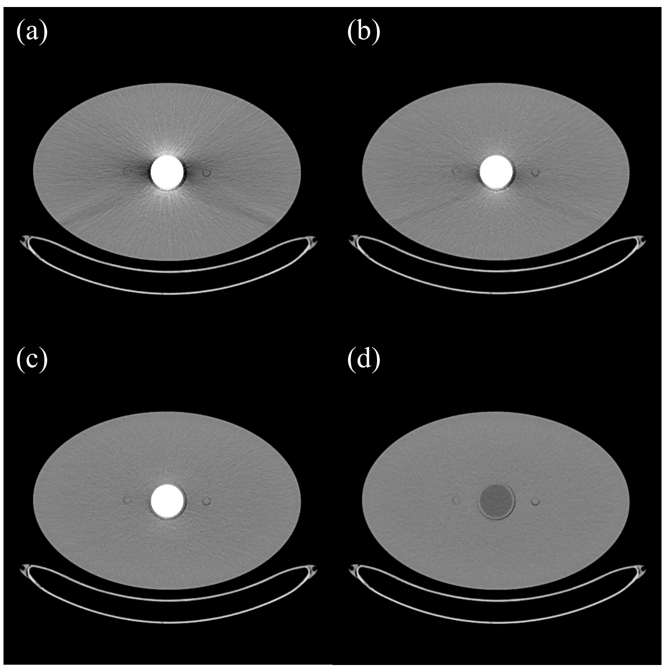

Fig. (4): Example images from the CT AEC phantom for **(a)** 50%, **(b)** 25%, **(c)** 12.5% and **(d)** 0% contrast mix on the Siemens CT scanner with iterative reconstruction. All images have the same window/level settings.

presence of significant streak artefacts across the image, as shown visually in Fig. **(4a)**. At 25% contrast concentration, the artefact level is reduced but still appreciable **(Fig. 4b)**. At 12.5% contrast concentration the artefacts are minimal and deemed acceptable **(Fig. 4c)**. The results for filtered back projection demonstrated the same trends with phantom size, but with higher absolute noise levels when compared with iterative reconstruction **(Fig. 4d)**. A visual comparison of images for 50% contrast on the Siemens and Philips scanners with filtered back projection is shown in Fig. **(5a** and **b)**. The mean, maximum, and minimum increase in image noise across all phantom sizes are shown in Table **2**. In contrast, at concentrations above 25%, image noise will be at least double compared with the non-contrast scan, but at lower concentrations, the increase in image noise is less *e.g.*, 12.5% contrast strength results in less than 50% increase in image noise on average. Subjective assessment by the senior authors found no significant artefacts at concentrations less than or equal to 12.5% and the degree of artefacts at 25% was deemed to be acceptable.

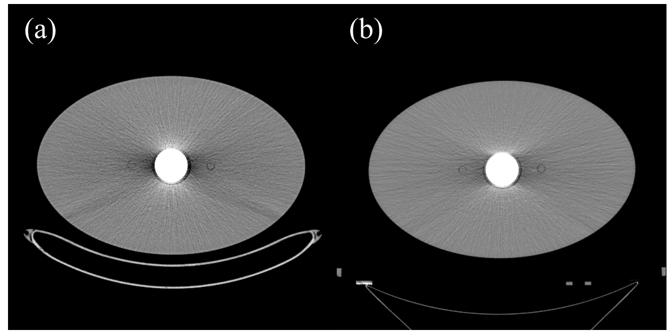

Fig. (5): Example images from the CT AEC phantom for 50% contrast acquired on **(a)** the Siemens and **(b)** Philips scanners with filtered back projection. All images have the same window/level settings.

Table 2: Mean, maximum, and minimum percentage increases in image noise for the three scanners for the difference contrast agent concentrations.

Scanner	**Contrast Conc.**	**Percentage Increase in Image Noise Compared with 0% Contrast (%)**		
		Mean	**Max**	**Min**
Siemens IR	50%	360	552	191
	25%	157	228	97
	12.5%	53	65	36
	6.75%	22	25	14
Siemens FBP	50%	233	347	152
	25%	100	142	74
	12.5%	36	44	31
	6.75%	17	18	14
Philips FBP	50%	203	229	174
	25%	93	131	70
	12.5%	48	81	34
	6.75%	21	40	12

The average noise reduction of IR against FBP for the five different contrast agent concentrations used in this study was also assessed. It is interesting to note that IR does not have a significant impact on image noise for higher concentrations, as would normally be expected when compared with FBP, with noise reductions typically around 10-16% for 50% contrast and 25% contrast, respectively. For lower contrast agent concentrations, the same exposure factors gave typical noise reductions of around 30%, which is more in line with vendor specifications for IR techniques. This is due to the prevalence of streaking artefacts for high contrast agent concentrations, which the IR techniques cannot resolve due to photon starvation.

Case Examples

Water-soluble contrast agents are preferred to barium-containing agents in the setting of hollow visceral perforation or post-operative leak due to reduced complications [12]. In our institution, we routinely use Omnipaque 300, 50mls diluted in 250mls water at least an hour before the CT. The presence of free air has traditionally been used to assess for leaks; however, this is fraught with difficulties in interpretation. Artefacts from radio-opaque surgical material can also hamper assessment.

Case 1 is of a patient who became unwell a few days after undergoing Roux-en-Y bypass surgery, and an anastomotic leak was clinically suspected. Initial CT was performed with water-soluble conventional OCM. Free fluid is seen in the sub-hepatic region; however, it is difficult to appreciate whether there is an anastomotic leak **(Fig. 6a)**. A repeat CT scan with HD-OCM was performed. The dense oral contrast is seen leaking **(Fig. 6b)** out of the Roux loop into the sub-hepatic space and through the corrugated drain. There is a significant streak artefact observed in Fig. **(6a)** which is predominantly due to surgical material. This hinders the assessment of the origin of the leak with conventional OCM but is clearly identified with HD-OCM.

Case 2 is of a 23-year-old lady who underwent a gastric bypass procedure for obesity. The initial post-procedure fluoroscopic study appeared normal. The patient deteriorated with increasing abdominal pain and raised inflammatory markers. An initial CT was performed, which identified only free fluid within the abdomen. Her condition worsened, and a repeat CT with HD-OCM was performed, which demonstrated a leak at the gastro-jejunal anastomosis as shown in Fig. **(7)**.

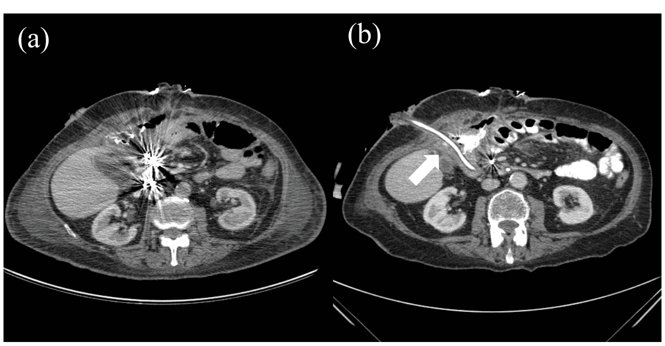

Fig. (6): Case 1: Post Roux-en-Y surgery. Images taken **(a)** before HD-OCM and **(b)** after HD-OCM. Dense oral contrast is seen along he drain in (b), in keeping with an anastomotic leak.

Fig. (7): Case 2: Post gastric bypass surgery. High-density oral contrast (arrow) leaking from the gastro-jejunal anastomosis into the peri-splenic space.

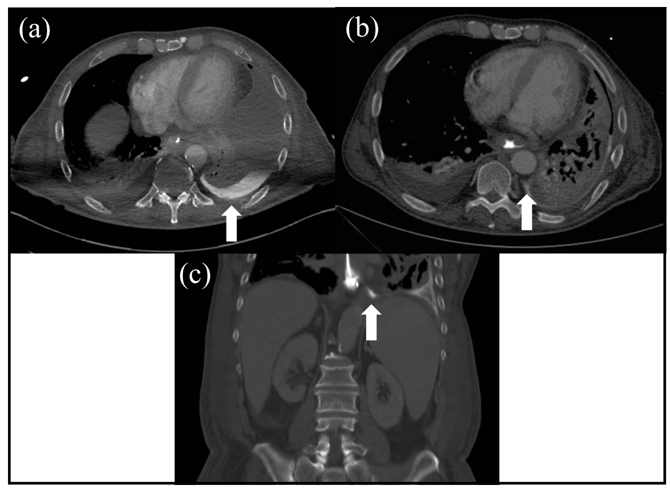

Fig. (8): Case 3: Known oesophageal tumour. **(a)** Initial imaging with left pleural effusion. **(b, c)** Subsequent imaging with axial and coronal views demonstrating high-density oral contrast leaking into the left pleural space, in keeping with an oesophageal perforation.

Case 3 is of a 76-year-old gentleman with a known oesophageal tumour who became acutely unwell. Initial CT demonstrated a left pleural effusion **(Fig. 8a)**. The patient remained unwell, and a repeat CT with HD-OCM was performed 48 hours later. This clearly demonstrated an oesophageal perforation into the left pleural cavity **(Fig. 8b** and **8c)**.

Case 4 is of a 78-year-old gentleman who underwent anterior resection for bowel cancer. He had a difficult post-operative period with ongoing abdominal pain and a slow clinical recovery. A CT scan with routine oral contrast was performed, which demonstrated free fluid within the abdomen. A further CT study with HD-OCM was used. This demonstrated the site of bowel leak with contrast extravasation into the peri-hepatic space **(Fig. 9)**.

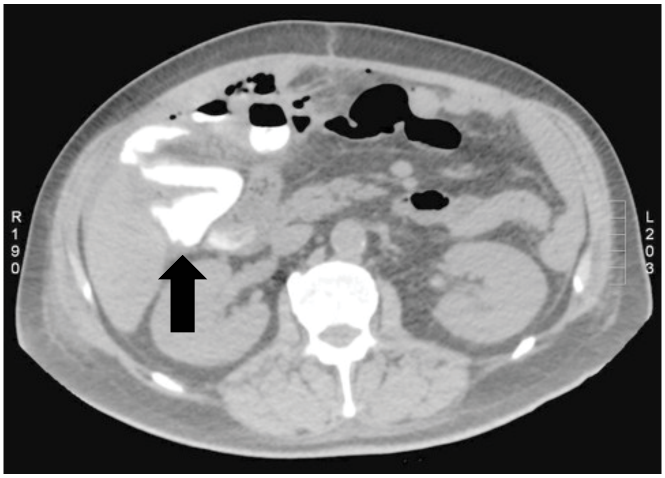

Fig. (9): Case 4: Post anterior resection. Extraluminal high-density oral contrast in the peri-hepatic region in keeping with anastomotic leak.

Fig. (10): Case 5: Post-reversal of ileostomy and adhesiolysis. Extraluminal high-density oral contrast in the right iliac fossa in keeping with bowel perforation.

Case 5 is of a patient with a high sigmoid cancer who developed adhesional small bowel obstruction after multiple bowel surgeries. This was treated by laparoscopic adhesiolysis. An initial CT study was performed, which demonstrated a small amount of free gas and free fluid, which could be post-operative. She was managed conservatively, and a repeat CT study with HD-OCM was performed. This clearly demonstrated the site of the leak in the right iliac fossa **(Fig. 10)** and was treated surgically.

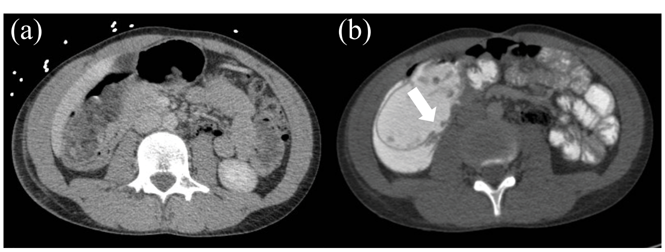

Fig. (11): Case 6: Post motor vehicle accident. **(a)** The study performed without HD-OCM does not clearly demonstrate an anastomotic leak; and **(b)** after HD-OCM, it clearly demonstrates a duodenal intimal tear.

Fig. (12): Case 7: Hypotensive patient with severe abdominal pain. **(a)** Axial and **(b)** sagittal views of extraluminal high-density contrast material in keeping with a duodenal perforation.

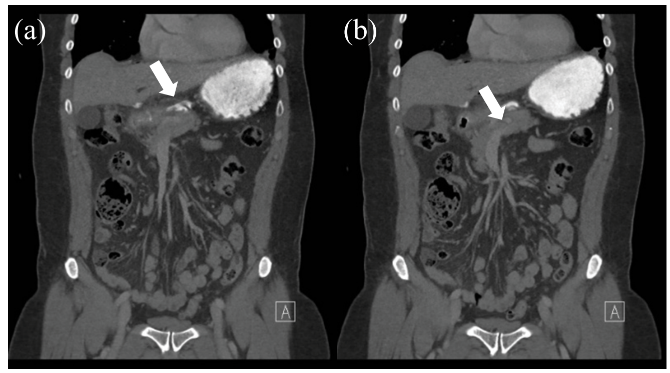

Fig. (13): Case 8: Patient with sudden onset abdominal pain. **(a)** Demonstrates a duodenal mural defect, and **(b)** shows high density contrast in the peritoneal cavity.

Case 6 is of a 26-year-old male driver who was involved in a motor vehicle accident. The initial trauma study that was performed did not identify any abnormality. His abdominal pain worsened, and a repeat CT was performed, this time with conventional OCM, which failed to demonstrate an abnormality **(Fig. 11a)**. As his symptoms progressed, a repeat CT study was performed using HD-OCM, which demonstrated a duodenal intimal tear **(Fig. 11b)**, which was not visible initially.

Case 7 is of a 77-year-old gentleman who presented with severe upper abdominal pain and melaena and was found to be hypotensive. A CT study was performed with HD-OCM, which clearly demonstrated a defect in the posterior duodenal wall with enteric contrast extravasation **(Fig. 12a** and **12b)**.

Case 8 is of a 46-year-old male who presented to the Emergency department with sudden onset abdominal pain and right shoulder tip pain. He underwent abdominal CT with HD-OCM, which clearly showed a defect in the first part of the duodenum and contrast extravasation into the peritoneal cavity **(Fig. 13a** and **13b)**.

CONCLUSION

Water-soluble HD-OCM can aid in accurately demonstrating acute perforations and anastomotic leaks without significant image degradation, even with older generation CT scanners and FBP reconstruction. We recommend that, in such patients, consideration should be given to use HD-OCM in the first instance, to increase diagnostic yield, which could obviate the need for repeat examinations and aid in timely management.

CONSENT FOR PUBLICATION

Not applicable.

FUNDING

None.

CONFLICT OF INTEREST

T. Wood acts as a Scientific Advisor to Leeds Test Objects Ltd.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

1. Tsili AC, Argyropoulou MI. Advances of multidetector computed tomography in the characterization and staging of renal cell carcinoma. World J Radiol 2015; 7(6): 110-27. DOI: https://doi.org/10.4329/wjr.v7.i6.110
2. Buttigieg EL, Grima KB, Cortis K, Soler SG, Zarb F. An evaluation of the use of oral contrast media in abdominopelvic CT. Eur Radiol 2014; 24: 2936-44. DOI: https://doi.org/10.1007/s00330-014-3285-8
3. Berther R, Patak MA, Eckhardt B, Erturk SM, Zollikofer CL. Comparison of neutral oral contrast *versus* positive oral contrast medium in abdominal multidetector CT. Eur Radiol 2008; 18: 1902-9. DOI: https://doi.org/10.1007/s00330-008-0958-1
4. Macari M, Megibow AJ, Balthazar EJ. A pattern approach to the abnormal small bowel: Observations at MDCT and CT enterography. Am J Roentgenol 2007; 188: 1344-55. DOI: https://doi.org/10.2214/AJR.06.0712
5. Mang T, Graser A, Schima W, Maier A. CT colonography: Techniques, indications, findings. Eur J Radiol 2007; 61(3): 388-99. DOI: https://doi.org/10.1016/j.ejrad.2006.11.019
6. Makarawo TP, Negussie E, Malde S, Tilak J, Gayagoy J, Watson J, *et al.* Water as a contrast medium: A re-evaluation using the multidetector-row computed tomography. Ann Surg 2013; 79(7): 728-33. DOI: https://doi.org/10.1177/000313481307900719
7. Winter TC, Ager JD, Nghiem HV, Hill RS, Harrison SD, Freeny PC. Upper gastrointestinal tract and abdomen: Water as an orally administered contrast agent for helical CT. Radiology 1996; 201: 365-70. DOI: https://doi.org/10.1148/radiology.201.2.8888224
8. Horton KM, Eng J, Fishman EK. Normal enhancement of the small bowel: Evaluation with spiral CT. J Comput Assist Tomogr 2000; 24: 67-71. DOI: https://doi.org/10.1097/00004728-200001000-00014
9. Megibow AJ, Babb JS, Hecht EM, Cho JJ, Houston C, Boruch MM, *et al.* Evaluation of bowel distention and bowel wall appearance by using neutral oral contrast agent for multi-detector row CT. Radiology 2006; 238: 87-95. DOI: https://doi.org/10.1148/radiol.2381041985
10. Hara AK, Leighton JA, Sharma VK, Heigh RI, Fleisher DE. Imaging of small bowel disease: Comparison of capsule endoscopy, standard endoscopy, barium examination, and CT. RadioGraphics 2005; 25: 697-718. DOI: https://doi.org/10.1148/rg.253045134
11. Vessal K, Montali RJ, Larson SM, Chaffee V, James AE. Evaluation of barium and gastrografin as contrast media for the diagnosis of esophageal ruptures or perforations. Am J Roentgenol Radium Ther Nucl Med 1975; 123: 307-19. DOI: https://doi.org/10.2214/ajr.123.2.307
12. Pickhardt PJ, Kim DH. CT Colonography: Pitfalls in Interpretation. Radiol Clin North Am 2013; 51(1): 69-88. DOI: https://doi.org/10.1016/j.rcl.2012.09.005