ORIGINAL ARTICLE

Water as neutral oral contrast agent in abdominopelvic CT: comparing effectiveness with Gastrografin in the same patient

Chau Hung Lee, FRCR[1], Han Zi Gu, MBBS[2], Balamurugan A Vellayappan, FRANZCR[3], Cher Heng Tan, FRCR[1]

[1]Department of Radiology, Tan Tock Seng Hospital, Singapore, [2]Ministry of Health Holdings, Singapore, [3]National University Cancer Institute Singapore, National University Hospital

ABSTRACT

Introduction: Positive oral contrast is no longer deemed necessary for abdominopelvic computed tomography (CT) scans. Studies have shown water to be an equally effective oral contrast agent. However, to our knowledge no study has compared effectiveness between gastrografin and water in the same patient, which will provide a more objective evaluation of the two oral contrast agents. We aim to make a head-to-head comparison of water as neutral oral contrast (OC) against gastrografin as positive OC for abdominopelvic CT scans in the same patient.

Methods: A retrospective review of 206 abdominopelvic CT scans of 103 patients was performed. The scans were reviewed in consensus by two blinded radiologists. The ability to visualise each abdominopelvic organ, contrast-associated artefacts and small bowel wall delineation, was qualitatively scored on a 5-point scale. Each patient had two sets of scores, one with water and another with gastrografin as OC. Paired scores from the two OCs were evaluated by Wilcoxon signed rank test to determine any significant difference in performance between the two OCs for visualisation of abdominopelvic anatomy on CT.

Results: There was significantly better delineation of duodenal wall ($p<0.001$) and overall visualisation of the duodenum ($p=0.011$) using water as OC compared to gastrografin. No statistically significant differences were demonstrated between water and gastrografin for visualisation of the rest of the abdominopelvic organs, wall-delineation of the rest small bowel and contrast-associated artefacts.

Conclusions: Water can be used in place of gastrografin as oral contrast in abdominopelvic CT without compromising visualization of abdominopelvic organs.

KEY WORDS:
Computed Tomography; Oral Contrast; Small Intestine; Gastrografin; Water

INTRODUCTION

Multidetector-row computed tomography (CT) is widely available as part of diagnostic work-up for many acute clinical conditions, as well as an integral part of follow-up management of chronic or malignant diseases and evaluation of treatment response in many clinical scenarios.

Positive oral contrast (OC) has been traditionally used in abdominopelvic CT to achieve more accurate visualisation of bowel. This was necessary in the early days of CT imaging where relatively long acquisition time and lower resolutions resulted in blurring of bowel images from bowel peristalsis.[1] Moreover it may sometimes be difficult to distinguish collapsed bowel loops from peritoneal pathology. Positive OC such as gastrografin was often required to improve delineation of bowel.

Recent studies have suggested that negative and neutral OC agents are equally effective in achieving bowel distension and delineation.[2-4] In addition, problems associated with iodinated or barium compounds used in positive OC, such as aspiration, requirement of higher radiation exposure to reduce effect of beam-hardening, cost, patient discomfort, time delay, can be minimised by substituting positive OC with a negative or neutral OC or omitting OC altogether.[3,5]

Our institution implemented a change in CT scan protocol in the third quarter of 2011, substituting gastrografin as positive OC with water as neutral OC for routine abdominopelvic CT scans. Many patients, particularly oncologic patients on long-term follow-up, will therefore have undergone CT scans with both OC agents at some point in time. This gives us an opportunity to compare the effectiveness between water and gastrografin as OC for abdominopelvic CT scans in the same patient. We believe comparison between the two oral contrast agents in the same patient has not been performed before.

MATERIALS AND METHODS

Data collection

A retrospective analysis of abdominopelvic CT scans from 1 January 2008 to 31 December 2011 was approved by our institutional review board. All abdominopelvic CT scans from 1 January 2008 to 31 December 2011 were retrieved from our institution's Patient Archiving and Communication System (PACS) database. This was done electronically by filtering study modality ("CT, Abdomen and Pelvis"), and study date ("2008", "2009", "2010", "2011").

This article was accepted:
Corresponding Author: Chau Hung, Lee, Tan Tock Seng Hospital, Department of Radiology, 11 Jalan Tan Tock Seng, Singapore, 308433 Singapore
Email: powerlee_1999@yahoo.com

Inclusion criteria were adult patients who have had at least two abdominopelvic CT scans with intravenous contrast done in the routine portovenous phase, one with gastrografin as positive OC (prior to third quarter of 2011) and the other with water as neutral OC (after the third quarter of 2011). Excluded were patients who did not have CT scans with both water and gastrografin performed within that period of time, patients under the age of 18, patients with CT scans done from the emergency department as no OC was administered for these group of patients, scans without intravenous contrast, or scans with specific protocols (such as liver or pancreatic multiphasic protocol, CT enteroclysis).

One hundred and three patients who met the criteria were selected by convenience sampling.[6] This is based on selecting patients because of their most convenient accessibility and proximity. This is the most common of sampling techniques although it may not be representative of the population. For each patient, the most recent CT study with gastrografin as positive OC, and the first CT study with water as neutral OC were selected, so that the interval between the two scans was as short as possible. This provided 103 CT scans with gastrografin as positive OC paired with 103 CT scans with water as neutral OC for each patient (total of 206 scans). The patient age, gender, type of OC used, referring department, scan parameters, interval between the two scans, and the presence of small bowel pathology was recorded.

CT technique

All scans were performed on either a 64-slice or a 128-detector CT scanner (Somatom, Siemens, Erlangen, Germany). Scans were acquired in the axial plane using 3.0 mm collimation (pitch 1, increment 2.5 mm with overlap of 0.5 mm, 160 mAs, 120kV) and reconstructed to 3.0 mm thick slices for analysis on PACS. Prior to scanning, intravenous administration of 70-90 cc of iodinated contrast was administered at a rate of between 1.5 to 2.0 ml/s for each patient. Scans were acquired in the portovenous phase using automatic bolus triggering; threshold of 100 HU was applied with the region of interest in the aorta at the level of the coeliac trunk. Post-acquisition coronal reconstruction was performed for all scans.

Under the old OC protocol prior to the third quarter of 2011, one litre of gastrografin was administered orally over about an hour before the scan. Under the new protocol, 500 mls of water was administered orally 15 to 30 minutes prior to scan. The volume of OC under the new protocol was reduced as many patients had difficulty consuming one litre of fluid under the old protocol.

Image analysis

Twelve major organs were assessed on each CT scan: 1. Duodenum, 2. Jejunum and Ileum (assessed together), 3. Stomach, 4. Liver, 5. Spleen, 6. Gallbladder, 7. Pancreas and Adrenal glands (assessed together), 8. Kidney with Ureters and Bladder (assessed together), 9. Appendix, 10. Large bowel, 11. Ovaries and Uterus (assessed together where applicable), and 12. Peritoneum.

Each major organ in the abdominopelvic CT scan was graded based on two parameters: organ visualisation, contrast-associated artefacts. For small bowel (duodenum, jejunum and ileum) a third parameter: wall delineation, was also assessed. Organ visualisation was graded based on ability to identify the specific anatomical structure distinctly. Contrast-associated artefact was graded based on extent of streak artefact from adjacent high-density contrast and whether they affected organ visualisation. Small bowel wall delineation was graded based on ability to visualise wall separate from the intraluminal contents and the ability to appreciate the mucosal folds. A five-point scale was used for each parameter (1 = whole organ is not visualised, 2 = less than half the organ visualised, 3 = about half the organ visualised, 4 = more than half the organ visualised, 5 = whole organ visualised). If the organ has been surgically removed (for example hysterectomy or cholecystectomy), that organ was excluded from analysis. For bowel assessment, the length of the bowel and degree of distension was taken into consideration when assigning the score.

Each of the 206 CT scans was read by two radiologists, one with subspecialty training in body imaging (T), the other a general radiologist (L). The scans were selected randomly by a third author G, therefore both T and L were blinded to the identity of the patient, clinical history and diagnosis. A single score was assigned in consensus by both readers.

Statistical analysis

CT scans were qualitatively analysed in two groups: Group A scans used water as neutral OC; Group B scans used gastrografin as positive OC. In each group, five gastrointestinal (GI) organs (stomach, duodenum, jejunum and ileum, large bowel and appendix) were analysed together, and the other seven organs (solid organs and peritoneum) were analysed together. The peritoneum (excluding retroperitoneum) was also analysed on its own. As part of small bowel analysis, the duodenum was analysed separate from jejunum and ileum. A subgroup analysis for oncology follow-up patients analysing duodenum separate from jejunum and ileum was also performed.

For each OC group, the arithmetic mean of the scores for each group of organs (GI organs, solid organs, peritoneum) were collated for each parameter (overall visualisation, contrast-associated artefacts, wall delineation of small bowel). This was obtained by averaging the scores for each organ within the group for each patient then obtaining the average over the 103 patients. The mean scores of each group of organs were then compared between the two OC groups using the Wilcoxon signed rank test.7 Significance was set at 5%. Subgroup analysis for small bowel (duodenum, jejunum and ileum) in all 103 patients and in the 68 patients on oncology follow-up was performed in similar fashion.

RESULTS

A total of 206 scans from 103 patients, each with two scans (one with water as neutral OC and one with gastrografin as positive OC) were analysed.

There were 66 male and 37 female patients. Mean age was 62.9 years (20 to 88). Majority of the patients had the two scans with different OC agents performed within one year (79 of 103 patients). The basic study population characteristics are presented in Table I.

Table I: Study population characteristics

Study population characteristics		No. of patients	% among the study population
Gender	Male	66	64.1
	Female	37	35.9
Age (years)*	20-39	7	6.8
	40-59	33	32
	60-79	53	51.5
	> 80	10	9.7
Time gap^ (months)	1-3	40	38.8
	3-6	17	16.5
	6-9	14	13.6
	9-12	8	7.8
	>12	24	23.3
Reasons for referral	Oncology pts	68	66
	Non-oncology	35	34
No. of patients with small bowel pathology	7 6.6		

(*mean age: 62.9, ^median time gap: 5 months)

Table II: Results of overall analysis comparing water as neutral OC (Group A) and gastrografin as positive OC (Group B)

Group	Overall visualisation			Contrast-associated artefact		
	GI organs	Solid organs	Peritoneum	GI organs	Solid organs	Peritoneum
A	4.4±1.2	4.3±1.6	4.7±0.58	4.6±1.1	4.3±1.6	4.8±0.52
B	4.3±1.3	4.4±1.6	4.8±0.55	4.6±1.2	4.3±1.6	4.8±0.51
p-value*	0.12	0.078	0.65	0.65	0.78	0.72

Note: The 12 organs for each patient were assessed in 3 groups: 5 GI organs, 7 solid organs (including peritoneum) and peritoneum separately. The scores assigned reflect the mean scores of each group of organs averaged over all 103 patients, for each OC group. Standard deviations are reported alongside. *p-value is calculated using Wilcoxon signed rank test.

Table III: Results of subgroup analysis comparing water as neutral OC (Group A) and gastrografin as positive OC (Group B) in assessment of the small bowel (duodenum, jejunum and ileum)

Group	Overall visualisation		Contrast-associated artefact		Wall delineation#	
	Duodenum	Jejunum and Ileum	Duodenum	Jejunum and Ileum	Duodenum	Jejunum and Ileum
A	4.5±1.0	4.5±0.62	4.6±1.0	4.7±0.57	4.3±1.1	4.1±0.84
B	4.3±1.1	4.5±0.61	4.6±1.0	4.7±0.57	3.7±1.1	4.0±0.74
p-value*	0.011	0.89	0.74	0.56	<0.001	0.22

Note: The scores assigned reflect the mean scores for each part of the small bowel averaged over all 103 patients, for each OC group. Standard deviations are reported alongside. *p-value is calculated using Wilcoxon signed rank test. #Wall delineation was defined as ability to visualize wall separate from the intraluminal contents and the ability to appreciate the mucosal folds.

Table IV: Results of subgroup analysis comparing water as neutral OC (Group A) and gastrografin as positive OC (Group B) in assessment of the small bowel (duodenum, jejunum and ileum) in patients on oncology follow-up

Group	Overall visualisation		Contrast-associated artefact		Wall delineation#	
	Duodenum	Jejunum and Ileum	Duodenum	Jejunum and Ileum	Duodenum	Jejunum and Ileum
A	4.5±1.2	4.5±0.58	4.6±1.2	4.8±0.49	4.2±1.2	4.1±0.85
B	4.3±1.2	4.6±0.63	4.6±1.2	4.8±0.49	3.8±1.2	4.1±0.75
p-value*	0.18	0.87	0.51	0.58	<0.001	0.054

Note: The scores assigned reflect the mean scores for each part of the small bowel averaged over 68 oncology patients, for each OC group. Standard deviations are reported alongside. *p-value is calculated using Wilcoxon signed rank test. #Wall delineation was defined as ability to visualize wall separate from the intraluminal contents and the ability to appreciate the mucosal folds.

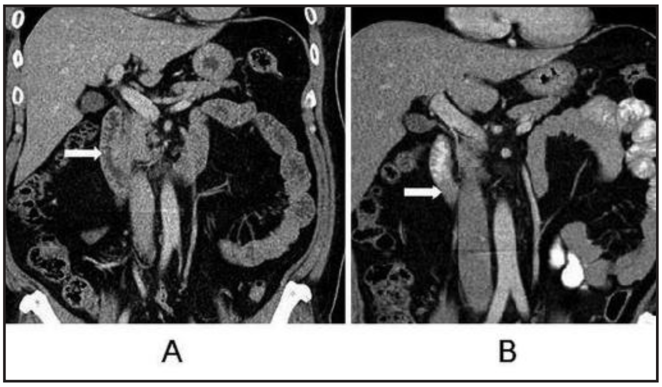

Fig. 1: Selected coronal CT images of a 50-year-old male patient with water (A) and gastrografin (B) as OC showing slightly better delineation of the duodenal wall with water as neutral OC. In this case, the mucosal folds was deemed better seen with water as OC compared to gastrografin (arrows).

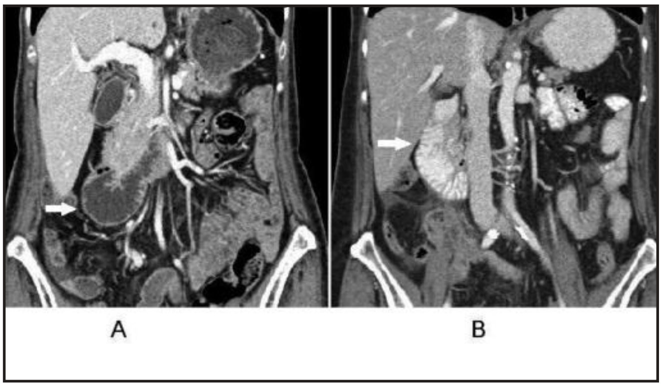

Fig. 2: Selected coronal CT images of a 65-year-old female patient with water (A) and gastrografin (B) as OC show comparable bowel wall delineation in the duodenum (arrows) with either OC agent.

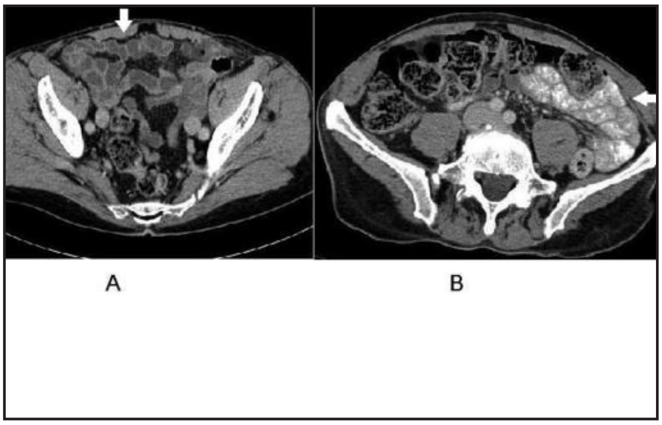

Fig. 3: Selected coronal CT images of a 77-year-old male patient with water (A) and gastrografin (B) as OC show comparable bowel wall delineation in the jejunum (arrows) with either OC agent.

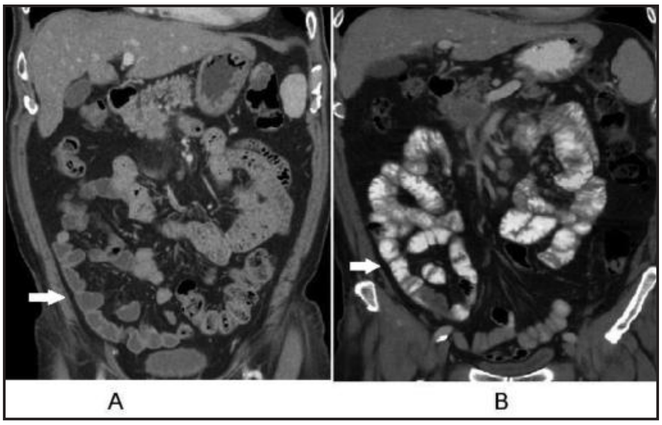

Fig. 4: Selected coronal CT images of a 67-year-old male patient with water (A) and gastrografin (B) as OC show comparable bowel wall delineation in the ileum (arrows) with either oral contrast agent.

In terms of overall organ visualisation, there was no statistically significant difference demonstrated between the two OC groups in visualising the GI organs, solid organs or peritoneum. With regards to whether contrast-associated artefacts limited organ visualisation, there was also no statistically significant difference between the two OC groups. These results are summarised in Table II.

With regards to small bowel, delineation of the duodenal wall was shown to be significantly better with water as neutral OC ($p<0.001$). There was also significantly better overall visualization of the duodenum with water ($p=0.011$). The Figs. 1A and 1B are scans from a patient where the duodenum was assessed to be better visualised and the wall better delineated using water as OC compared to gastrografin. The Figs. 2A and 2B show similar visualisation and wall delineation of the duodenum in another patient. The results for jejunum and ileum were similar between the two OC groups, in terms of overall visualisation, bowel wall delineation and contrast-associated artefact, showing no statistically-significant differences. This is illustrated in Figs. 3A and 3B, and Figs. 4A and 4B. The results for small bowel assessment are summarised in Table III.

Within the subgroup of oncology patients, water as OC as good as gastrografin for overall visualisation of duodenum ($p=0.18$) and significantly better than gastrografin in the delineation of the duodenal wall ($p<0.001$). No significant difference was seen between the two OC agents in the assessment of the jejunum and ileum. This result is shown in Table IV and is compatible with the overall analysis.

DISCUSSION

Advances in CT technology have resulted in widespread use of CT imaging as a diagnostic tool in clinical practice.[8,9] The use of OC in abdominopelvic CT scans has been intensively reviewed and positive OC has traditionally been thought to be necessary for delineation of bowel anatomy due to motion artefacts from bowel peristalsis. However with current multidetector technology where scans are acquired in seconds, such artefacts are greatly reduced, and current literature suggests that positive OC may not be necessary.[10,11] Given the risk of aspiration, time delay to allow OC to transit the bowel, increased radiation exposure to overcome effects of beam-hardening, cost, and unpalatability, various substitutes have been evaluated.[2,5,12] Fat-based agents such as milk or corn-oil emulsion provided good negative contrast but side-effects such as diarrhoea limited their wide-spread use.[3]

Water is now considered as a suitable substitute, as it is palatable, safe, and cheap while still allowing good visualisation of abdominopelvic organs.[2-4] A recent meta-analysis suggested that OC can be omitted altogether in blunt abdominal trauma due to urgency, but also recommended water as a neutral oral contrast to achieve some degree of small bowel distension.[13] In addition, using water as neutral oral contrast allows assessment of intraluminal contents that are otherwise obscured by high-density positive oral contrast. This is useful in detecting incidental foreign bodies and gastro-intestinal bleeds that may not have been initially suspected clinically. Based on current literature, our institution implemented a change of the CT oral contrast protocol from routinely using gastrografin as positive OC to water as a neutral OC. This change provided an opportunity to retrospectively evaluate the performance of the two OC agents.

Given the main role of OC in abdominopelvic CT in delineating small bowel and peritoneum, our analysis focuses mainly on these structures. The results suggest that water enables better overall visualisation of the duodenum and delineation of the duodenal wall compared to gastrografin and is as effective as gastrografin for visualisation of the rest of the small bowel and peritoneum. The other abdominopelvic anatomical structures are equally well-visualised regardless of whether water or gastrografin was used as OC. The new protocol using water as OC reduces waiting time between OC administration and scan, and we postulate this allows the duodenum to be remain more distended and hence better visualised. Moreover, gastrografin in the duodenum may be diluted by the time of scanning, causing intraluminal density to approach mural density and masking mural features.[4,14,15]

As majority of selected scans (66%) were for oncology patients on follow-up, we conducted a subgroup analysis to look specifically into this category of patients focusing on small bowel. The results in the oncology patients were similar to overall study population, confirming water as a suitable substitute for positive OC. This is supported by Harieaswar et al. who recommended removing the requirement of routine positive OC from cancer imaging protocols.[16]

We believe our study to be the first to directly compare efficacy of a neutral OC (water) with positive OC (gastrografin) head-to-head in the same patient. Comparing the scans between positive and neutral OC for the same patient eliminates variations in normal anatomy between individuals that may confound results of our analysis.[17] While small bowel distension was not directly assessed, our study has also incidentally shown that giving a reduced volume of the neutral OC agent (water) did not affect overall smaller bowel visualisation and wall delineation.

There are several limitations of our study. First, detection of abdominopelvic pathology was not directly assessed. However, it can be extrapolated that optimal visualization of normal anatomical structures with water as OC would generally translate into similar diagnostic confidence in detecting pathology.[2] Second, the two selected scans for each patient were performed at a median interval of five months apart. This may already allow some changes in body habitus and anatomy to occur (such as surgery, chemotherapy, weight loss or gain in the interim). Ideally the two scans should be performed at the same time to allow evaluation of both OC agents at a single point in time. Due to the retrospective nature of our study, this was not possible. Most importantly a prospective study requiring a patient to be scanned twice for this purpose would require unnecessary radiation dose and certainly not be approved by any institutional review board.

Third, the grading system adopted in our study, although used in several other studies evaluating alternative OC agents, is qualitative and can be subject to reader bias. This is because although both CT-readers are blinded to the patient identity and sequence of the CT scans, they cannot be blinded to the type of OC used. Furthermore, they already have background knowledge that water may not be inferior to gastrografin as OC agents. Efforts were made to reduce this bias by reading the scans in random sequence and analysing paired scores in the same patient.

Several studies have shown that overall sensitivity in detection of small anastomotic leaks or bowel perforations still remains low even with positive OC.[18-22] In small bowel obstruction, gastrografin is potentially therapeutic in reducing the need for surgery, however it is usually not necessary in the CT diagnosis.[23,24] This further strengthens the evidence that substituting gastrografin with water or completely omitting oral contrast altogether does not compromise scan quality and subsequent diagnosis.

Our study confirms that water as a neutral OC is comparable to gastrografin in terms of enabling visualisation of abdominopelvic organs. This is in agreement with evidence in the literature. Moreover, comparing performance of the two OC agents in the same patient in our study gives a more accurate assessment. We suggest that water can be used in place of gastrografin as oral contrast in abdominopelvic CT without compromising scan interpretation.

REFERENCES

1. Medscape: Oral contrast for abdominal CT: how important is it and how long does it take? [cited April 2008]. Available at: http://www.medscape.com/viewarticle/570343?src=top10.
2. 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(1): 87-95.
3. Ramsay DW, Markham DH, Morgan B, Rodgers PM, Liddicoat AJ. The use of dilute Calogen as a fat density oral contrast medium in upper abdominal computed tomography, compared with the use of water and positive oral contrast media. Clin Radiol 2001; 56(8): 670-3.
4. Erturk SM, Mortele KJ, Oliva MR, Ichikawa T, Silverman SG, Cantisani V et al. Depiction of normal gastrointestinal anatomy with MDCT: comparison of low- and high-attenuation oral contrast media. Eur J Radiol 2008; 66(1): 84-7.
5. Allen TL, Cummins BF, Bonk RT, Harker CP, Handrahan DL, Stevens MH. Computed tomography without oral contrast solution for blunt diaphragmatic injuries in abdominal trauma. Am J Emerg Med 2005; 23(3): 253-8.
6. Patton MQ, Qualitative research and evaluation methods. 3rd ed. Newbury Park, CA: Sage Publications, 2002.
7. Rosner B, Glynn RJ, Lee ML. The Wilcoxon signed rank test for paired comparisons of clustered data. Biometrics 2006; 62(1): 185-92.
8. Stuhlfaut JW, Soto JA, Lucey BC, Ulrich A, Rathlev NK, Burke PA et al. Blunt abdominal trauma: performance of CT without oral contrast material. Radiology 2004; 233(3): 689-94.
9. Holmes JF, Offerman SR, Chang CH, Randel BE, Hahn DD, Frankovsky MJ et al. Performance of helical computed tomography without oral contrast for the detection of gastrointestinal injuries. Ann Emerg Med 2004; 43(1): 120-8.
10. Hebert JJ, Taylor AJ, Winter TC, Reichelderfer M, Weichert JP. Low-attenuation oral GI contrast agents in abdominal-pelvic computed tomography. Abdom Imaging 2006; 31(1): 48-53.
11. Huynh LN, Coughlin BF, Wolfe J, Blank F, Lee SY, Smithline HA. Patient encounter time intervals in the evaluation of emergency department patients requiring abdominopelvic CT: oral contrast versus no contrast. Emerg Radiol 2004; 10(6): 310-3.
12. Anderson BA, Salem L, Flum DR. A systematic review of whether oral contrast is necessary for the computed tomography diagnosis of appendicitis in adults. Am J Surg 2005; 190(3): 474-8.
13. Lee CH, Haaland B, Earnest A, Tan CH. Use of positive oral contrast agents in abdominopelvic computed tomography for blunt abdominal injury: meta-analysis and systematic review. Eur Radiol. 2013; 23(9): 2513-21.
14. Thompson SE, Raptopoulos V, Sheiman RL, McNicholas MM, Prassopoulos P. Abdominal helical CT: milk as a low-attenuation oral contrast agent. Radiology 1999; 211(3): 870-5.
15. Latifi A, Labruto F, Kaiser S, Ullberg U, Sundin A, Torkzad MR. Does enteral contrast increase the accuracy of appendicitis diagnosis? Radiol Technol 2011; 82(4): 294-9.
16. Harieaswar S, Rajesh A, Griffin Y, Tyagi R, Morgan B. Routine use of positive oral contrast material is not required for oncology patients undergoing follow-up multidetector CT. Radiology 2009; 250(1): 246-53.
17. Wolfe JM, Smithline H, Lee S, Coughlin B. Polino J, Blank F . The impact of body mass index on concordance in the interpretation of matched noncontrast and contrast abdominal pelvic computed tomographic scans in ED patients with nontraumatic abdominal pain. Am J Emerg Med 2006; 24(2): 144-8.
18. Lee SY, Coughlin B, Wolfe JM, Polino J, Blank FS, Smithline HA. Prospective comparison of helical CT of the abdomen and pelvis without and with oral contrast in assessing acute abdominal pain in adult Emergency Department patients. Emerg Radiol 2006; 12(4): 150-7.
19. Nastanski F, Cohen A, Lush SP, DiStante A, Theuer CP. The role of oral contrast administration immediately prior to the computed tomographic evaluation of the blunt trauma victim. Injury 2001; 32(7): 545-9.
20. Stafford RE, McGonigal MD, Weigelt JA, Johnson TJ. Oral contrast solution and computed tomography for blunt abdominal trauma: a randomized study. Arch Surg 1999; 134(6): 622-6.
21. Hill BC, Johnson SC, Owens EK, Gerber JL, Senagore AJ. CT scan for suspected acute abdominal process: impact of combinations of IV, oral, and rectal contrast. World J Surg 2010; 34(4): 699-703.
22. Clancy TV, Ragozzino MW, Ramshaw D, Churchill MP, Covington DL, Maxwell JG. Oral contrast is not necessary in the evaluation of blunt abdominal trauma by computed tomography. Am J Surg 1993; 166(6): 680-4.
23. Choi HK, Chu KW, Law WL. Therapeutic value of gastrografin in adhesive small bowel obstruction after unsuccessful conservative treatment: a prospective randomized trial. Ann Surg 2002; 236(1): 1-6.
24. Thompson JS. Contrast Radiography and Intestinal Obstruction. Ann Surgery. 2002; 236(1): 7-8.