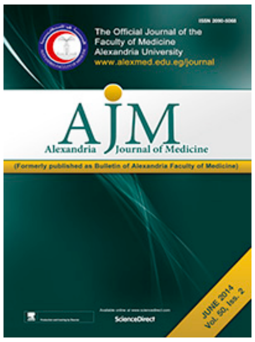

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The added value of coronal reformatted images using 16 slice multidetector computed tomography in non-traumatic-acute abdomen

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KEYWORDS
Acute abdomen;
MDCT

Abstract *Objective:* To assess the added value of coronal reformatted images using 16-MDCT in different encountered non-traumatic-acute abdominal disorders.
Patients and methods: 16-MDCT was performed in 100 patients with acute non-traumatic abdominal pain. Two independent readers blinded to the clinical information interpreted the axial scans alone, and then axial plus coronal scans for the presence of pathology. Confidence was scored with a 1–5 scale (1 = absent, 5 = present). The final diagnosis was determined by surgical and pathologic reports and by clinical follow-up in those who did not undergo surgery.
Results: Mean sensitivity and specificity for the readers together were 92.5% and 92% for axial scans alone and 93.5% and 92.5% for combined axial and coronal scans (not significant), respectively. For the most inexperienced reader, the coronal reformations were helpful in 81% of cases, while for the most experienced reader, the coronal reformations were helpful in 39% of the cases. The coronal images were helpful in an average of 60% of the cases for the two readers.
Conclusions: Axial and coronal reformations of 16 slice MDCT have equal sensitivity and specificity for the diagnosis of acute abdominal pathology. However, coronal reformations improved the diagnostic confidence for all readers.

1. Introduction

Acute abdomen is a term frequently used to describe the acute abdominal pain in a subgroup of patients who are seriously ill and have abdominal tenderness and rigidity. Before the advent of widespread use of imaging, these individuals were candidates for surgery. However, with the present role of imaging, some patients with acute abdomen will not undergo surgery. Other patients with acute abdominal pain that does not meet the criteria to be defined as acute abdomen—for example,

Abbreviation: MDCT, multidetector computed tomography.

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many patients suspected of having acute appendicitis—will need surgery. In this article, we use the term acute abdominal pain to refer to the complete spectrum of acute abdominal pain in patients who are treated in the emergency department and require imaging.[1]

The causes of acute abdominal pain range from life-threatening to benign self-limiting disorders. Acute appendicitis, diverticulitis, cholecystitis, acute pancreatitis and bowel obstruction are common causes of acute abdominal pain. Other important but less frequent conditions that may cause acute abdominal pain include perforated viscus, incarcerated hernia and bowel ischemia.[1]

Numerous studies indicate that CT, when combined with careful physical examination and evaluation of laboratory results, provides useful diagnostic information in patients with an acute abdomen.[2–4] As a result, CT is increasingly used in the emergency department setting. MDCT is a technologic advance that allows simultaneous acquisition of multiple images during a single rotation of the X-ray tube.[5]

With 16-section multi-detector row CT, it is possible to scan the entire abdomen and pelvis within a single and comfortable breath hold at a resolution of less than 1 mm in the x, y, and z axes. These data sets result in voxels that are both submillimeter in dimension and isotropic, which suggests that reformations in any desired plane will have spatial resolution similar to that in the transverse plane.[6,7]

2. Aim of the work

The purpose of this study was to assess the added diagnostic value of the obtained coronal reformatted images using 16 slice MDCT in different encountered non-traumatic-acute abdominal disorders.

3. Patients and methods

This study was approved by the ethics committee of our institution; all the included cases gave informed consent.

Multidetector helical 16-section CT was performed in selected 100 patients (60 female and 40 male; their ages ranged from 9 to 85 years; mean age, 47 years) with acute non-traumatic abdominal pain who had been referred from the emergency department in the period from December 2011 till January 2013 and not diagnosed by conventional radiography and US.

All patients were thoroughly asked about the detailed clinical history after reviewing the referring imaging request and laboratory findings. Exclusion criteria for CT were as follows: severe previous allergic reactions to iodine contrast media, renal insufficiency (creatinine level, > 120 μmol/L or $\geqslant 1.5$ mg/L), also patients with traumatic acute abdomen and gall bladder stones were excluded from this study. The final diagnosis was determined by surgical and pathologic reports and by clinical follow-up in those who did not undergo surgery.

3.1. Patient preparation

The patients fasted for about 4 h before the appointment to minimize gastric upset when the contrast medium is injected during scanning. Depending on the patient's condition and provisional diagnosis, oral contrast was given to the patients 2–4 h before the exam during their stay in the emergency department. Patients drank 500 mL of neutral contrast medium (mannitol) diluted in 1000 mL water 1–2 h before scanning. Patients with a high suspicion of viscous perforation or those who could not drink contrast were submitted first for plain CT without oral contrast.

3.2. Scanning technique

Patients were positioned on the CT examination table in the supine position. Intravenous access via a large intravenous line (e.g., 18–20 gauges) was necessary to ensure easy injection of the viscous contrast agents at a flow rate of 3 mL/s. Scanning was performed from the mid of the chest to the pubic symphysis with a 16-MDCT scanner (Somatom, E-motion, Siemens, Germany). Then, 80–120 mL of iopamidol (Scanlux, 370 mg I/mL, Sanochemia, Austria) was injected at a rate of 3 mL per second using an automatic pump injector (CT 9000/USA) the amount of contrast depends on the patient's weight, with 60 s delayed scan to obtain imaging during the portal venous phase. The protocol was as follows: 130 kVp; 350 mA; sections, 16; section thickness, 0.625 mm; pitch, 1.75; table speed, 35 mm/s (17.5 mm per rotation with two rotations); and gantry speed, 0.5 s per rotation. The transverse section data were reconstructed twice: first with 5-mm-thick sections at 5-mm intervals in the transverse plane and then with 0.625-mm-thick sections at 0.625-mm intervals. The second set of reconstructed transverse scans was then reformatted in the coronal plane with 3-mm sections at 5-mm intervals.

3.3. Image analysis

The CT scans were anonymized and loaded onto a workstation. This included the CT scout scan, the transverse series, and the coronal reformatted series. Two readers with subspecialty training in abdominal imaging served as independent readers who were blinded to the clinical data; they had 10 and 3 years of experience dedicated to abdominal imaging, respectively. Readers first assigned confidence scores to the axial scans alone and then assigned scores to the combined axial and coronal scans, after that the readers judged whether the coronal scans added value to the axial scans.

A confidence score was obtained for characterizing and diagnosing the lesion, with a scale of 1–5 (1, definitely absent; 2, probably absent; 3, cannot determine; 4, probably present; and 5, definitely present). Scores of 4 or 5 were considered affirmative.

3.4. Statistical analysis

The sensitivity and specificity values of each reader were determined for both the axial scans alone and the axial and coronal scans combined. P values for comparisons of the mean sensitivity and specificity for the two readers between axial and combined axial and coronal scans were computed with the signed rank test. P values for comparisons of reader-specific values were computed by means of the McNemar test. For the purpose of this study, $P < .05$ was considered to indicate a significant difference.

Agreement between axial and coronal scan interpretations for each reader was determined by using the κ statistic. An

Table 1 Clinical data of patients included in the study.

Parameter	No. of patients (N:100)
Gender (F/M)	60/40
Mean (range) age (year)	47 {9–85}
Abdominal pains	100
Diabetes	10/100
Alcoholics	5/100
T.B.	2/100
Constitutional symptoms	20/100
Vomiting and/or constipation	40/100

Table 2 Different encountered acute abdominal disorders.

	Acute abdominal disorders	Total (100)
1	Acute appendicitis	42/100
2	Intestinal obstruction	28/100
	Adult Intussusceptions	4/28
	Venous bowel ischemia	4/28
	Arterial bowel ischemia	2/28
	Adhesive	14/28
	Inflammatory	2/28
	Malignant	2/28
3	Acute pancreatitis	10/100
4	Perforated duodenal ulcer	6/100
5	Peritonitis	4/100
6	Diverticulitis	4/100
7	Splenic infarction	2/100
8	Ureteric small stone	2/100
9	Tubo-ovarian abscess	2/100

average κ value and a range of κ values were determined for all readers for each diagnosis. Standard errors for a range of κ and average κ were computed by using the statistical jackknife method applied over cases. K values of 0.21–0.40 were considered to indicate fair agreement; κ values of 0.41–0.60, moderate agreement; κ values of 0.61–0.80, substantial agreement; and κ values of 0.81–1.00, almost perfect agreement.[8]

4. Results

Multidetector helical 16-section CT was performed in selected 100 patients (60 female and 40 male; their ages ranged from 9 to 85 years; mean age, 47 years) with acute non-traumatic abdominal pain who had been referred from the emergency department. Patients' clinical data are shown in Table 1.

Acute appendicitis, intestinal obstruction, acute pancreatitis, perforated duodenal ulcer, peritonitis, diverticulitis, ureteric obstructing small stone, splenic infarction, tubo-ovarian abscess were the different acute abdominal disorders encountered in this work as shown in Table 2.

On the basis of the readers' results, a mean sensitivity of 92.5% and a mean specificity of 92% were calculated for the axial images, a mean sensitivity of 93.5% and a mean specificity of 92.5% for the combined axial and coronal images. There was no significant difference in sensitivity or specificity between axial images and axial plus coronal images for any reader (Table 3).

4.1. Reader agreement

On the basis of the readers' findings, there was reader agreement (κ range, 0.70–0.80) between the two readers for the axial scans alone. For the combined coronal and axial scans, the κ values (range, 0.77–0.86) were even greater, indicating a higher level of agreement for the axial and coronal combination over the axial images alone. This difference was significant with a P-value <0.05 (Table 4).

The mean confidence scores for the two readers are shown in Table 5. There was a significant ($P < 0.05$) difference for the detection of ''definitely present'' pathology using the combination of axial and coronal images in comparison to the axial images alone.

4.2. Added value of coronal scans

In addition, the two readers reported that the coronal scans were an added value to an average of 60% of the cases. The most experienced reader reported an additional value of the coronal images in 39% of the cases. The second reader reported an added value of the coronal scans to axial scans in 81% of the cases as shown in Table 6.

4.3. Acute appendicitis

Forty-two patients were encountered with acute appendicitis, 5 of them showed appendicular mass/abscess (Fig. 1). Dilated

Table 3 Sensitivity and specificity values for the diagnosis of pathologies.

Reader	Axial scans alone		Combined axial and coronal scans	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Reader 1	94	93	95	94
Reader 2	91	91	92	91
Mean	92.5	92	93.5	92.5

Table 4 Reader agreement for the diagnosis of abdominal pathology.

Reader combination	Axial scans alone	Combined axial and coronal scans
Readers 1 and 2	0.70–0.80	0.77–0.86

Numbers are the mean weighted κ statistics. The differences between image sets were statistically significant ($P < 0.05$).

Table 5 Mean confidence scores for detection of abdominal pathology ($n = 100$).

Confidence score	Axial scans alone		Combined axial and coronal scans	
	R1	R2	R1	R2
1 (Definitely absent)	0	0	0	1
2 (Probably absent)	1	1	1	0
3 (Cannot determine)	3	6	3	2
4 (Probably present)	29	41	15	33
5 (Definitely present)	67	52	81	64

Data were given as number of patients. The differences between the two readers in the two imaging sets were significant ($P < 0.05$).

Table 6 Added value of coronal scans.

Readers	Added value of coronal scans (%)
Reader 1	39
Reader 2	81
Mean	60

fluid-filled appendix, periappendiceal inflammation and enhancement of the appendiceal wall following intravenous bolus administration were seen in all patients with acute appendicitis. Calcified appendicoliths were seen in 5 patients (Fig. 2).

4.4. Acute pancreatitis

Seven patients had one attack of acute pancreatitis while three patients had recurrent attacks. Serum amylase was high in all

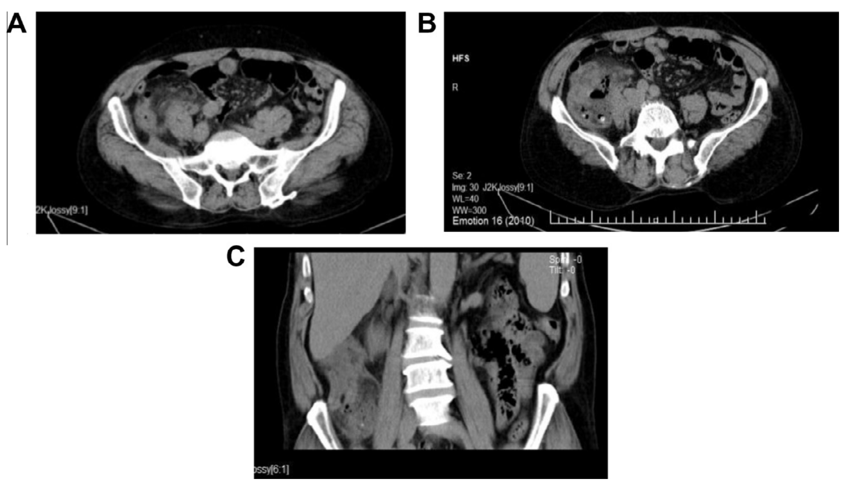

Figure 1 (A–C) 65-year-old male with right lower quadrant pain and fever. Axial MDCT scan (A and B) with coronal reformatted (C) obtained with oral and IV contrast agents shows dilated fluid-filled appendix, periappendiceal inflammation and enhancement of the appendiceal wall surrounded by appendicular mass.

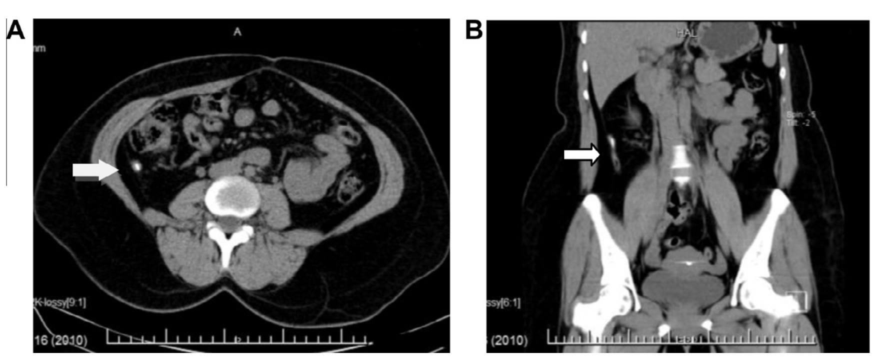

Figure 2 (A and B): (A) 34-year-old woman with right lower quadrant pain and fever. Axial MDCT scan obtained with oral and IV contrast agents shows gas- and fluid-filled structure (*arrow*) posterior to cecum with appendicolith. (B) 34-year-old woman with right lower quadrant pain and fever. Coronal reformation of MDCT scan shows tubular structure (*arrow*) posterior to cecum. High-attenuation structure clearly represents appendicolith.

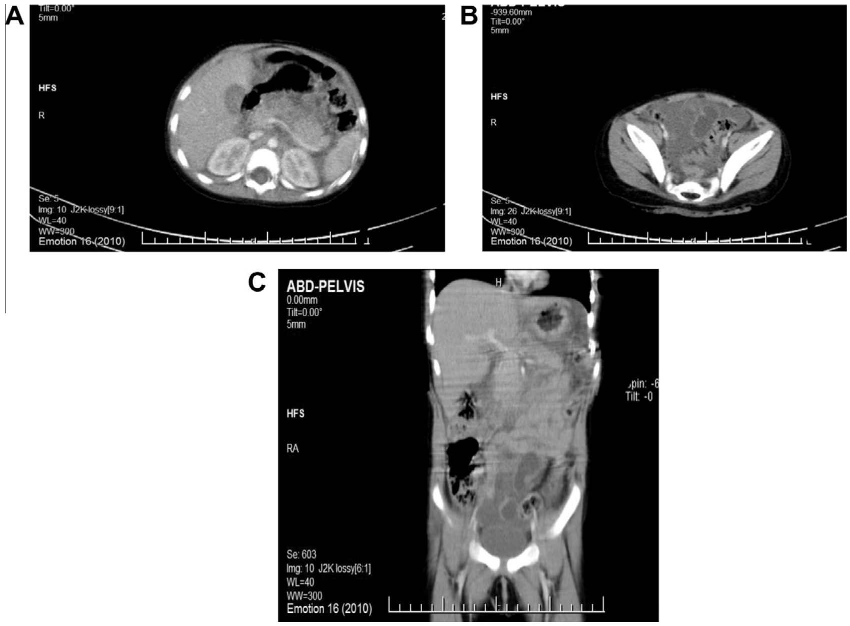

Figure 3 (A–C) 2-year-old female with acute epigastric pain. Axial MDCT scan (A and B) with coronal reformation (C) obtained with oral and IV contrast agents shows diffuse pancreatic enlargement with altered parenchymal density, blurred peripancreatic fat planes, peripancreatic inflammatory fluid collection and ascites.

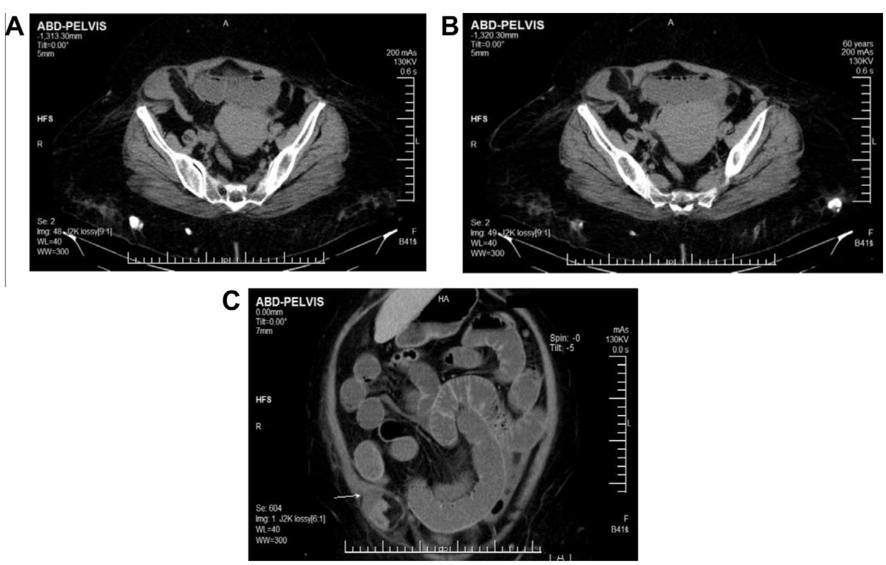

Figure 4 (A and B) 60-year-old female with a 3-day history of crampy abdominal pain, nausea, and vomiting. Axial MDCT scan obtained with IV and oral contrast agents shows dilated small bowel and collapsed colon. Note dilated bowel in region of speglian hernia (*arrow*). (C) 60-year-old female with a 3-day history of crampy abdominal pain, nausea, and vomiting. Coronal CT reformation of MDCT scan shows bowel dilatation throughout abdomen. "Knuckle" of bowel (*arrow*) passes through speglian hernia where there is an abrupt change in caliber. At surgery, incarcerated bowel within speglian hernia was reduced.

patients and nearly all patients with recurrent pancreatitis were alcoholic. Pancreatic calcification was seen in two patients with recurrent pancreatitis. Diffuse pancreatic enlargement with altered parenchymal density, blurred peripancreatic fat planes and peripancreatic inflammatory fluid collection were seen in all patients encountered with phlegmon seen in most patients. The inflammatory free fluid collection was seen in the peripancreatic, lesser sac, anterior pararenal and peritoneal spaces (Fig. 3). Pleural effusion and basal lung consolidation were seen in 20 patients.

4.5. Bowel obstruction

Bowel obstruction is a frequent cause of abdominal pain and accounts for 20% of all surgical admissions. In some patients with a dilated proximal bowel and a decompressed distal

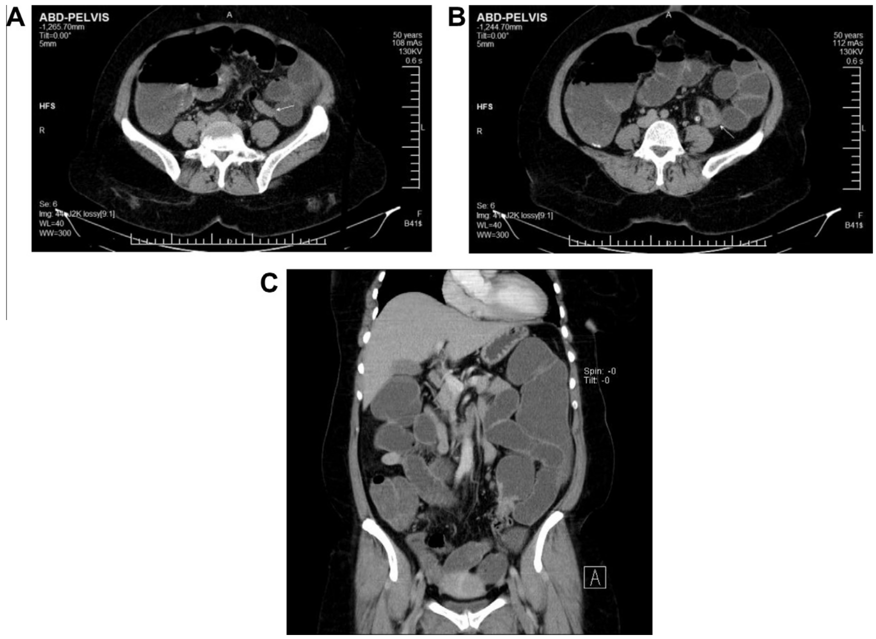

Figure 5 (A–C) Large bowel obstruction. Axial (A and B) and coronal reformatted (C) images show malignant stricture involving the sigmoid/descending colon junction with dilated proximal colon. The coronal reformatted image clarifying the confusing anatomy in axial images adds confidence to the diagnosis.

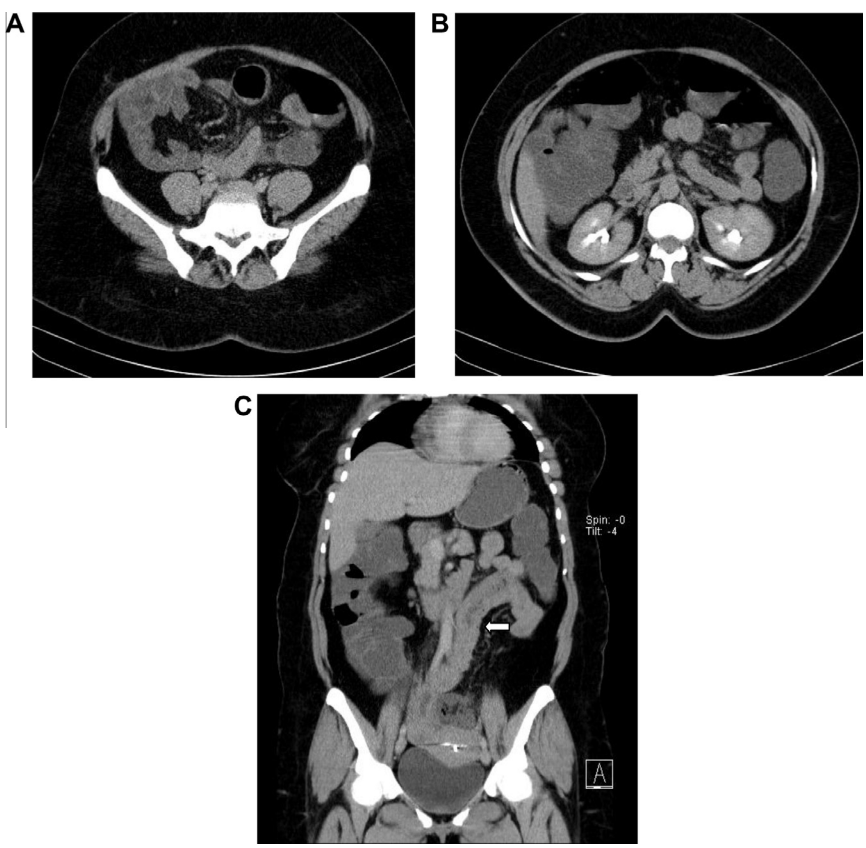

Figure 6 (A–C) Venous small bowel ischemia. Axial (A and B) and coronal reformatted images (C) show small bowel mural thickening and pneumatosis intestinalis (arrow) better detected in the coronal image.

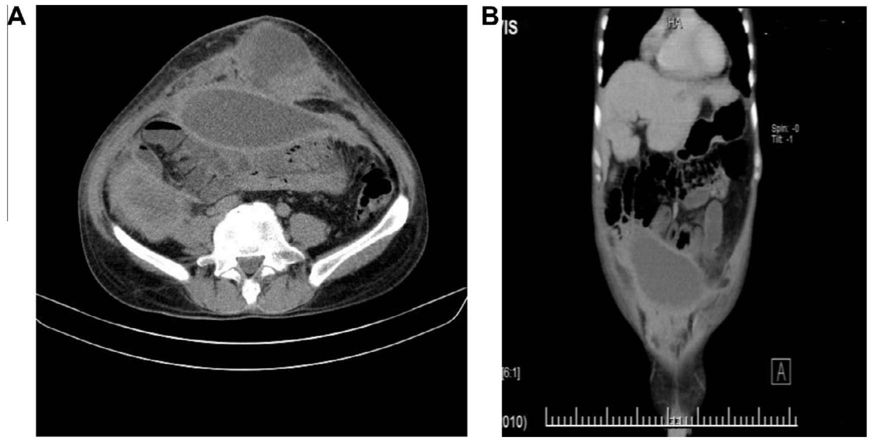

Figure 7 (A and B) 55-year-old man with diffuse abdominal pain. Axial (A) Coronal (B) CT reformation of MDCT scan with oral and IV contrast shows pelvi-abdominal encysted fluid with uniform mural enhancement consistent with abscess formation.

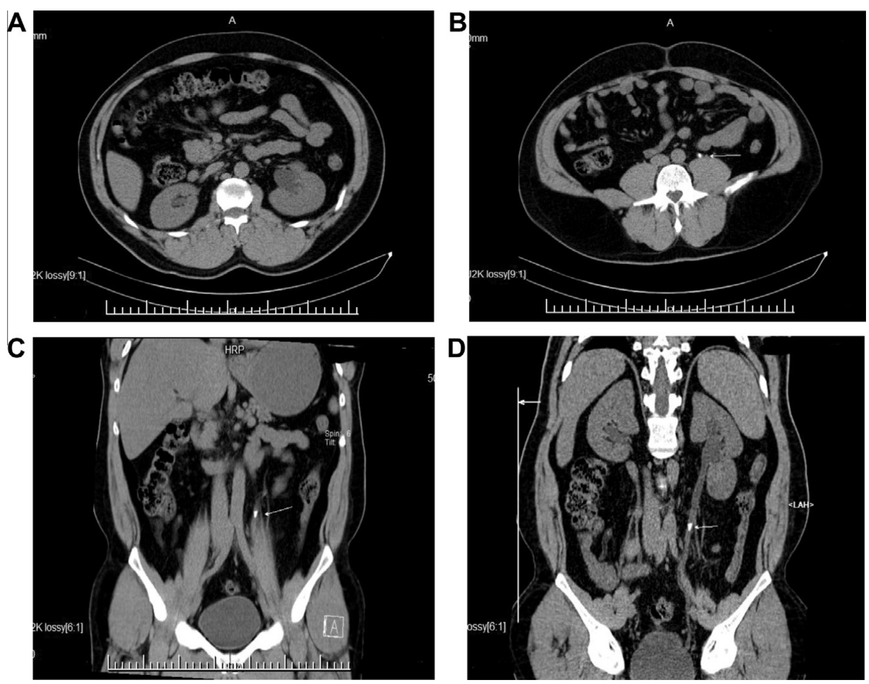

Figure 8 (A–D) 50-year-old male with acute left loin pain. Axial (A and B) Coronal (C and D) CT reformation of MDCT scan shows mild left-sided pelvicaliectasis (*arrowhead*). Dilated ureter can be traced to 4-mm obstructing calculus (*arrow*).

bowel, the specific point of transition may be difficult to determine using axial images alone. Coronal reformations allow one to view the presumed site of obstruction from a different perspective and may help one to determine the presence or absence of a transition point with greater confidence.[9] Careful inspection of the transition point, wall thickness, bowel size and luminal contents of the bowel, and assessment of mesenteric vessels were the target points of the CT findings (Figs. 4–6).

4.6. Peritonitis

Four patients presented with clinical peritonitis. All patients showed free pelviabdominal fluid collection of different degrees, peritoneal thickening and enhancement, and dilated bowel loops related to the ileus. T.B. peritonitis was proven in 2 patients with deeply seated pelvic abscess in one patient (Fig. 7) and ileocecal pathology in one patient.

4.7. Miscellaneous

Various abnormalities may be better visualized in the coronal plane including ureteral obstruction from small stone; focal bowel diseases such as intussusceptions, volvulus, and bowel ischemia; and the extent of bowel involvement from inflammatory bowel disease. Coronal images nicely illustrate the mesenteric fat tissue and vessels that often lay within the coronal plane. Inflammatory conditions such as mesenteric adenitis or mesenteric venous or arterial thrombosis may be well delineated on coronal reformations. Ureteric small stone, diverticulitis, splenic infarction and tubo-ovarian abscess are illustrated in Figs. 8–11.

5. Discussion

Acute abdominal pain is a common chief complaint in patients examined in the emergency department (ED) and can be related to a myriad of diagnoses. Of all patients who present to the ED, 4–5% have acute abdominal pain. Obtaining a careful medical history and performing a physical examination are the initial diagnostic steps for these patients. On the basis of the results of this clinical evaluation and laboratory investigations, the clinician will consider imaging examinations to help establish the correct diagnosis.[1]

Prior to the development of 16-section multi–detector row CT, it was difficult to scan the entire abdomen and pelvis at a section thickness of less than 1 mm during a single comfortable breath hold. While a volume acquisition of the entire abdomen and pelvis was possible with single-detector row CT or four- or eight-section multi-detector row CT, section thicknesses typically ranged from 1.25 to 5.00 mm. The multiplanar reformations created from such data sets provided an overview of gross anatomy and large diseased areas, but they were degraded by stair-step artifact, noise, motion artifact, and suboptimal spatial resolution caused by decreased resolution in the z-axis.

We used a multi-detector row CT scanner with 16 sections, 0.625-mm section thickness, and a table speed of 35 mm/s,

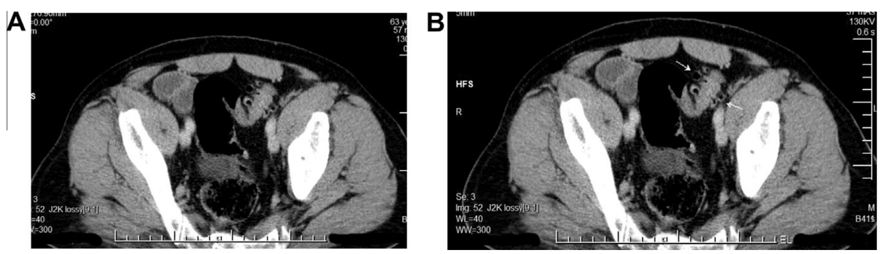

Figure 9 (A and B) 63-year-old male with lower abdominal pain. Axial (A and B) of MDCT scan shows colonic wall thickening in the presence of diverticulae, pericolonic fat stranding and small pericolic fluid collection (arrows).

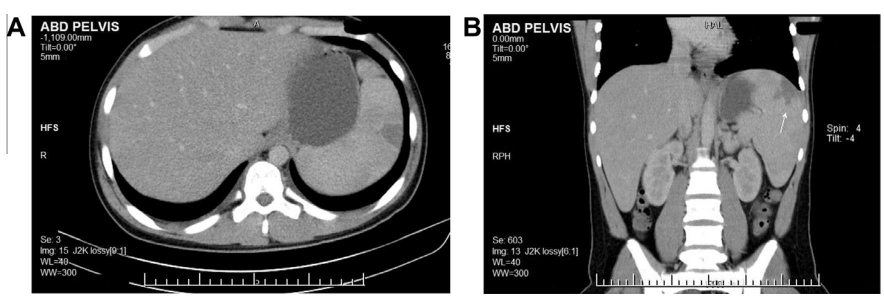

Figure 10 (A and B) 16-year-old male with acute left upper abdominal pain. Axial (A) coronal (B) CT reformation of MDCT scan with oral and I.V. contrast shows mildly enlarged liver and spleen with wedge-shaped supcapsular non-enhanced hypodense area at the diaphragmatic surface of the spleen consistent with splenic infarction.

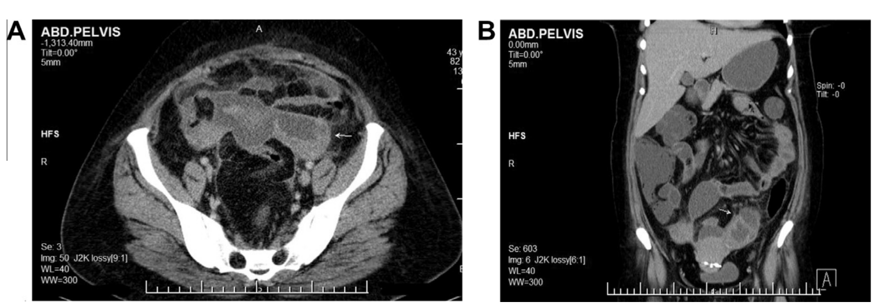

Figure 11 (A and B) 43-year-old female with lower abdominal pain. Axial (A) coronal (B) CT reformation of MDCT scan shows left adnexal multicystic structure with enhanced thick wall with difficult to delineate the adnexal structures from the uterus, pelvic side wall, small and large bowels, the coronal plane on MDCT clarifies the confusing anatomy and differentiating pyosalpinx from a multiseptate cystic ovarian mass. Confirmed to be tubo-ovarian abscess in operation.

which permits a single acquisition during a comfortable breath hold. Two sets of reconstructions were obtained. The first set was reconstructed in the transverse plane with 5-mm sections at 5-mm intervals. For a typical patient, this series resulted in approximately 70–100 scans. For the second set of reconstructions, the scans with 0.625-mm thickness were reconstructed at 0.625-mm intervals. This series resulted in approximately 560–800 scans, but the scans in this series were not used for diagnostic purposes because of the large number of scans and because noise caused problems that were due to the section thickness of only 0.625 mm. Rather, the second set of reconstructed transverse scans was reformatted in the coronal plane, with 3-mm sections at 5-mm intervals, which resulted in 50–75 scans per patient. In our practice, the 5-mm transverse and coronal scans are sent to the picture archiving and communication system as a series for interpretation. The 0.625-mm transverse scans are archived but are not interpreted or sent to the picture archiving and communication system.[10]

In this study, 16-multislice CT was used in evaluating various conditions manifested with acute abdominal pain; and non-diagnostic by conventional radiography and US. CT machine was fast with high diagnostic accuracy. The biliary causes have been excluded from the research because ultrasound was the imaging modality of choice in these disorders. Acute appendicitis, acute pancreatitis, intestinal obstruction, perforated duodenal ulcer, peritonitis, diverticulitis, splenic infarction, ureteric obstructing small stone, tubo-ovarian abscess were the different acute abdominal disorders encountered in this work.

In our study, a mean sensitivity of 92.5% and a mean specificity of 92% were calculated for the axial images, a mean sensitivity of 93.5% and a mean specificity of 92.5% for the combined axial and coronal images. There was no significant difference in sensitivity or specificity between axial images and axial plus coronal images for any reader. This is in agreement with Paulson et al.[11] who reported that the sensitivity and specificity for the combined axial and coronal scans were similar to those for the axial scans alone in diagnosis of acute appendicitis and ranged from 92% to 96% for sensitivity and from 93% to 95% for specificity.

In our study, there was reader agreement (κ range, 0.70–0.80) between the two readers for the axial scans alone. For the combined coronal and axial scans, the κ values (range, 0.77–0.86) were even greater, indicating a higher level of agreement for the axial and coronal combination over the axial images alone. This difference was significant with a P-value < 0.05. This is in agreement with Paulson et al.[11] who reported that submillimeter coronal reformations add to the confidence level of readers for the diagnosis of acute appendicitis. Caoili et al.[12] and Furukawa et al.[13] reported that multiplanar reformations are helpful for the evaluation of small bowel obstruction, particularly in the identification of the point of transition from dilated to decompressed bowel.

In our study, the two readers' results showed that the coronal scans were an added value to an average of 60% of the cases. The most experienced reader reported an additional value of the coronal images in 39% of the cases. The second junior reader reported an added value of the coronal scans to axial scans in 81% of the cases. This is in agreement with Zangos et al.[14] who reported that even experienced reviewers can benefit from the addition of coronal reformations. In their study, coronal reformations were helpful in an average of 62.3% of cases. The most experienced reader reported an additional value of the coronal images in 32%; 2; the senior- and second-year radiology residents reported an added value in 59% and 63% of the cases, respectively; and for the most inexperienced reader, the coronal images were helpful in 95% of the cases. Matsumoto et al.[15] reviewed their pediatric experience with coronal reformations of the abdomen and pelvis from isotropic voxels; although no new diagnoses were made with the coronal reformations, these images improved confidence in 25% of the abdominal examinations.

There was limitation as we were evaluating 100 consecutive patients who presented with acute abdominal pain and not those with specific disease entities, such as previous studies in which specific etiologies were evaluated (e.g., acute appendicitis and small bowel obstruction). This likely resulted in limited numbers of these specific disease processes.

In our study the coronal scans were interpreted after the interpretation of the axial scans. Impressions from the axial scans were fresh in the minds of the interpreters. Such a design may bias the results in favor of the subsequent interpretation, in this case the coronal scans. Our intention was to demonstrate the value of the coronal reformations as an adjunct to the axial scans alone, not as a stand-alone sequence; we believe that in most clinical settings, it is unlikely that radiologists would abandon the axial scans in favor of the coronal scans alone.

6. Conclusion

In patients with acute abdominal pain, MDCT with coronal reformations provides a useful adjunct to axial images. The coronal reformations should not replace careful evaluation of the axial images. However, in patients with an acute abdomen, the coronal images may clarify confusing anatomy, add confidence to interpretation, and provide a perspective familiar to the referring surgeons.

Conflict of interest

Authors reported agreement and no conflict of interest.

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