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Computed tomography of bowel obstructions: The contribution of multi-planar reformations in comparison with axial slices alone in determining the transition zone

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ABSTRACT

Several studies have demonstrated that determining the transition zone could facilitate the diagnosis of bowel obstruction (BO) using multi-detector row computed tomography (MDCT). We aimed to evaluate the contribution of multi-planar reformations (MPR) in comparison with axial slices alone to determine the transition zone. Sixteen-slice MDCT examinations of 66 consecutive patients with mechanical BO were reviewed by an experienced abdominal radiologist who had been blinded to the patients' clinical diagnoses. The scans were first reviewed using the axial slices alone and later were reviewed using MPR with respect to the assigned four-point confidence scale in a random order. The diagnostic accuracy and mean confidence score were evaluated for both reviewing methods. The accuracy for determining the transition zone using axial slices alone was 92% in patients with small bowel obstruction (SBO) and 93% in those with large bowel obstruction (LBO). The levels of accuracy for MPR were exactly the same with axial slices alone both for SBO and LBO. The mean confidence score for the determination of the transition zone using axial slices alone was 3.59 for SBO and 3.71 for MPR (P=0.057). After evaluating patients with LBO, the mean confidence score using axial slices alone was 3.80, which was identical to that of MPR. Like MPR, axial CT source slices can also provide high levels of accuracy in the determination of the transition zone in patients with BO. However, particularly in SBO, MPR will increase confidence in the diagnosis.

1. Introduction

Bowel obstruction (BO) is a relatively frequent disorder that comprises 20% of all surgical admissions for acute abdomen (Jaffe et al., 2006; Yaghmai et al., 2006; Filippone et al., 2007a, 2007b). A diagnosis of BO depends on the patient's history, clinical signs and radiological findings (Yaghmai et al., 2006; Filippone et al., 2007b; Furukawa et al., 2011). These findings may play a leading role in the diagnosis and help guide patient care. For instance, the character of the bowel distension is a key finding that differentiates a mechanical obstruction from a functional (adynamic) one. A transition zone where the bowel width changes from high-calibre to low-calibre is indicative of mechanical obstruction (Balthazar and George, 1994; Filippone et al., 2007a; Hodel et al., 2009). Because the determination of a transition zone identifies the site and cause of the obstruction, it is a crucial

component in the diagnosis of mechanical BO (Jaffe et al., 2006; Filippone et al., 2007b; Hodel et al., 2009). Nevertheless, determining the transition zone may be difficult, especially in patients with significantly distended loops or a scarcity of intra-abdominal fat tissue (Lazarus et al., 2004; Jaffe et al., 2006; Filippone et al., 2007b; Hodel et al., 2009).

Multi-detector row computed tomography (MDCT) has proven to be a valuable imaging modality in the diagnosis of BO (Maglinte et al., 1993; Balthazar and George, 1994; Sinha and Verma, 2005a; Hodel et al., 2009). While experts are accustomed to using conventional axial slices to interpret MDCT scans, recent developments have enabled the review of the entire abdomen and pelvis using multi-planar reformations (MPR); the resultant reformations in any desired plane will be similar in spatial resolution to those in the axial plane without any loss of information (Paulson et al., 2004; Filippone et al., 2007b; Hodel et al., 2009). Several studies (Caoili et al., 2000; Khurana et al., 2002; Lazarus et al., 2004; Jaffe et al., 2006; Filippone et al., 2007b; Hodel et al., 2009; Furukawa et al., 2011) have suggested that MPR may be helpful in determining the transition zone, especially in patients with small-bowel obstruction (SBO). However, it is still controversial whether MPR is required for the assessment because of the high levels of accuracy achieved using axial slices alone (Filippone et al., 2007a; Hodel et al., 2009, Keoplung et al., 2013).

Therefore, the purpose of this study was to evaluate the contribution of MPR in comparison with axial source slices alone to determine the transition zone using CT in patients with BO.

Experimental procedure

Patient population

The study protocol was approved by the institutional review board of our hospital, and informed written consent was obtained from all patients. We identified 92 consecutive patients who were referred to the emergent CT unit at our hospital for sudden abdominal pain and underwent 16-slice MDCT between 1 January 2010 and 1 September 2015 to rule out suspected BO. The medical records of these patients were retrospectively analysed. We solicited cases of mechanical BO so that a transition zone might be determined (Balthazar and George, 1994; Filippone et al., 2007a; Hodel et al., 2009). Of the 92 (72%) patients, 66 were diagnosed with mechanical BO. The diagnosis was made when there was surgical proof or a relief of the obstructive symptoms after conservative treatment accompanied by CT findings that also suggested the condition. Of the 66 patients, 41 were men and 25 were women; they ranged in age from 8-86 years with a mean age of 59.

Scanning technique

Scanning was performed using a 16-slice CT scanner (Somatom Sensation, Siemens, Erlanger, Germany) in accordance with our institutional Abdomen and Pelvis CT Protocol, which was designed for patients with suspected BO. According to this protocol, enhanced axial CT scans from the dome of the diaphragm to the symphysis pubis were obtained to view the internal orifices of the inguinal channels using 2-mm thick sections with a slice collimation of 16x1.5 mm, a 0.5-s rotation time, a table speed of 18 mm/rotation, and an exposure of 120 kV: 160 mA for adults and 120 kV: 55 mA for paediatric patients. During the image acquisition, patients were asked to take a deep breath and hold it. A mechanical power injector (Medrad Inc., Indianola, PA, USA) was used to intravenously administer 2 ml/kg and 1 ml/kg of iodinated contrast material (Omnipaque-300, GE Healthcare) for adults and children, respectively, at a rate of 3 ml/s using varying sizes of catheters placed in an antecubital vein. The image acquisition began approximately 70 s after the start of the intravenous injection during the portal venous phase. None of the patients were asked to ingest oral contrast material.

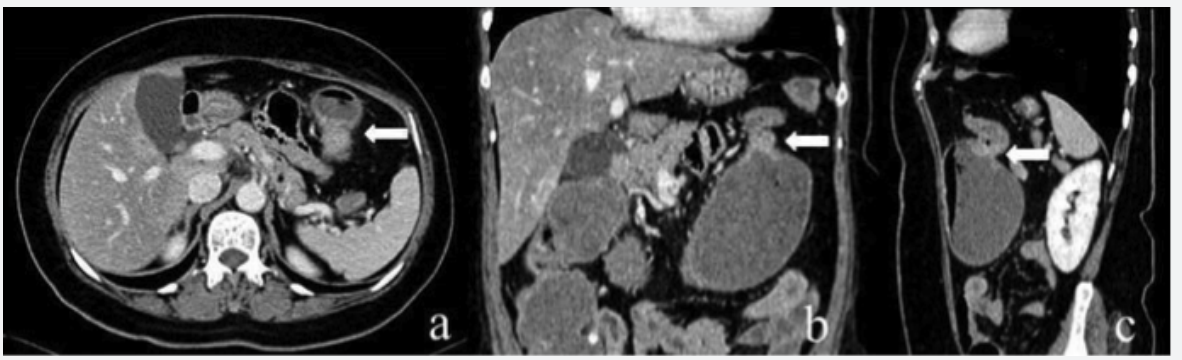

Fig. 1. a-c: An 86-year-old woman with SBO caused by inguinal herniation. The transition zone (arrows) could be determined in the axial, coronal and sagittal planes (a, b and c)

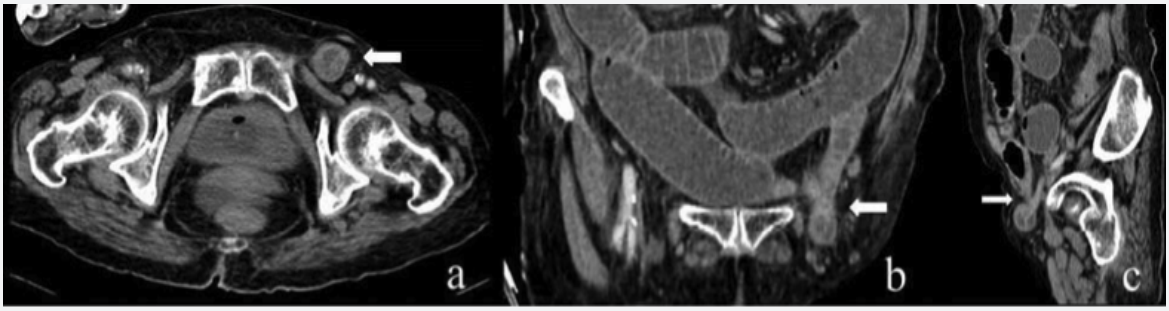

Fig. 2. a-c: A 57-year-old woman with LBO caused by a tumour at the splenic flexure. The transition zone (arrows) was visible in the axial, coronal and sagittal planes (a, b and c)

Assessment of the CT examinations

A radiologist who was experienced in abdominopelvic CT and had been blinded to both the clinical histories and the surgical diagnoses of the patients reviewed the CT examinations on a workstation (Wizard, Siemens, Germany). The reader was asked to locate a transition zone with respect to a 4-point confidence scale where 1=definitely absent, 2=probably absent, 3=probably present and 4=definitely present. A score of 3 or 4 was considered positive, while a score of 1 or 2 was considered negative for the determination of the transition zone (Fig. 1, 2). The CT examinations were randomly analysed on the workstation; initially, axial slices were examined alone, and then MPR with the axial, coronal and sagittal planes was assessed one month later to avoid bias. The radiologist used the workstation to perform the image reconstruction. MPRs were obtained via a reconstruction of the raw data set with a slice thickness of 2 mm and intervals of 1.5 mm.

Statistical analysis

The difference between the accuracy of the axial and MPR assessments for the determination of the transition zone was calculated to compare the resultant quantitative proportions. To assess the difference regarding the mean confidence score, a paired t-test was used in SBO patients, and the Wilcoxon test was employed for those with a large bowel obstruction (LBO). A P value of less than 0.05 was considered to indicate a statistically significant difference for both analyses.

3. Results

Fifty-one of the 66 patients (77%) showed SBO, whereas the remaining 15 (23%) demonstrated an LBO. Adhesions were the leading cause and accounted for 44% of all cases. Table 1 presents the distribution of the causes of BO.

Table 1. The distribution of the causes of BO

Causes of obstruction	Number of cases (%)
Adhesions	29 (43.9%)
Tumour	16 (24.2%)
Herniation	9 (13.6%)
Bezoar	5 (7.5%)
Others	
Inflammatory bowel disease	2 (3%)
Radiation enteritis	1 (1.5%)
SMA syndrome*	1 (1.5%)
Invagination	1 (1.5%)
Intra-abdominal abscess	1 (1.5%)
Volvulus	1 (1.5%)

SMA: Superior mesenteric artery; **BO:** Bowel obstruction

The accuracy for determining the transition zone using axial slices alone was 92% (47 of 51 patients) in SBO, while it was 93% (14 of 15 patients) in LBO. The CT scans in which a transition zone could not be determined using either axial slices alone or MPR belonged to the same patients. For both SBO and LBO, the level of accuracy with MPR was exactly the same as that obtained using axial slices alone (Table 2); no improvement in accuracy was detected with MPR.

Table 2. Accuracy in the determination of the transition zone

	Axial slices alone (%)	MPR (%)
SBO	47/51 (92%)	47/51 (92%)
LBO	14/15 (93%)	14/15 (93%)

SBO: Small bowel obstruction**; LBO:** Large bowel obstruction

The mean confidence score for determining the transition zone in SBO using axial slices alone was 3.59, while it was 3.71 with MPR. The evaluation of patients with LBO revealed that the mean confidence score determined with axial slices alone was 3.80, which was identical to that of MPR (Table 3). The results of the paired t-test revealed a trend towards improved confidence with MPR in SBO (P=0.057).

Table 3. The mean confidence score for determining the transition zone

	Axial slices alone (mean)	MPR (mean)	P-value
SBO	3.59	3.71	0.057*
LBO	3.80	3.80	1.000**

*P and **P values were calculated using a paired t-test and Wilcoxon test, respectively
SBO: Small bowel obstruction**; LBO:** Large bowel obstruction

4. Discussion

MDCT has been shown to be useful in demonstrating the presence as well as the site and cause of BO (Sinha and Verma, 2005a; Jaffe et al., 2006; Yaghmai et al., 2006; Filippone et al., 2007a; Filippone et al., 2007b). In addition, MDCT can reliably depict secondary signs of obstruction and probable complications (Sinha and Verma, 2005a; Jaffe et al., 2006; Filippone et al., 2007b). Therefore, MDCT has become the primary imaging modality of choice in patients with suspected BO (Hodel et al., 2009).

The crucial step for the clinical management of patients with BO is first to confirm mechanical bowel obstruction and then to differentiate between SBO and LBO and finally identify signs of severity (strangulation). The determination of a transition zone allows SBO to be distinguished from LBO and also aids practitioners in assessing the cause of the obstruction (Hodel et al., 2009). For example, an obstruction that comprises all the bowel loops in the absence of a transition zone indicates paralytic ileus or pseudo-obstruction, which require medical therapy but not surgery (Sinha and Verma, 2005b; Jaffe et al., 2006).

Several studies have suggested that MPR may be helpful in the identification of the transition zone and may also improve diagnostic accuracy (Caoili et al., 2000; Khurana et al., 2002; Lazarus et al., 2004; Jaffe et al., 2006; Yaghmai et al., 2006; Filippone et al., 2007b; Hodel et al., 2009; Furukawa et al., 2011). Indeed, MPR has recently been adopted as an indispensible supplement of the assessment of acute abdomen. Filippone (Filippone et al., 2007a) suggested that axial slices often demonstrate bowel loops in their short axis; therefore, it may be troublesome to follow up their course and find the transition zone. Yaghmai (Yaghmai et al., 2006) and Jaffe (Jaffe et al., 2006) proposed that a single coronal section could depict more bowel loops, making it a more effortless way to trace their course (Jaffe et al., 2006; Yaghmai et al., 2006). Coronal reformations in particular are able to ensure a conceivable overview of the anatomy (Jaffe et al., 2006; Yaghmai et al., 2006; Hodel et al., 2009). Moreover, Yaghmai (Yaghmai et al., 2006) also claimed that coronal reformations may be substituted for conventional axial slices. However, in general, it is not advisable to rely upon reformatted images alone (Jaffe et al., 2006; Hodel et al., 2009). The study by Jaffe (Jaffe et al., 2006) concluded that coronal reformations alone do not improve the accuracy of an SBO diagnosis and suggested that coronal reformations used as a supplement to axial slices remarkably enhance the agreement level as well as the confidence level in diagnosing BO (Jaffe et al., 2006). Therefore, as also suggested by Hodel (Hodel et al., 2009), reformatted images should be correlated with axial source slices.

We evaluated the contribution of MPR that comprised axial, coronal and sagittal reformations, yet the study was not restricted to any of these except the axial plane. The level of accuracy using axial slices alone was identical to that of MPR in both SBO and LBO (92% and 93%, respectively). Therefore, MPR did not provide any improvement in the accuracy of determining the transition zone. The high levels of accuracy achieved using axial slices alone were concordant with the results of several previous studies (Filippone et al., 2007a; Hodel et al., 2009; Keoplung et al., 2013). For instance, Hodel (Hodel et al., 2009) reported a relatively high accuracy level of 86% using only axial slices, which indicates that axial source slices alone offer accuracy levels that are comparable to MPR for determining the transition zone. In other words, if it is difficult to locate a transition zone using axial slices alone, it would also be troublesome to do so with MPR. While MPR slightly boosted the confidence in the determination of the transition zone in SBO, there was no similar improvement for LBO. This result confirmed the findings of former studies (Filippone et al., 2007a; Hodel et al., 2009). It is well accepted that MPR can enhance the confidence of interpreting the CT scans of patients with intestinal disorders, such as SBO and acute appendicitis (Paulson et al., 2005; Jaffe et al., 2006, Hodel et al., 2009). The ability to trace the course of bowel loops, particularly small bowel loops, in different planes makes the reader feel more confident in the diagnosis despite the fact that MPR multiplies the number of images to be reviewed.

There were limitations to this study that could have influenced the outcome. First, the CT scans were interpreted by only one radiologist; it would have been more efficient if we had assessed the inter-observer variability using more readers. Moreover, the total time spent to reach each diagnosis was not calculated. In addition, while 66 patients were included in the study, the number of patients with LBO remained relatively insufficient.

In conclusion, our results indicated that axial source slices can provide high levels of accuracy in the determination of the transition zone that are equivalent to those of MPR. However, particularly in SBO, MPR will increase the confidence in the diagnosis.

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