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CT attenuation of colorectal polypoid lesions: evaluation of contrast enhancement in CT colonography

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Abstract The aim of this study was to calculate pre- and postcontrast CT attenuation values of benign colorectal polyp and carcinoma lesions detected by virtual colonoscopy, and to investigate whether contrast enhancement of these lesions can be potentially used for differentiation from residual fluid in the colon. Fifteen benign polyps and 21 colorectal carcinoma lesions detected by virtual colonoscopy in 18 patients were included in our study. All of the polyps and carcinoma lesions were confirmed by colonoscopic biopsy. Measurement of CT attenuation values was performed in precontrast (supine) and postcontrast (prone) scans for each polyp and carcinoma. The CT attenuation values of residual fluid in the colon was also measured from the same location before and after intravenous contrast administration. On unenhanced CT scan mean attenuation values of benign polyps and colorectal carcinomas were 32.4 and 42.6 HU, respectively. Following contrast enhancement, mean attenuation value increased to 78.9 HU for polyps and 90.7 HU for carcinomas. Increase in the CT attenuation values of these lesions was significant (p <0.0001). Mean CT attenuation value of residual fluid before and after administration of IV contrast were 14.6 and 13.8 HU, respectively. The difference between CT attenuation value of residual fluid in the colon before and after contrast material was not significant (p =0.29). Colorectal benign polyps and carcinomas demonstrate significant enhancement following contrast administration and use of intravenous contrast material during virtual colonoscopy may help in some cases in differentiating these solid lesions from residual colonic fluid that does not enhance.

Keywords CT colonography · Colorectal cancer · Polyp

Introduction

Computed tomographic colonography is a recently developed and currently evolving technique for the detection of colorectal polyps and cancer. Several studies have demonstrated promising results for CT colonography with sensitivities of 85–100% for detection of polyps larger than 10 mm in diameter [1, 2, 3, 4, 5, 6]. The authors of some recent studies have suggested that this imaging method is competitive as a full structural colon examination and has enormous potential for colorectal screening in the future [1, 7]; however, if CT colonography will be used for colonic cancer screening, optimization and standardization of the technique is essential. Although there is consensus on certain aspects of CT colonography technique (such as choosing narrow collimation and reconstruction intervals, additional prone scanning, etc.), some technical points still remain to be discussed and to be further refined [8, 9, 10].

The routine use of intravenous contrast material during CT colonography is one of those controversial issues which received relatively limited acceptance due to its

Table 1 Size, localization, and pre- and postcontrast CT attenuation values of benign polyps. *HU* Hounsfield units, *S* sigmoid colon, *D* descending colon, *R* rectum, *RS* rectosigmoid colon, *HF* hepatic flexure, *SF* splenic flexure, *C* caecum

Lesion no.	Localization	Size (mm)	Precontrast CT attenuation of benign polyps (HU)	Postcontrast CT attenuation of benign polyps (HU)	Precontrast CT attenuation of residual fluid (HU)	Postcontrast CT attenuation of residual fluid (HU)
1	S	10	17	50	21	25
2	SF	11	30	83	None	None
3	S	12	18	58	12	7
4	S	18	36	94	7	13
5	S	27	30	91	10	5
6	S	7	40	106	None	None
7	SF	16	25	70	22	29
8	S	13	20	87	None	None
9	D	25	31	88	None	None
10	SF	10	57	83	None	None
11	R	10	28	78	4	6
12	R	30	46	97	7	11
13	C	15	50	83	5,6	4
14	S	10	32	65	11	16
15	RS	9	26	50	21	25

additional cost and contrast material related adverse reactions. To our knowledge, there is only one study specifically addressing the effect of intravenous contrast material on the reader confidence and diagnostic accuracy in the detection of colorectal polypoid lesions [11]. This study concluded that the use of intravenous contrast material significantly improved the ability of CT colonography to depict medium-sized polyps in suboptimally prepared colons. Enhancement of colorectal carcinomas have been previously observed and mentioned in prior studies investigating the accuracy of CT in staging colorectal neoplasms [12, 13]; however, since non-contrast scans were not obtained in these studies, pre-contrast CT attenuation values of these lesions and quantitative data about their enhancement could not be acquired. The aims of this study were to calculate the CT attenuation values of colorectal benign and malignant lesions before and after intravenous contrast administration, and to investigate whether contrast enhancement of these lesions can be potentially used for differentiation from residual fluid in the colon.

Materials and methods

Patients who are at high risk to have colorectal cancer (family history of colorectal cancer or multiple polyps, positive occult blood test, history of adenomatous polyps or cancer, age >50 years) were recruited to undergo CT colonography. A total of 89 examinations were performed. All patients with polypoid lesions detected on CT colonography were included in the study. All of these polypoid lesions were confirmed by either same-day conventional colonoscopy or surgery. Pathologic proof of each lesion was obtained.

Technique of CT colonography

All patients received a standard colonoscopy bowel preparation consisting of 2 days of liquid diet prior to examination 90 ml sodium phosphate (Fleet fosfo-soda, Kozmed) preparation taken the evening before the examination.

The CT colonography examination was performed according to a standard protocol. Patients were placed in the right lateral decubitus position on the CT table and a 14-F Foley catheter was inserted rectally. Patients were then turned supine and room air was gently insufflated into the colon to the patient tolerance. One milligram of Buscopan was administered intravenously to allow optimal colonic distension, minimize peristaltism, and alleviate spasm. A standard CT scout image was obtained in the supine position to assess the degree of colonic distension. Images were obtained with the patient first in the supine position and then in the prone position, with reinsufflation as needed based on the scout image. Prone CT images were obtained after administration of 150 ml iohexol (Omnipaque, Opakim) or iopromid (Ultravist, Schering) at a rate of 3–4 ml/s after a delay of 70 s.

All CT examinations were performed using a helical CT scanner (Philips Tomoscan AVE1). Images were acquired using a 5-mm collimation, pitch of 1.5, reconstruction index of 2.5 mm, 110 kVp, 125 mA, and a 512×512 matrix. A single breath-hold acquisition was used when possible to cover the entire colon.

The CT data was then transferred to an independent work station (Philips Easy Vision). Each volumetric data set was analyzed by two radiologists. Magnified axial supine and prone images were viewed in a cine mode by using both soft tissue windows (level=50 HU, width=400 HU) and lung windows (level=–500 HU, width=–1250 HU). Multiplanar reformation and 3D volume-rendered CT colonography was used only for problem solving in areas of bowel that could not be confidently evaluated by axial images.

The number, size, and localization of polyps and masses were recorded by one radiologist (A.O.) who is experienced in abdominal imaging. Nineteen benign polyps in 14 patients and 21 colorectal carcinomas in 18 patients were detected by CT colonography. Twelve patients had single carcinoma lesion and 7 patients had single polyps. Other patients (n=8) had multiple lesions including multiple polyps (n=2), multiple cancer (n=1), and simultaneous polyps and cancer lesions (n=5). Size, localization, and histopathologic diagnosis of the detected lesions are summarized in Tables 1 and 2. Histopathologic diagnosis was confirmed by colonoscopic biopsy in 11 benign polyps and by surgery in 8 benign polyps. All of the patients with colorectal carcinomas underwent surgical resection and pathologic diagnosis was made from the

Table 2 Size, localization, and pre- and postcontrast CT attenuation values of carcinoma. *HU* Hounsfield units, *S* sigmoid colon, *D* descending colon, *R* rectum, *RS* rectosigmoid colon, *HF* hepatic flexura, *SF* splenic flexure

Lesion no.	Localization	Size (mm)	Precontrast CT attenuation of carcinoma (HU)	Postcontrast CT attenuation of carcinoma (HU)	Precontrast CT attenuation of residual fluid (HU)	Postcontrast CT attenuation of residual fluid (HU)
1	S	40	55	84	None	None
2	D	50	50	83	None	None
3	D	30	51	90	21	16
4	R	50	45	101	9	1
5	R	35	41	69	None	None
6	RS	70	36	76	6	7
7	S	30	48	89	None	None
8	D	40	41	99	6	5
9	D	25	43	87	None	None
10	HF	70	37	85	None	None
11	S	50	31	83	4	6
12	HF	50	45	98	16	10
13	R	25	48	106	34	22
14	S	50	43	99	16	7
15	RS	150	48	88	40	30
16	S	30	23	80	5	11
17	R	30	45	97	33	25
18	R	40	38	90	17	16
19	R	30	37	100	17	16
20	S	40	45	102	17	18
21	SF	50	44	98	12	7

surgical specimen. The presence of detected lesions was correlated with the results of conventional colonoscopy and surgery. Histopathologic outcome was obtained for each lesion.

Data analysis

The CT attenuation value measurements from the polypoid lesions were acquired retrospectively by two radiologists (A.O. and V.G.) by consensus reporting. Since this was a retrospective study, approval from the local ethics committee and informed consent from patients specifically for this study were not obtained. The CT attenuation value of each lesion larger than 5 mm in diameter was measured both in the non-contrast (supine) and contrast-enhanced (prone) images. Three lesions smaller than 5 mm in 2 patients were excluded since the partial-volume effect did not allow an accurate attenuation measurement. Attenuation of the 1.5-cm lipoma in another patient was excluded from the statistical analysis because of its negative value; thus, a total of 15 benign polyps in 11 patients and 21 carcinoma in 18 patients were included in the study group. Attenuation of each lesion was measured by the largest possible region-of-interest circle that did not cause partial-volume averaging between the polyp and surrounding air, colon wall, or pericolonic fat. Three measurements from three different sites of each lesion were made and an average of three measurements were accepted as the CT attenuation value of the lesion. Soft tissue settings (sensitive to contrast enhancement) were used during attenuation measurements. Window settings were adjusted individually for each lesion in order to obtain the best delineation of the lesion from the surrounding tissues. The CT attenuation of the residual fluid in the colon was measured (when present) in both non-contrast and contrast-enhanced images at the same segment of the colon. Mean CT attenuation value of benign polyps and carcinomas were calculated separately for non-contrast and contrast-enhanced images. Mean enhancement of benign polyps, carcinomas, and residual fluid were also calculated. Independent sample test was used to compare the CT attenuation value of benign polyps with colorectal carcinomas (both before and after intravenous contrast). Paired sample test was used to compare the non-contrast and post-contrast attenuation of benign polyps, colorectal carcinomas, and residual fluid.

Results

Density of 15 benign polyps were measured on non-contrast and contrast-enhanced images.

The CT examinations

Mean CT attenuation of benign polyps before and after administration of intravenous contrast was 32.4±3.0 and 78.9±4.4 HU, respectively (Fig. 1). The difference between contrast-enhanced and non-contrast attenuation of polyps was significant (p=0.00). The CT attenuation of all 21 colorectal carcinomas could be measured. Mean CT attenuation of colorectal carcinomas before and after administration of intravenous contrast was 42.6±1.6 HU and 90.7±2.1 HU, respectively (Fig. 2). The difference between contrast-enhanced and non-contrast CT attenuation of polyps was significant (p=0.00). The CT attenuation of the residual fluid could be measured in 25 of 39 patients. Mean CT attenuation of residual fluid before and after administration of intravenous contrast material was 14.6 and 13.8 HU, respectively (Fig. 3). The differ-

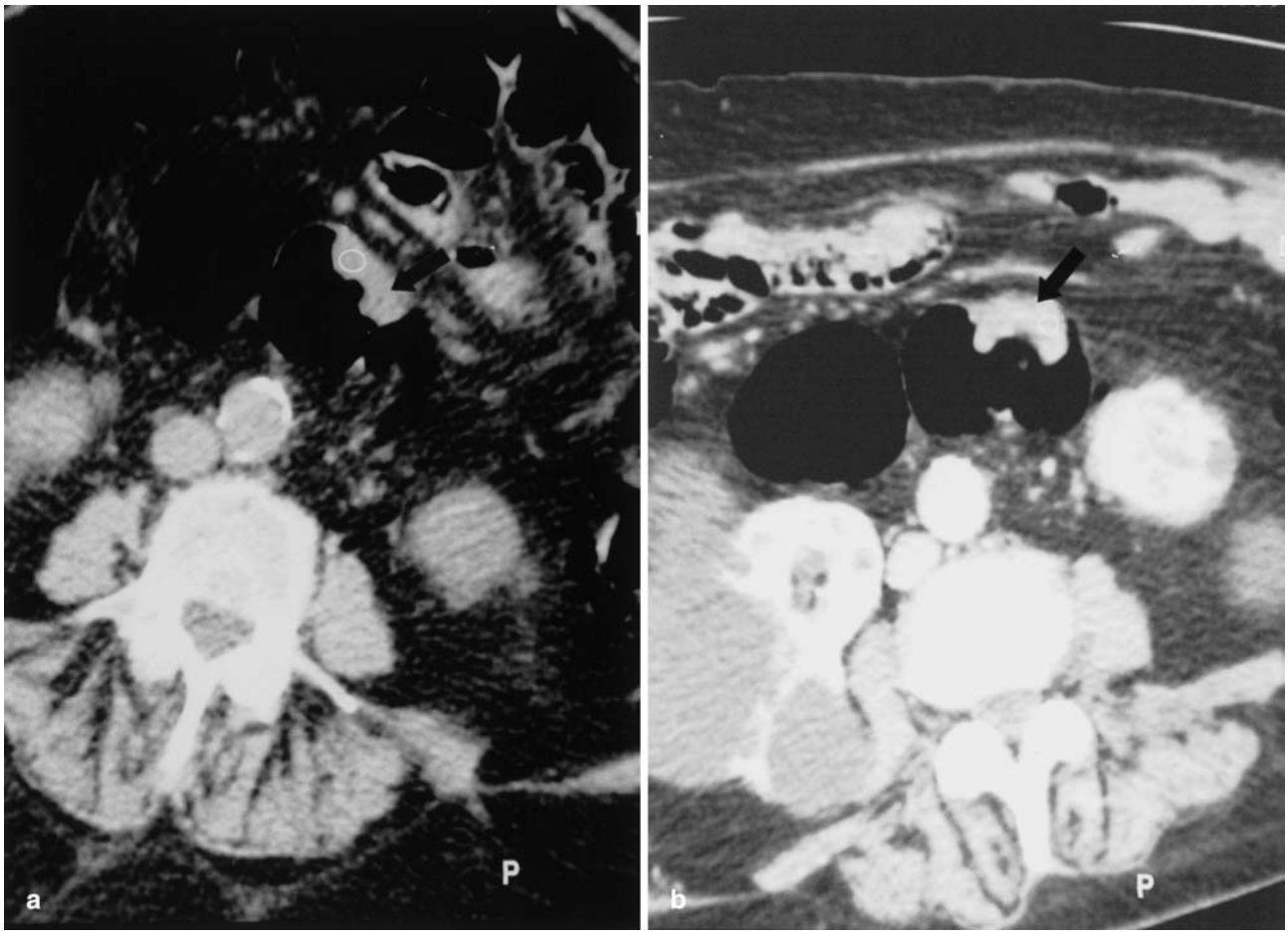

Fig. 1 Benign polyp on the anterior wall of the sigmoid colon (*arrows*) on non-contrast, **a** supine and **b** contrast-enhanced prone axial CT image. Region-of-interest (ROI) circle is on the lesion to measure its CT attenuation which was 30 HU on non-contrast images and 87 HU on post-contrast images

ence between the mean CT attenuation of the residual fluid in the colon before and after intravenous contrast administration was not significant (p=0.29). All of the benign polyps and colorectal carcinomas demonstrated enhancement. Measurement of the CT attenuation was difficult in one sessile polyp compared with other lesions.

When the mean CT attenuation of the benign polyps were compared with the mean CT attenuation of colorectal carcinomas, the difference was significant both before (p=0.007) and after (p=0.024) intravenous contrast.

Mean of the difference between the attenuation value measurements obtained before and after contrast enhancement for benign polyps and colorectal carcinoma were 46.5±3.78 and 48.1±2.2 HU, respectively. The difference was not significant (p=0.69, t=0.4).

No serious side effect was observed during the CT colonography examination.

Discussion

Use of intravenously administered contrast material during spiral CT pneumocolon was first described by Amin et al. [14]. In that study the authors managed to show the primary colonic neoplasms in all cases as enhancing soft tissue masses. The value of intravenously administered contrast material in the improvement of colorectal polyp detection was investigated in a single study in the literature [11]. In that study intravenous contrast material was administered during prone imaging and was shown to improve reader confidence in the assessment of the colon, improve the bowel wall conspicuity, and enhance the detection of the medium-sized polyps in suboptimally prepared colons. As a conclusion, the authors advised the use of intravenous contrast material during prone scanning in patients with suboptimally prepared colons. Intravenous contrast material (gadolinium) is also administered at MR colonography for depiction of polyps and carcinoma. Luboldt et al. stated that contrast enhancement was found to be evident in all masses greater than 10 mm and most of the 5- to 10-mm lesions [15]. In a more recent study, Lauenstein et al. showed that intravenous injection of gadolinium caused avid enhancement

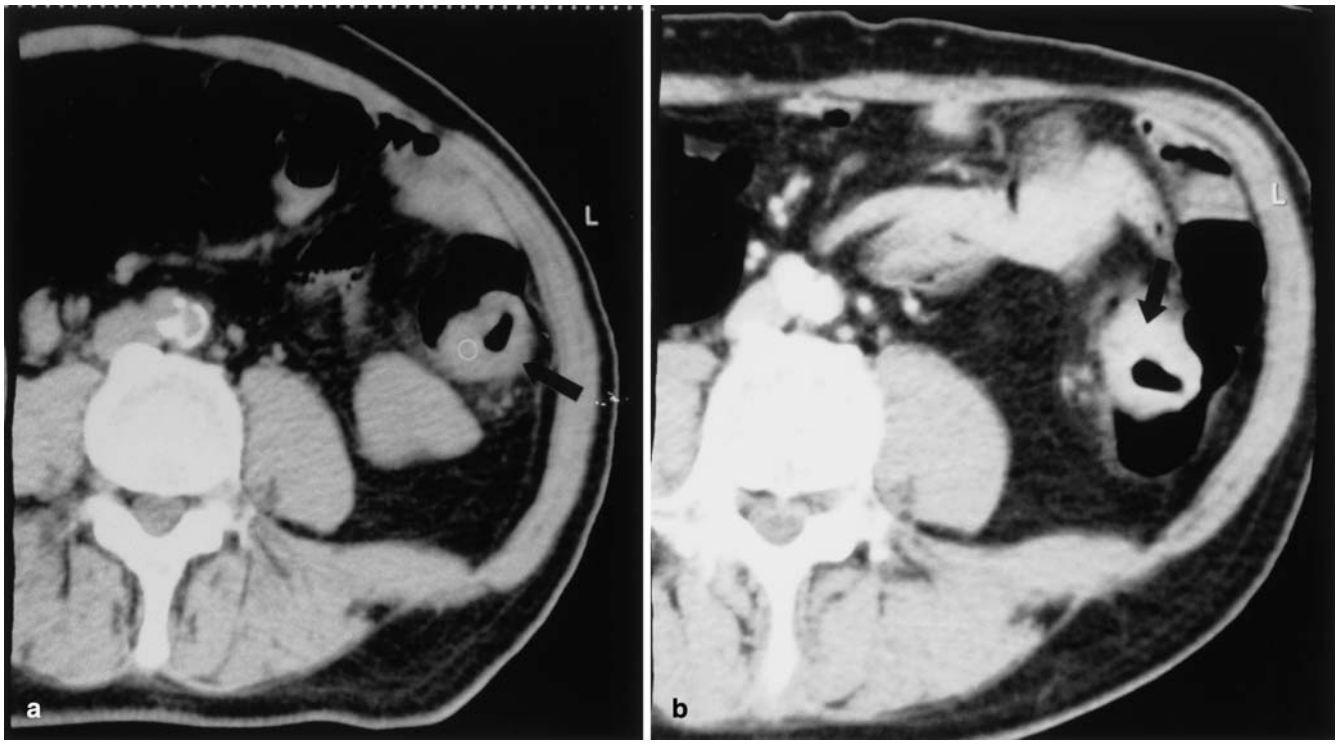

Fig. 2 Adenocarcinoma in the descending colon (*arrows*) on non-contrast, **a** supine and **b** contrast-enhanced, prone axial CT image. The ROI circle is on the lesion to measure its CT attenuation which was 51 HU on non-contrast images and 90 HU on post-contrast images

of both lesions and also the colonic wall [16]. The rationale of administering intravenous contrast during CT colonography is based on the common observation that colorectal polyps and carcinomas enhance. In two different studies performed by Harvey et al. [12] and Hundt et al. [13], helical CT showed all carcinomas of the colon as enhancing masses; however, in both of these studies, only post-contrast attenuation of the lesions were measured and pre-contrast scans were not obtained. To our knowledge, CT measurements of benign and malignant lesions before and after contrast enhancement and comparison with residual colonic fluid have not been previously reported.

In our study we demonstrated that both benign polyps and colorectal carcinomas enhanced significantly after intravenous contrast material administration, whereas retained fluid did not show any enhancement. Another interesting and unexpected finding in our study was the significantly higher CT attenuation value of the colorectal carcinomas compared with benign polyps. This may be due to the small number of lesions in each group rather than a true difference, and its validity needs to be evaluated in larger series. Similar to our results, Harvey et al. [12] measured CT attenuation of 38 colorectal carcinoma lesions following IV contrast and found mean CT attenuation value of 83.7 HU, which was higher (although not significantly) than the mean attenuation of various benign lesions in their series (including polyps, diverticular stricture, ischemic stricture). In another study Hundt et al. [13] did not compare the mean post-contrast CT attenuation of colorectal carcinomas with benign lesions; however, their CT attenuation values for post-contrast colorectal carcinomas were also in the range between 84.8 and 122.5 HU. Although the difference between the mean CT attenuation values benign polyps and carcinoma lesions was significant in our data, the clinical relevance and use of this difference are questionable. Because of the many overlapping attenuation values in each group, it seems very difficult (if even possible) to define a threshold attenuation value which enables the differentiation of these lesions. We think investigation of CT attenuation values and enhancement pattern of colorectal lesions in larger series is necessary to reach more certain results about the use of these parameters in characterization of these lesions. In our CT colonography protocol, the collimation was 5 mm and reconstruction interval was 2.5 mm. Measurement of the CT attenuation of the polyps smaller than 5 mm would not be accurate due to partial-volume effect between the lesion and surrounding air. This is why we excluded these lesions from our study group. We think this finding correlates well with Morrin's study which did not show any improvement in detection of small polyps (<5 mm)

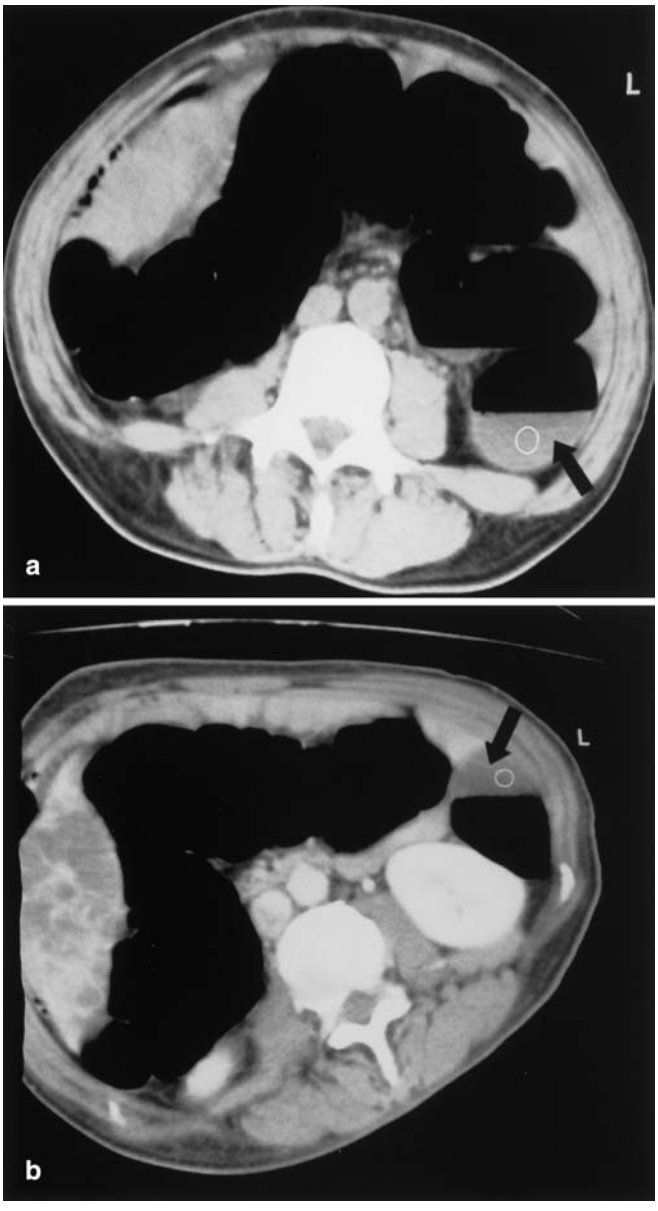

Fig. 3 Retained fluid in the colon (*arrows*) in CT colonography. The CT attenuation was measured on non-contrast, **a** supine and **b** contrast-enhanced, prone images from the fluid at the same segment of the colon. The CT attenuation was 17 HU on non-contrast images and 16 HU on contrast-enhanced images

after contrast enhancement [11]. In small polyps it is extremely difficult, if even possible, to appreciate enhancement both by observation and also quantitatively. With the utilization of thinner collimation and reconstruction interval by multi-detector scanners, we assume that it may be possible to measure the CT attenuation values of lesions smaller than 5 mm. Another potentially difficult lesion for observation of the enhancement is the sessile polyp. In our series there was only one sessile polypoid lesion. Although it was difficult to delineate the lesion from the surrounding wall and air, measurement of the density of the lesion could be possible on magnified axial images.

Another important issue to consider is the delay time after administration of contrast material. In our study we preferred a delay time of 70 s which is the optimum scanning time for the liver. Instead, Morrin et al. chose a delay time of 45 s in their study [11]. Hundt et al. [13] measured CT attenuation of 37 colorectal carcinomas in both arterial (30-s delay) and portal venous phase (70-s delay), and concluded that arterial phase was superior for local tumor staging and portal venous phase was superior for lymph node assessment. Our results suggest that a delay of 70 s allows both detection of the enhancement of polyps and colorectal carcinoma and also evaluation of the liver for possible focal lesions.

In our study in most cases the amount of residual fluid was minimal, and with the help of prone and supine scanning we did not have cases where fluid and lesions were not distinguishable. In most cases small amount of residual fluid had an air--fluid level and moved to the dependent surface during the prone scanning. Again, since fecal material was not present in any of the cases, we did not experience the advantage of IV contrast in differentiation of neoplasms from feces; however, we assume that increased density after IV contrast will help differentiation from residual colonic material especially in cases with suboptimal bowel cleansing as suggested by Morrin et al. [11].

Conclusion

In conclusion, our findings show that colorectal benign polyps and carcinomas show enhancement after intravenous administration of contrast material. This feature may be helpful in differentiating them from residual fluid in the colon. Further studies with larger numbers of patients, aiming to investigate the CT attenuation and contrast enhancement pattern of colorectal lesions, may be helpful for better characterization of these lesions.

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