Eur Radiol (2004) 14:763–767
DOI 10.1007/s00330-004-2244-1

John F. Bruzzi
Alan C. Moss
Darren D. Brennan
Padraic MacMathuna
Helen M. Fenlon

Colonic surveillance by CT colonography using axial images only

Received: 17 July 2003
Revised: 16 December 2003
Accepted: 5 January 2004
Published online: 19 February 2004

J. F. Bruzzi · D. D. Brennan
H. M. Fenlon (✉)
Department of Radiology,
Mater Misericordiae Hospital,
Eccles Street, Dublin 7, Ireland
e-mail: hfenlon@eircom.net
Tel.: +353-1-8032274

A. C. Moss · P. MacMathuna
Department of Gastroenterology,
Mater Misericordiae Hospital,
Eccles Street, Dublin 7, Ireland

Abstract Patients at increased risk of colon cancer require strict colon surveillance. Our objective was to establish the efficacy of 2D axial CT colonography as a surveillance test when performed in routine clinical practice. Eighty-two patients at increased risk of colon cancer underwent CT colonography followed by conventional colonoscopy on the same morning. CT colonography studies were performed on a four-ring multidetector CT scanner (100 mAs, 120 kVp, 4×2.5 collimation) and were interpreted by two radiologists using 2D axial images only. Results were correlated with findings at colonoscopy. Note was made of subsequent histology reports from polypectomy specimens. A total of 52 polyps were detected at colonoscopy. Using 2D axial images alone, with no recourse to 2D multiplanar or 3D views, the sensitivity of CT colonography was 100, 33 and 19% for polyps larger than 9, 6–9 and smaller than 6 mm, respectively. Per-patient specificities were 98.8, 96 and 81.5%, respectively. Twenty-nine percent of polyps smaller than 1 cm were adenomatous and there were no histological features of severe dysplasia. CT colonography is a useful colon surveillance tool for patients at increased risk of colon cancer. It has a high specificity for identifying patients who should proceed to colonoscopy and polypectomy, while allowing further colon examination to be deferred in patients with normal studies. Using 2D axial images only, CT colonography can be performed as part of the daily CT workload, with a very low rate of referral for unnecessary colonoscopy.

Keywords CT colonography · Colon surveillance · Colon cancer · Colonic polyps · Colonoscopy

Introduction

Certain patients are at increased risk of colon cancer. These include patients with a history of colonic neoplasia, those with a strong family history of colon cancer at a young age [1–4], and patients with inflammatory bowel disease [5]. Colonic surveillance in such patients can prevent colon cancer [6, 7]. Current guidelines recommend that surveillance of these patients is performed by total colon examination every 3–5 years with colonoscopy [6–8]. Other methods of surveillance have been criticised for their poor sensitivity and specificity [9, 10], and until recently there has been no viable alternative to colonoscopy for total colon examination.

The recent development of CT colonography introduced a new technique for examining the entire colon with a high sensitivity for polyps larger than 1 cm [11–16]. To date, most researchers have used a combination of axial CT images supplemented by multiplanar (MPR) and/or 3D reconstructions as necessary for interpretation of CT colonography studies. The need to generate MPR and/or 3D images increases the complexity of CT colonography in terms of time and the operator experience required. With the advent of thin-section multi-

slice CT acquisition, it is our experience that additional post-processing of the dataset is rarely required, thereby allowing CT colonography studies to be read in a timely manner, as part of the normal CT workload, by a wide range of radiologists. The purpose of our study was to evaluate the potential use of CT colonography as a primary surveillance tool in a population at increased risk of colonic neoplasia using this simple and rapid technique of axial image interpretation only.

Patients and methods

A total of 82 patients (M:F, 39:43; mean age, 57 years; range 26–81 years) were enrolled into the study. Eligible patients included those who required surveillance following polypectomy of colonic adenomas (*n*=34), those with a history of colon cancer (*n*=7), and those with a strong family history of colon cancer (*n*=41). The last group comprised patients with at least one first-degree relative with a history of colon cancer under the age of 60 years or two second-degree relatives with a history of colon cancer under 50 years of age. The study was approved by the ethics review board at our institution and informed written consent was obtained from all patients.

Patients underwent CT colonography followed by conventional colonoscopy on the same morning. Bowel-cleansing regimens comprised either 4 l of a polyethylene glycol solution (Klean-prep, Helsinki Birex Pharmaceuticals, Dublin, Ireland) or a phospho-soda preparation (Fleet Prep, De Witt International, David Mayers Ltd, Dublin, Ireland). CT colonography was performed by a radiologist in every case. Following insertion of a soft-tipped enema tube, the colon was insufflated with air using a hand pump up to maximum patient tolerance. A smooth muscle spasmolytic was not routinely used. The degree of distension was assessed on the CT scout image, and further air insufflated if necessary.

CT colonography scanning was performed on a four-ring multidetector CT scanner (4 Plus VolumeZoom, Siemens, Erlangen, Germany) using the following parameters: 100 mAs, 120 kVp, 4×2.5 mm collimation and 12.5 mm table feed (pitch of 1.25). Scans were reconstructed with a slice width of 3 mm and a slice increment of 1.5 mm. All patients were scanned firstly in the supine position followed by prone scanning, with further gentle insufflation of air before the prone scan. Intravenous contrast medium was not used. Following CT colonography examination, patients proceeded to the GI endoscopy unit for their scheduled conventional colonoscopy.

CT colonography studies were interpreted separately by two radiologists (HF and JB) on a remote workstation using 2D axial images only. Magnified images were reviewed using the "colon-tracking" technique described elsewhere [17], moving manually from rectum to caecum in a retrograde fashion without use of cine mode. No recourse was made to 2D MPR reconstructions or to 3D endoluminal views. All images were examined both at lung (C/W: −200/1,500) and soft tissue (C/W: +10/400) window settings (Figs. 1, 2, 3). Both radiologists had read more than 50 CT colonography scans prior to commencing the study. Where a discrepancy arose in their interpretation of a scan, the relevant images were reviewed jointly a third time and a consensus was reached.

Polyps detected at CT colonography were documented with respect to the segment location and size. For the purposes of denoting segment location, the colon was divided into six segments: the rectum, sigmoid colon, descending colon, transverse colon, ascending colon and caecum. Polyps were measured using electronic callipers at lung window settings and the maximum diameter of the polyp was recorded. Results from CT colonography were sub-

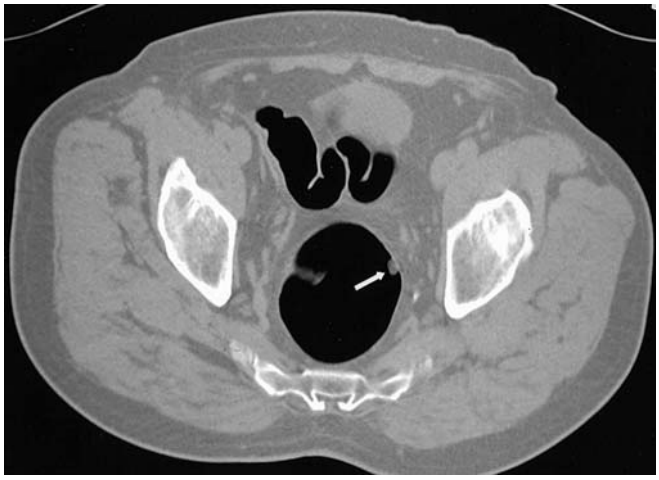

Fig. 1 A small polyp, less than 6 mm in size, is demonstrated in the rectum (*arrow*). Optimal distension of the colon facilitates distinction between polyps and haustral folds

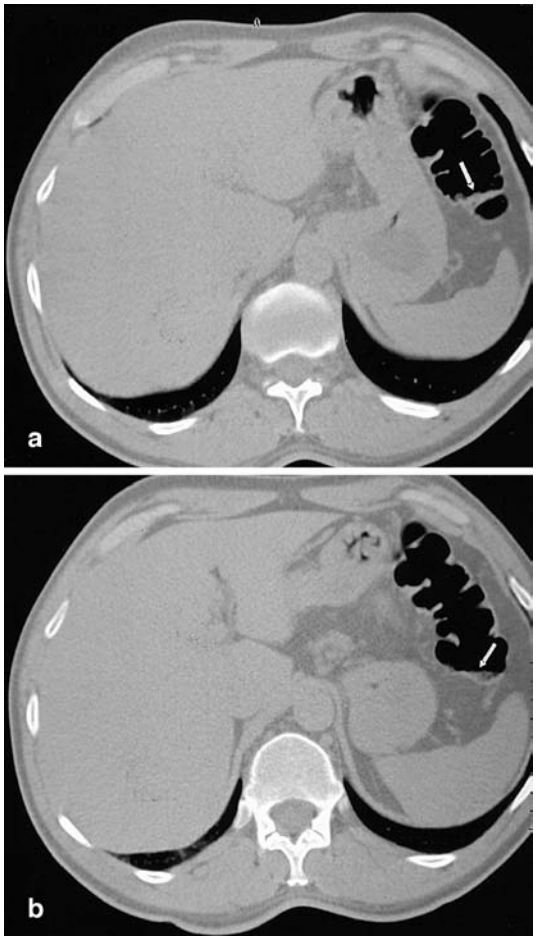

Fig. 2a, b Retained faecal contents. **a** Residual faecal material (*arrow*) can often be confused with polyps or thickened folds. **b** The presence of air within the abnormality (*arrow*), best appreciated on 2D images at lung window settings on this slightly more caudal image, confirms the benign nature of the abnormality

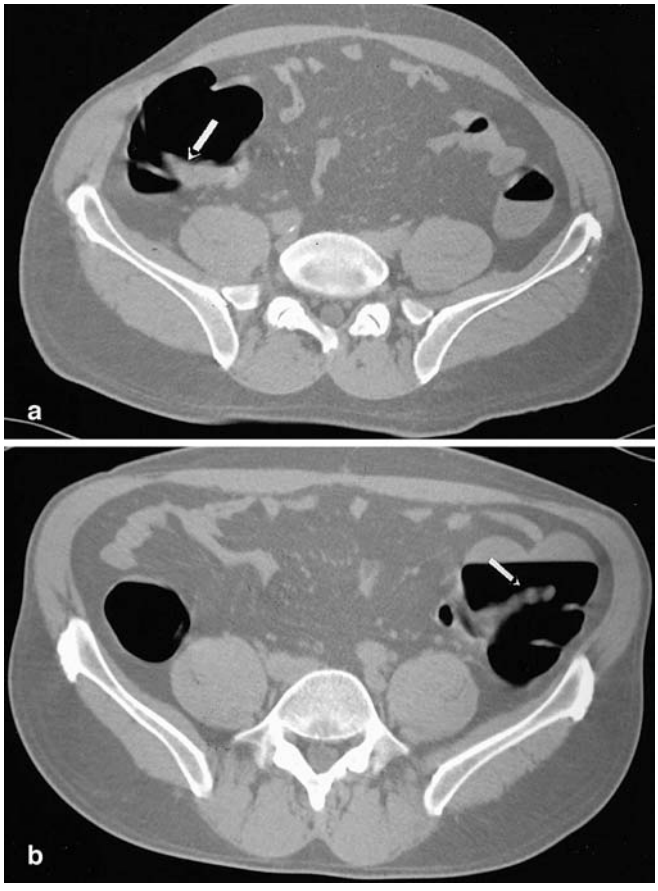

Fig. 3a, b The value of prone scanning. Caecal polyp. **a** On this supine axial image of the caecum, the presence of retained fluid hampers detection of a submerged caecal polyp. A bulbous caecal valve is a common finding and distinction from a caecal polyp can be troublesome. **b** Re-scanning with the patient in the prone position results in a redistribution of retained fluid and permits easier identification of the underlying caecal polyp

sequently compared with findings at conventional colonoscopy to enable a determination of sensitivity and specificity. A true-positive finding was recorded if a polyp found at CT colonography corresponded to a polyp of similar size and shape seen at conventional colonoscopy either in the same segment or in a contiguous section of an adjacent segment. Sensitivity of CT colonography was calculated both on a per-polyp and a per-patient basis. Specificity was calculated on a per-segment and on a per-patient basis, referring to the number of colonic segments and patients, respectively, without any polyps or masses. Histology reports from polypectomy specimens were also reviewed to allow an assessment of the prevalence of adenomatous polyps and the degree of neoplasia and dysplasia in removed specimens.

Results

Eighty-two patients consented to undergo both CT colonography and conventional colonoscopy. Colonoscopy was complete in 72 patients (88%), yielding a

Table 1 Characteristics of polyps detected at colonoscopy in study population at increased risk of colon cancer

Polyp size	No. of polyps	Adenomatous polyps	Hyperplastic polyps	No. of patients with polyps (*n*=82)
>9 mm	3	3 (100%)	0 (0%)	2 (2%)
6–9 mm	6	3 (50%)	3 (50%)	6 (7%)
<6 mm	43	11 (26%)	32 (74%)	27 (33%)

Table 2 Diagnostic performance of CT colonography compared to colonoscopy as a surveillance tool in a population at increased risk of colon cancer

Polyp size	Per-polyp sensitivity (%)	Per-patient sensitivity (%)	Per-segment specificity (%)	Per-patient specificity (%)
>9 mm	100	100	99.8	100
6–9 mm	33	33	98.7	95
<6 mm	19	32	94	83

total of 465 segments that were visualised both at conventional colonoscopy and at CT colonography. For the purposes of calculating polyp specificity per-segment, only segments that were examined by both modalities were considered (i.e. 465 segments). Patients who did not undergo complete colonoscopy were not included in the calculation of per-patient sensitivity and specificity.

A total of 52 polyps were detected at conventional colonoscopy. There were 43 polyps smaller than 6 mm, 6 polyps of 6–9 mm, and 3 polyps larger than 9 mm (Table 1). Polyps were present in 34 patients (41%), with many patients having more than one polyp. Colonoscopy did not detect any polyps in 48 patients (59%). A total of 80 patients (98%) did not have any polyps or masses larger than 9 mm.

CT colonography detected all polyps larger than 9 mm. The sensitivity of CT colonography was 100, 33 and 19% for polyps larger than 9, 6–9 and smaller than 6 mm, respectively. Per-segment specificity was 99.8, 98.7 and 94%, respectively. On a per-patient basis, the sensitivity of CT colonography was 100, 33 and 32% for patients with polyps larger than 9, 6–9 and smaller than 6 mm, respectively. The respective per-patient specificity was 100, 95 and 83% (Table 2).

CT colonography correctly identified 100% (72/72) of patients without polyps larger than 9 mm. There was only one false-positive finding of a polyp larger than 9 mm at CT colonography (one rectal polyp which could not be identified on repeat colonoscopy, and was thought to represent a bulbous fold). Retrospective analysis of this abnormality using 2D MPR and 3D endoluminal views failed to clarify the lesion and would not have influenced inter-

pretation of the 2D axial views. This patient did not have a complete colonoscopy and was therefore not included in calculation of per-patient specificity.

Twenty-nine percent of all polyps smaller than 1 cm were adenomatous, and most of these (79%) were smaller than 6 mm. Of the 43 polyps smaller than 6 mm detected at conventional colonoscopy, 42 (98%) were retrieved. Of these, 11 were adenomatous (26%) and 31 were hyperplastic (74%). All six of the 6–9-mm polyps detected at colonoscopy were biopsied and retrieved. Three (50%) of these were adenomas and three (50%) were hyperplastic or consisted of inflammatory mucosal tags.

There were no histological features of severe dysplasia in any of the polyps retrieved for histological examination. Interpretation times of CT colonography studies were not formally recorded but most cases were read by both reviewers in under 10 min.

Discussion

Colon cancer arises in a predictable fashion from precursor adenomatous polyps. In an average-risk population approximately 50% of people over the age of 50 will have colonic polyps, with half of these being adenomas [9]. Patients with adenomatous polyps are deemed to be at increased risk of colon cancer, and will require regular colonic surveillance following polypectomy according to current guidelines [8]. However, compared to the small percentage of patients at high risk of colon cancer (those with previous colon cancer or those with a genetic predisposition), patients with only one or two small tubular adenomatous polyps are at only slightly increased risk of developing significant pathology in the early post-polypectomy period. Such patients comprise a significant proportion of the surveillance workload for colonoscopists, and yet most of these surveillance examinations will be normal. Recently published screening and surveillance guidelines have modified previously existing recommendations, stressing that surveillance strategies should now be stratified according to risk, such that patients with adenomas larger than 1 cm or with multiple adenomas should undergo colonoscopy every 3 years, while surveillance for patients with only one or two small tubular adenomatous polyps can be deferred to every 5 years, or even longer [8].

CT colonography is a non-invasive test with high sensitivity and specificity for polyps larger than 1 cm in average-risk to high-risk patients. Although it has not been incorporated into existing surveillance recommendations, CT colonography is of potential benefit to increased-risk patients by virtue of its strong negative predictive value. Previous studies have demonstrated improved detection and characterisation of colonic polyps using 2D MPR and 3D endoluminal views in addition to 2D axial views [18–21]; however, it has been our experience that reformatted 2D and 3D images prolong interpretation times and are rarely required for the interpretation of CT colonography datasets.

In our study, we were able to demonstrate that using the interpretation of 2D axial images only, CT colonography had a high sensitivity and specificity for lesions larger than 1 cm. The technique also had a high negative predictive value for such polyps (100%), which would have safely allowed avoidance of a colonoscopy for patients with normal colons and deferred further colon examination for a number of years.

Sensitivity for polyps smaller than 1 cm was poorer. However, only 29% of polyps smaller than 1 cm in our study were adenomas, and most of these (79%) were smaller than 6 mm, of doubtful clinical significance. None of these polyps contained any histological features of severe dysplasia. In our own clinical practice, it is our policy to report only small polyps for which the interpreter has a high degree of diagnostic confidence in order to minimise unnecessary referral for colonoscopy, leading to a high specificity for these lesions. It seems reasonable to presume that very few of these small polyps would pose any significant mortality risk in the interval before their next surveillance examination, by that time they should be of a size that would be readily detectable.

If CT colonography is to become a successful colon surveillance tool it must be shown to be not only an accurate technique, but also one that is widely available. The use of 3D and MPR images in CT colonography requires dedicated software and familiarity with these image-manipulation techniques. It has been recommended that radiologists be trained in such techniques prior to interpreting CT colonography studies in a clinical setting [22]. In a busy department staffed by general radiologists, it may not be practical to devote the effort to including CT colonography in the routine work list. On the other hand, 2D axial CT images are immediately familiar to most radiologists and the method of "lumen tracking" for interpreting the 2D axial image dataset is a readily accessible technique [17].

CT colonography performed in the manner we describe, using only 2D axial images, represents a test that, like the barium enema, can be learned by most radiologists and should be available wherever there is a multislice CT scanner. Studies can be readily performed and interpreted by general radiologists within routine CT work lists. CT colonography is generally well tolerated by patients [23–25] and, in the context of a surveillance programme, patient compliance could be expected to be higher than for conventional colonoscopy. In addition, recent experience with low-dose scanning indicates that regular surveillance of patients using ultra-low-dose CT colonography should be possible without significantly compromising polyp detection [26].

Limitations of our study include the relatively small number of polyps present that were larger than 6 mm, despite the fact that we included patients at high risk of colonic cancer in our study, such as those with a strong

family history of colon neoplasia or a personal history of colon cancer. Such patients were included in order to ensure a polyp-rich surveillance population. Nevertheless, despite the small number of polyps, we were still able to demonstrate a high negative predictive value for CT colonography.

By helping to triage patients into those for whom colonoscopy can provide a major survival benefit and those in whom further colon examination can be deferred, CT colonography represents a powerful tool that deserves inclusion in colon surveillance recommendations for patients at increased risk of colon cancer.

References

1. Bonelli L, Martines H, Conio M, Bruzzi P, Aste H (1998) Family history of colorectal cancer as a risk factor for benign and malignant tumors of the large bowel: a case-control study. Int J Cancer 41:513–517
2. Fuchs CS, Giovannucci EL, Colditz GA, Hunter DJ, Speizer FE, Willett WC (1994) A prospective study of family history and the risk of colorectal cancer. N Engl J Med 331:1669–1674
3. Slattery ML, Kerber RA (1994) Family history of cancer and colon cancer risk: the Utah Population Database. J Natl Cancer Inst 86:1618–1626
4. St John DJ, McDermott FT, Hopper JL, Debney EA, Johnson WR, Hughes ES (1993) Cancer risk in relatives of patients with common colorectal cancer. Ann Intern Med 118:785–790
5. Ekbom A, Helmick C, Zack M, Adami HO (1990) Ulcerative colitis and colorectal cancer. A population-based study. N Engl J Med 323:1228–1233
6. Winawer SJ, Zauber AG, Ho MN, O'Brien MJ, Gottlieb LS, Sternberg SS, Waye JD, Schapiro M, Bond JH, Panish JF (1993) Prevention of colorectal cancer by colonoscopic polypectomy. N Engl J Med 329:1977–1981
7. Winawer SJ, Zauber AG, O'Brien MJ, Ho MN, Gottlieb L, Sternberg SS, Waye JD, Bond J, Schapiro M, Stewart ET et al (1993) Randomized comparison of surveillance intervals after colonoscopic removal of newly diagnosed adenomatous polyps. N Engl J Med 328:901–906
8. Winawer S, Fletcher R, Rex D, Bond J, Burt R, Ferrucci J, Ganiats T, Levin T, Woolf S, Johnson D, Kirk L, Litin S, Simmang C, Gastrointestinal Consortium Panel (2003) Colorectal cancer screening and surveillance: clinical guidelines and rationale—update based on new evidence. Gastroenterology 124:544–560
9. Glick S (2000) Double-contrast barium enema for colorectal cancer screening: a review of the issues and a comparison with other screening alternatives. Am J Roentgenol 174:1529–1537
10. Winawer SJ, Stewart ET, Zauber AG, Bond JH, Ansel H, Waye J, Hall D, Hamlin JA, Schapiro M, O'Brien MJ, Sternberg SS, Gottlieb LS for the National Polyp Study Work Group (2000) A comparison of colonoscopy and double-contrast barium enema for surveillance after polypectomy. N Engl J Med 342:1766–1772
11. Fenlon HM, Nunes DP, Schroy PC III, Barish MA, Clarke PD, Ferrucci JT (1999) A comparison of virtual and conventional colonoscopy for the detection of colorectal polyps. N Engl J Med 341:1496–1503
12. Fletcher JG, Johnson CD, Welch TJ, MacCarty RL, Ahlquist DA, Reed JE, Harmsen WS, Wilson LA (2000) Optimization of CT colonography technique: prospective trial in 180 patients. Radiology 216:704–711
13. Laghi A, Iannaccone R, Carbone I, Catalano C, Di Giulio E, Schillaci A, Passariello R (2002) Detection of colorectal lesions with virtual computed tomographic colonography. Am J Surg 183:124–131
14. Yee J, Akerbar GA, Hung RK, Steinauer-Gebauer AM, Wall SD, McQuaid KR (2001) Characteristics of CT colonography for the detection of colorectal neoplasia in 300 patients. Radiology 219:685–692
15. Morrin MM, Farrell RJ, Kruskal JB, Reynolds K, McGee JB, Raptopoulos V (2000) Utility of intravenously administered contrast material at CT colonography. Radiology 217:765–771
16. Macari M, Bini EJ, Xue X, Milano A, Katz SS, Resnick D, Chandarana H, Krinsky G, Klingenbeck K, Marshall CH, Megibow AJ (2002) Colorectal neoplasms: prospective comparison of thin-section row CT colonography and conventional colonoscopy for detection. Radiology 224:383–392
17. Fenlon HM, Clarke PD, Ferrucci JT (1998) Virtual colonoscopy: imaging features with colonoscopic correlation. Am J Roentgenol 170:1303–1309
18. Macari M, Milano A, Lavelle M, Berman P, Megibow AJ (2000) Comparison of time-efficient CT colonography with two- and three-dimensional colonic evaluation for detecting colorectal polyps. Am J Roentgenol 174:1543–1549
19. Hara AK, Johnson CD, Reed JE, Ehman RL, Ilstrup DM (1996) Colorectal polyp detection with CT colonography: two- versus three-dimensional techniques. Radiology 200:49–54
20. McFarland EG, Brink JA, Pilgram TK, Heiken JP, Balfe DM, Hirseli DA, Weinstock L, Littenberg B (2001) Spiral CT colonography: reader agreement and diagnostic performance with two- and three-dimensional image display techniques. Radiology 218:375–383
21. Dachman AH, Kuniyoshi JK, Boyle CM, Samara Y, Hoffmann KR, Rubin DT, Hanan I (1998) CT colonography with three-dimensional problem solving for detection of colonic polyps. Am J Roentgenol 171:989–995
22. Gluecker T, Meuwly JY, Pescatore P, Schnyder P, Delarive J, Jornod P, Meuli R, Dorta G (2002) Effect of investigator experience in CT colonography. Eur Radiol 12:1405–1409
23. Gluecker TM, Johnson CD, Harmsen WS, Offord KP, Harris AM, Wilson LA, Ahlquist DA (2003) Colorectal cancer screening with CT colonography, colonoscopy, and double-contrast barium enema examination: prospective assessment of patient perceptions and preferences. Radiology 227:378–384
24. Ristvedt SL, McFarland EG, Weinstock LB, Thyssen EP (2003) Patient preferences for CT colonography, conventional colonoscopy, and bowel preparation. Am J Gastroenterol 98:578–585
25. Svensson MH, Svensson E, Lasson A, Hellstrom M (2002) Patient acceptance of CT colonography and conventional colonoscopy: prospective comparative study in patients with or suspected of having colorectal disease. Radiology 222:337–345
26. Iannaccone R, Laghi A, Catalano C, Mangiapane F, Passariello R (2002) Feasibility of ultra-low-dose multislice CT colonography for the detection of colorectal lesions: preliminary experience. Eur Radiol 13:1297–1302