Japanese Journal of Radiology (2020) 38:973–978
https://doi.org/10.1007/s11604-020-00999-1

ORIGINAL ARTICLE

# Factors of incomplete colonoscopy for stenosing colorectal cancer: CT colonography features

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Received: 27 March 2020 / Accepted: 3 June 2020 / Published online: 10 June 2020


## Abstract

**Purpose** The purpose of this study was to examine the relation between computed tomography colonoscopy (CTC) features of colorectal cancer (CRC) and incomplete colonoscopy.

**Materials and methods** The subjects of this retrospective study consisted of 108 patients with advanced CRC (57 men, 51 women; age range, 32–87 years; median, 65 years) who underwent CTC. We compared local CTC features between the groups of complete ($n=74$) and incomplete colonoscopy ($n=34$). We performed a receiver operating characteristic (ROC) analysis to assess a diagnostic performance of CTC features to predict incomplete colonoscopy.

**Results** The cross-sectional area of tumor and stenosis of complete colonoscopy group were significantly smaller and larger than those of incomplete colonoscopy group ($p=0.001$ and $<0.001$). Circumferential tumor extent rate (CER) showed significantly higher in the incomplete colonoscopy group than complete colonoscopy group ($p<0.001$). In the ROC analysis, the cross-sectional area of stenosis showed AUC of 0.916, which was the best to predict incomplete colonoscopy.

**Conclusion** CTC features including larger cross-sectional area of tumor, smaller cross-sectional area of stenosis and 100% CER were significantly associated with incomplete colonoscopy for the patients with CRC.

**Keywords** Colorectal cancer · CT colonography · Colonoscopy

## Introduction

Optical colonoscopy is widely used colorectal cancer (CRC) or polyp screening tool and is recommended as the CRC test before treatment. A complete examination of the colon and rectum is favorable for any screening program, however, incomplete colonoscopy occurs in approximately 10% of cases [1–4]. Previous studies reported that various patient-related factors including age, sex, high or low body mass index, body habitus, bowel preparation, a history of abdominal surgery, colonic loops or angulation, and diverticular disease were associated with incomplete colonoscopy [2, 5–7], and it can be also caused by luminal narrowing of CRC. As a result of incomplete colonoscopy for the patients with CRC, they may miss a chance to diagnose synchronous tumors which prevalence of 1–7% proximal to the stenosing cancer, which may result in secondary surgery [8–16].

Some authors examined the factors related to incomplete colonoscopy using computed tomography colonoscopy (CTC), and concluded that larger diameter of sigmoid colon, colonic elongation, tortuosity, and advanced diverticular disease were associated with incomplete colonoscopy [17–19]. However, it is unclear whether the CTC features of local tumors influence on the incomplete colonoscopy for the patients with CRC.

The purpose of this study was to examine the relation between CTC features of CRC and incomplete colonoscopy.

## Materials and methods

### Study participants

This retrospective study was approved by our institutional review board, and informed consent was waived. From April 2012 to March 2015, 117 consecutive patients with advanced

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CRC (histologically proven adenocarcinoma) evaluated by optical colonoscopy and CTC before treatment at our department were enrolled in this study. For the purpose of this study, cases with cecal lesion ($n=6$) and with poor CTC quality (intestinal collapse, $n=3$) were excluded. There was no case with incomplete colonoscopy due to other reasons such as anatomic factors, adhesion after preoperative status or diverticular disease. There was one case of rectal cancer pathologically proven to invade to bladder after surgery (stage of T4b). All resected CRC were staged according to 8th edition of the UICC TNM Classification. Finally, a total of 108 patients were analyzed in this study. The patients' clinicopathological characteristics are presented in Table 1.

## CT colonography procedures

For each patient, CTC was performed on the same day and within one hour after a colonoscopy using a bowel preparation method utilizing polyethylene glycol. Before the CTC, a single balloon tube was inserted into the rectum by the transanal route, and colonic insufflation with carbon dioxide using a $CO_2$ injector (PROTOCO2L; Bracco, Princeton, NJ, USA) was performed for each patient. The CTC was performed using a 320-slice MDCT (Aquilion One; Canon Medical Systems) with the following parameters: 120 kV, 100–300 mA, beam collimation 1 mm, slice thickness 1 mm, reconstruction interval 1 mm, pitch of 65. All patients underwent both supine and prone scans. The CT scans were performed with a bolus triggered technique; 2 mL/kg of nonionic contrast material (Iopamiron 370; Bayer Health Care, Osaka, Japan) was injected by an automated power injector with three scanning (arterial, portal and delayed phase).

**Table 1** Clinicopathological characteristics

| | Characteristics | Value |
|---|---|---|
| Age (years; median, range) | | 65 (32—87) |
| Sex | Male | 57 |
| | Female | 51 |
| Location | Ascending colon | 16 |
| | Transverse colon | 9 |
| | Descending colon | 4 |
| | Sigmoid colon | 28 |
| | Rectum | 51 |
| TNM category | T2 | 13 |
| | T3 | 73 |
| | T4 | 22 |
| | N0 | 46 |
| | N1 | 37 |
| | N2 | 25 |
| | M0 | 89 |
| | M1 | 19 |
| Stage | I | 6 |
| | II | 38 |
| | III | 46 |
| | IV | 18 |
| Total colonoscopy | Complete | 74 |
| | Incomplete | 34 |

## CT colonography analysis

The CTC data sets (mainly of the patients with supine position but prone for the rectal lesion) were loaded onto a workstation (Synapse Vincent, Fujifilm Medical, Tokyo, Japan). All CTC examinations were reviewed by two board-certified radiologists who had 14- and 7-years' experience of interpreting CTC in consensus. The CRC lesions were identified using the colonoscopy records of the same day as a reference. The readers measured a cross-sectional area of stenosis and tumor on multiplanar reconstruction (MPR). A section of the narrowest cancer canal was chosen as a representative. The cross-sectional area ($mm^2$) of stenosis and tumor on the same section were measured by manual tracing. The readers measured a tumor length (cm), circumferential tumor extent rate (CER, %), and distance from anus (cm) on virtual colon dissection (VCD). A viewing mode of VCD is the three-dimensional (3D) model of the colon virtually unrolled, sliced open, and displayed as a flat 3D rendering of the mucosal surface, similar to a gross pathologic specimen [20]. A maximum length of the tumor on VCD was defined as the tumor length. For the measurement of the CER, the reviewers determined representative section line (normally center) within the tumor, then measured maximal diameters of the tumor and normal mucosa. They calculated the CER according to the following formula: maximal diameter of tumor/maximal diameter of normal mucosa × 100. The absolute value of the maximal tumor diameter was not available for the analyses because of bowel distortion on VCD. The distance from anus was automatically measured when a cursor was placed on the anal side of the tumor on VCD (Fig. 1).

## Statistical analysis

We divided the study cohort into two groups with complete ($n=74$) and incomplete ($n=34$) colonoscopy according to descriptions on the endoscopic records and then compared CTC features between the two groups. The CTC features included cross-sectional area of stenosis and tumor on MPR, and tumor length, CER, number of 100% CER cases, and distance from anus on VCD. Continuous and categoric variables were examined by student t test or Wilcoxon rank sum test (for nonparametric variables) and the $\chi^2$ test or Fisher's exact test. We also performed a receiver operating characteristic (ROC) analysis according to the results above and

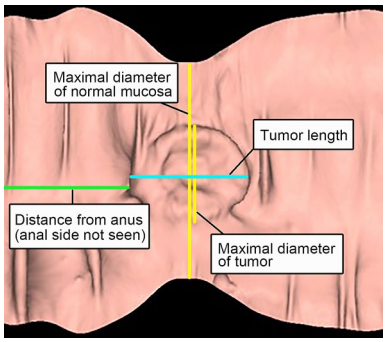


**Fig. 1** Shema of measurement on VCD

calculated the sensitivity, specificity and area under the curve (AUC) to assess a diagnostic performance of those CTC parameters above to predict incomplete colonoscopy. Differences with $p$ values $< 0.05$ were accepted as significant. Statistical analyses were performed using SPSS 21.0 for Windows software.

## Results

Cross-sectional area of tumor and stenosis were significantly different between the two groups ($p = 0.001$ and $< 0.001$) according to the Wilcoxon rank sum test. The cross-sectional area of tumor and stenosis of complete colonoscopy group were significantly smaller and larger than those of incomplete colonoscopy group. CER and number of 100% CER cases were also significantly different between the two groups ($p < 0.001$). Median CER of complete and incomplete colonoscopy group was 45.0% and 100.0%. Accordingly, number of 100% CER cases was lower in complete colonoscopy group (20/74) than in incomplete colonoscopy group (32/34). Tumor length and distance from anus were not significantly different between the two groups (Table 2).

In the ROC analysis, when the optimal cut-off; was set at 457 $mm^2$ for cross-sectional area of tumor, 168 $mm^2$ for cross-sectional area of stenosis and 100% for CER, the sensitivities were 93.9, 96.9 and 94.1%, and the specificities were 45.8%, 79.2% and 73.0, respectively. The cross-sectional area of stenosis showed AUC of 0.916, which was the best to predict incomplete colonoscopy among the three variables (Table 3, Fig. 2). Example of the images of incomplete colonoscopy are shown in Fig. 3.

## Discussion

Our study results showed that larger cross-sectional area of tumor and smaller cross-sectional area of stenosis on MPR were significantly related to incomplete colonoscopy. According to that result, it is speculated that CRC would grow increasing its volume and advancing bowel stenosis. It could finally cause incomplete colonoscopy for the patient with CRC. Park et al. performed CT volumetry for CRC and concluded that tumor volume of CRC showed an incremental trend with T-stage [21]. Yang et al. analyzed the clinicopathologic characteristics of obstructive CRC; the number of cases increased with the increasing level of T category [22].

We examined relationship between incomplete colonoscopy and VCD features in this study and found that incomplete colonoscopy significantly correlated with CER but not with tumor length. Incomplete colonoscopy group included

**Table 3** Results of ROC analysis

| Variables | Cut-off | Sensitivity (%) | Specificity (%) | AUC |
|---|---|---|---|---|
| Area of tumor | 457 $mm^2$ | 93.9 | 45.8 | 0.706 |
| Area of stenosis | 168 $mm^2$ | 96.9 | 79.2 | 0.916 |
| CER | 100% | 94.1 | 73.0 | 0.839 |

*CER* circumferential tumor extent rate, *AUC* area under the curve

**Table 2** CTC features of CRC with complete and incomplete TCS

| | Total colonoscopy | | $p$ value |
|---|---|---|---|
| | Complete ($n = 74$) | Incomplete ($n = 34$) | |
| MPR | | | |
| Area of tumor ($mm^2$; median, range) | 527 (136–2413) | 757 (317–1607) | 0.001 |
| Area of stenosis ($mm^2$, median, range) | 499 (0–2588) | 17 (0–777) | < 0.001 |
| VCD | | | |
| Length (cm; median, range) | 4.5 (1.5–11.9) | 4.5 (1.1–11.2) | 0.419 |
| | | | < 0.001 |
| CER (%; median, range) | 45.0 (13.7–100.0) | 100.0 (35.4—100.0) | < 0.001 |
| Number of 100% CER cases (%) | 20 (27.0) | 32 (94.1) | < 0.001 |
| Distance from anus (cm; median, range) | 23.0 (1.0–212.3) | 36.3 (2.4–215.3) | 0.214 |

MPR multiplanar reconstruction, VCD virtual colon dissection, CER circumferential tumor extent rate

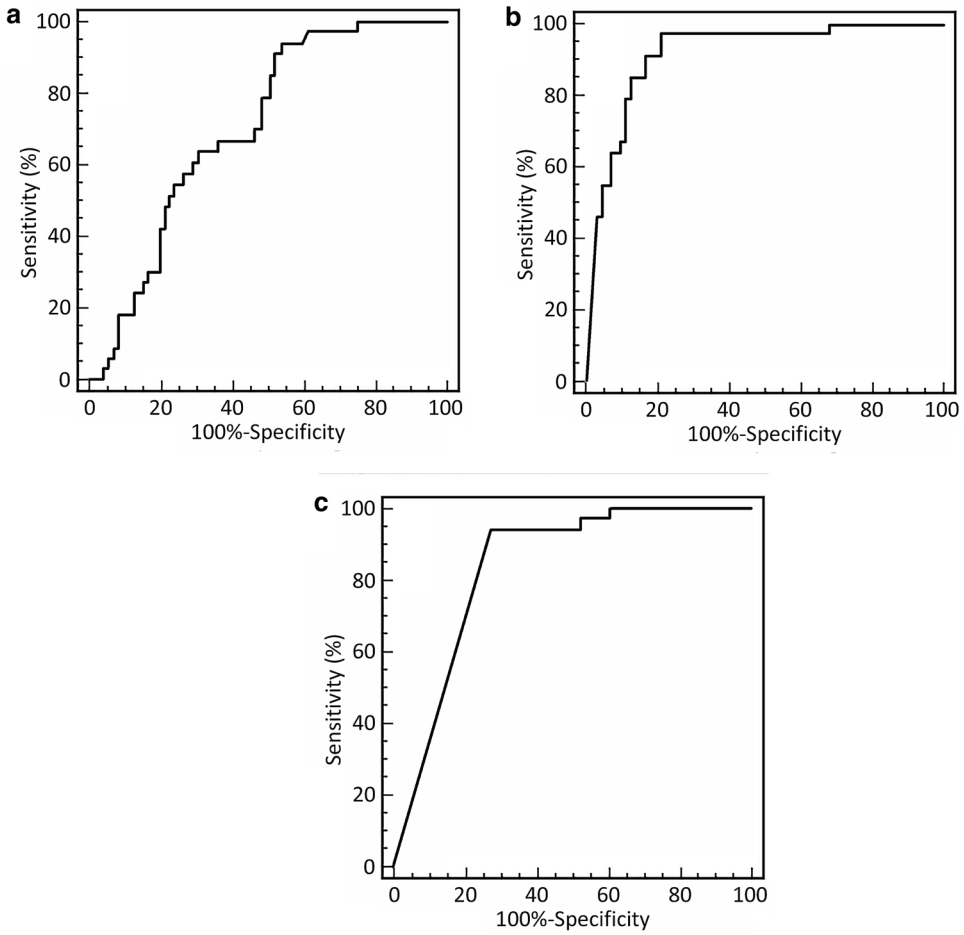


**Fig. 2** ROC curves for diagnosing incomplete colonoscopy (**a** cross-sectional area of tumor, **b** cross-sectional area of stenosis, **c** CER)

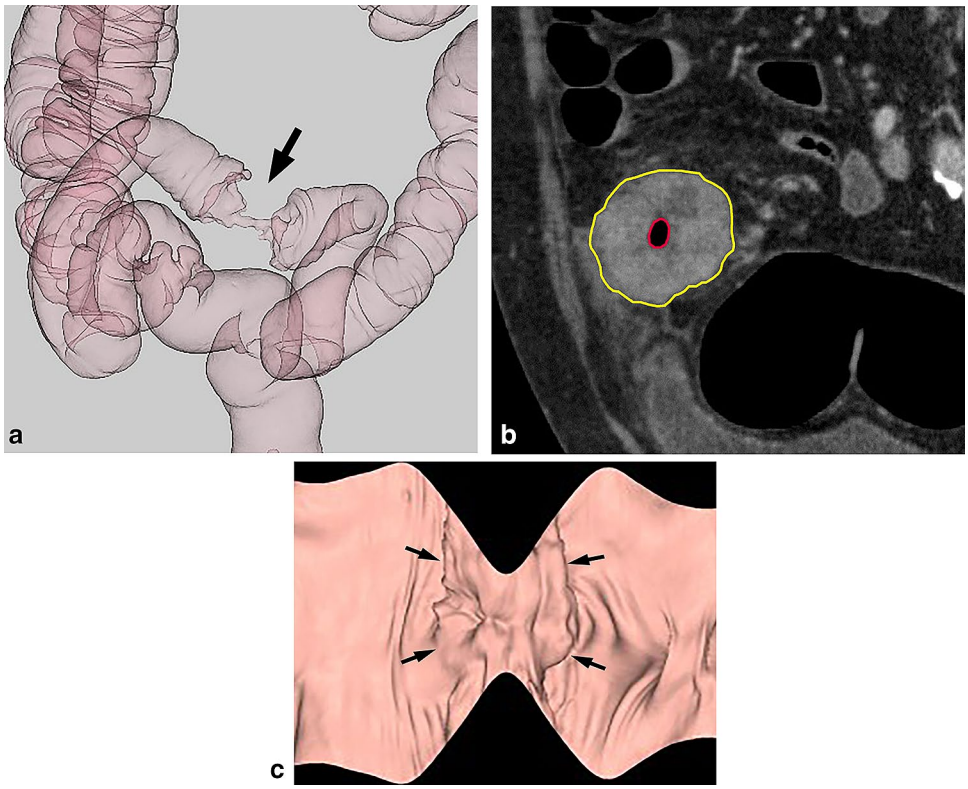


**Fig. 3** A case of incomplete colonoscopy in a 75-year-old man with a sigmoid colon cancer. **a** Air enema image shows severe stenosis forming "apple-core sign" in the sigmoid colon (arrow). **b** MPR image shows complete circumferential thickening of colonic wall. A cross-sectional area of tumor and stenosis was 1443 $mm^2$ (yellow line) and 52 $mm^2$ (red line). **c** VCD image shows the tumor with 100% CER (arrows)

only two cases of CER of less than 100%. According to that results, CRC may extend with circumferential spread rather than extend along with long axis direction of colonic lumen, finally result in incomplete colonoscopy.

Various image display techniques are used to interpret CTC including a two-dimensional (2D) axial review, 2D MPR review, and various 3D display options. VCD, one of the 3D displays of CTC, has advantages over other display options providing overview of the entire mucosal surface of bowel with high objectivity and reproducibility. Advanced CRC was easily detected in this study, and the parameters including tumor length, CER and distance to anus were also easily estimated. Accordingly, 100% CER may be one of the useful CTC parameters of incomplete colonoscopy that can be applicable in clinical setting.

There have been several papers that examined CTC features of cases with incomplete colonoscopy for screening colonoscopy. Hanson et al. reported that anatomic features associated with failure to reach the cecum at optical colonoscopy included colonic elongation, tortuosity, and advanced diverticular disease [18]. Eickhoff et al. examined CTC of normal colon anatomy focusing on length, number of flexures and tortuosity and assessed frequency and type of looping. Their results showed that increased colonic length, tortuosity and redundancy of the colon could be associated with an increased risk of looping and/or incomplete colonoscopy [17]. Lee et al. reported that larger colonic diameter of sigmoid colon corresponds to incomplete colonoscopy according to their research using CTC focusing on the colonic diameter [19]. According to the ROC results of our study, local CTC features including cross-sectional area of tumor and stenosis and CER were found to be parameters which predict incomplete colonoscopy for the patients with CRC. The cross-sectional area of stenosis showed the highest AUC among them.

Our study has several limitations. First, this was a retrospective analysis with a relatively small number of patients. Second, we did not analyze other parameters of colon such as tortuosity nor colon diameter. Furthermore, we did not take distortion caused by VCD into consideration. It may cause a small bias to the results. Third, the imaging analyses performed by two radiologists in consensus may not be fully objective nor reproductive. However, it would not have great influence on the result.

## Conclusion

Our study showed that local CTC features including larger cross-sectional area of tumor, smaller cross-sectional area of stenosis on MPR and 100% CER on VCD were significantly associated with incomplete colonoscopy for the patients with CRC. These features may be helpful in predicting scope passage for CRC lesion found by CTC prior to colonoscopy.

**Funding** The authors did not accept any grant.

## Compliance with ethical standards

**Conflict of interest** The authors declare no conflict of interest associated with this manuscript.

**Ethical approval** This study was approved by the institutional review board of our institution.

## References

1. Rex DK, Petrini JL, Baron TH, Chak A, Cohen J, Deal SE, et al. Quality indicators for colonoscopy. Am J Gastroenterol. 2006;101(4):873–85.
2. Shah HA, Paszat LF, Saskin R, Stukel TA, Rabeneck L. Factors associated with incomplete colonoscopy: a population-based study. Gastroenterology. 2007;132(7):2297–303.
3. Neerincx M, Terhaarsive Droste JS, Mulder CJ, Rakers M, Bartelsman JF, Loffeld RJ, et al. Colonic work-up after incomplete colonoscopy: significant new findings during follow-up. Endoscopy. 2010;42(9):730–5.
4. Koido S, Ohkusa T, Nakae K, Yokoyama T, Shibuya T, Sakamoto N, et al. Factors associated with incomplete colonoscopy at a Japanese academic hospital. World J Gastroenterol. 2014;20(22):6961–7.
5. Witte TN, Enns R. The difficult colonoscopy. Can J Gastroenterol. 2007;21(8):487–90.
6. Oh SY, Sohn CI, Sung IK, Park DI, Kang MS, Yoo TW, et al. Factors affecting the technical difficulty of colonoscopy. Hepatogastroenterology. 2007;54(77):1403–6.
7. Waye JD. Difficult colonoscopy. Gastroenterol Hepatol (N Y). 2013;9(10):676–8.
8. Huisman JF, Leicher LW, de Boer E, van Westreenen HL, de Groot JW, Holman FA, et al. Consequences of CT colonography in stenosing colorectal cancer. Int J Colorectal Dis. 2017;32(3):367–73.
9. Billingsley KG, Morris AM, Dominitz JA, Matthews B, Dobie S, Barlow W, et al. Surgeon and hospital characteristics as predictors of major adverse outcomes following colon cancer surgery: understanding the volume-outcome relationship. Arch Surg. 2007;142(1):23–31 **(discussion 2)**.
10. Deans GT, Krukowski ZH, Irwin ST. Malignant obstruction of the left colon. Br J Surg. 1994;81(9):1270–6.
11. Serpell JW, McDermott FT, Katrivessis H, Hughes ES. Obstructing carcinomas of the colon. Br J Surg. 1989;76(9):965–9.
12. Ascanelli S, Navarra G, Tonini G, Feo C, Zerbinati A, Pozza E, et al. Early and late outcome after surgery for colorectal cancer: elective versus emergency surgery. Tumori. 2003;89(1):36–41.
13. Lam AK, Chan SS, Leung M. Synchronous colorectal cancer: clinical, pathological and molecular implications. World J Gastroenterol. 2014;20(22):6815–20.
14. Mulder SA, Kranse R, Damhuis RA, de Wilt JH, Ouwendijk RJ, Kuipers EJ, et al. Prevalence and prognosis of synchronous colorectal cancer: a Dutch population-based study. Cancer Epidemiol. 2011;35(5):442–7.
15. Horvat N, Raj A, Ward JM, Smith JJ, Markowitz AJ, Gollub MJ. Clinical value of CT colonography versus preoperative

colonoscopy in the surgical management of occlusive colorectal cancer. AJR Am J Roentgenol. 2018;210(2):333–40.
16. Flor N, Ceretti AP, Luigiano C, Brambillasca P, Savoldi AP, Verrusio C, et al. Performance of CT colonography in diagnosis of synchronous colonic lesions in patients with occlusive colorectal cancer. Am J Roentgenol. 2020;214(2):348–54.
17. Eickhoff A, Pickhardt PJ, Hartmann D, Riemann JF. Colon anatomy based on CT colonography and fluoroscopy: impact on looping, straightening and ancillary manoeuvres in colonoscopy. Dig Liver Dis. 2010;42(4):291–6.
18. Hanson ME, Pickhardt PJ, Kim DH, Pfau PR. Anatomic factors predictive of incomplete colonoscopy based on findings at CT colonography. Am J Roentgenol. 2007;189(4):774–9.
19. Lee ES, Kim BC, Hur BY, Kim MJ, Park HJ, Park SB, et al. Risk factors associated with incomplete colonoscopy based on the analysis of computed tomographic colonography findings. J Comput Assist Tomogr. 2018;42(5):675–9.
20. Silva AC, Wellnitz CV, Hara AK. Three-dimensional virtual dissection at CT colonography: unraveling the colon to search for lesions. Radiographics. 2006;26(6):1669–866.
21. Park JY, Kim SH, Lee SM, Lee JS, Han JK. CT volumetric measurement of colorectal cancer helps predict tumor staging and prognosis. PLoS ONE. 2017;12(6):e0178522.
22. Yang Z, Wang L, Kang L, Xiang J, Peng J, Cui J, et al. Clinicopathologic characteristics and outcomes of patients with obstructive colorectal cancer. J Gastrointest Surg. 2011;15(7):1213–22.