Dig Dis Sci (2017) 62:2120–2125
DOI 10.1007/s10620-017-4591-1

ORIGINAL ARTICLE

Endoscopic Localization of Colon Cancer Is Frequently Inaccurate

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Received: 5 October 2016 / Accepted: 25 April 2017 / Published online: 2 May 2017

Abstract
Background Colonoscopic location of a tumor can influence both the surgical procedure choice and overall treatment strategy.
Aims To determine the accuracy of colonoscopy in determining the location of colon cancer compared to surgical localization and to elucidate factors that predict discordant colon cancer localization.
Methods We conducted a retrospective cross-sectional study of colon cancers diagnosed on colonoscopy at two academic tertiary-care hospitals and two affiliated community hospitals from 2012 to 2014. Colon cancer location was obtained from the endoscopic and surgical pathology reports and characterized by colon segment. We collected data on patient demographics, tumor characteristics, endoscopic procedure characteristics, surgery planned, and surgery performed. Univariate analyses using Chi-squared test and multivariate analysis using forward stepwise logistic regression were performed to determine factors that predict discordant colon cancer localization.
Results There were 110 colon cancer cases identified during the study period. Inaccurate endoscopic colon cancer localization was found in 29% (32/110) of cases. These included 14 cases (12.7%) that were discordant by more than one colonic segment and three cases where the presurgical planned procedure was significantly changed at the time of surgery. On univariate analyses, right-sided colon lesions were associated with increased inaccuracy (43.8 vs 24.4%, $p = 0.04$). On multivariate analysis, right-sided colon lesions remained independently associated with inaccuracy (OR 1.74, 95% CI 1.03–2.93, $p = 0.04$).
Conclusions Colon cancer location as determined by colonoscopy is often inaccurate, which can result in intraoperative changes to surgical management, particularly in the right colon.

Keywords Colonoscopy · Colon cancer · Accuracy · Discordance

Introduction

Colonoscopy is used to diagnose, localize, and provide surveillance for colorectal cancers. The location of identified tumors can influence both the surgical procedure choice and overall treatment strategy. Differentiating right from left colon tumor location is most important in guiding surgical planning. Additionally, the specific location of the tumor is also helpful. The localization in the rectum is particularly important as the potential need for neoadjuvant chemoradiotherapy and the possible need for permanent ostomy with abdominoperineal resection versus restoration of gastrointestinal continuity with low anterior resection with anastomosis depend heavily on the specific location in the rectum. The issue of tumor localization has perhaps become even more significant in the current era of minimally invasive approaches (laparoscopic and robotic) to

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colorectal cancer resections because the ability of the surgeon to directly palpate the colon is not possible [1].

Most prior studies have shown a high level of accuracy for tumor localization by colonoscopy approaching 85% [2–6]. However, one study showed a lower accuracy of 59.5% when assessing only patients who underwent right hemicolectomy [7]. The few studies that have looked at factors associated with inaccurate endoscopic tumor localization have shown incomplete colonoscopy to be a risk factor [8], but conflicting results on the significance of tumor location [4–6]. The aim of our study was to determine the accuracy of colonoscopy in determining the location of colon cancer compared to the gold standard of surgical localization. A secondary aim was to elucidate factors that predict inaccurate endoscopic colon cancer localization. Our hypothesis was that right-sided colon cancers would be more difficult to localize compared to left-sided cancers.

Methods

We conducted a retrospective cross-sectional study of colon cancer cases in which a colonoscopy was performed within 6 months of surgical resection of the colon tumor. Colon cancer resections performed at a single academic tertiary-care center from January 2012 through December 2014 were identified through query of a pathology database. Colonoscopies performed on these patients were identified through query of a data repository (Research Patient Data Registry). The data repository included colonoscopies performed at the hospital where the surgical resections were performed, as well as an affiliated academic tertiary-care center and two affiliated community hospitals. We included colonoscopies performed outside of our hospital but within our network, as patients in our system who have a colonoscopy performed at a community hospital often have their cancer resections done at the tertiary-care center. Colon cancer cases and colonoscopy reports were linked by medical record number. Colon cancer cases were included in the study if a colonoscopy was performed within 6 months of surgical resection of the colon tumor. Cases were excluded if there was no surgical resection pathology specimen. This study was approved by the Brigham and Women's Institutional Review Board.

For each case, we collected the following data from colonoscopy reports: endoscopist performing the examination, quality of bowel prep (excellent, good, fair, or poor), cecal intubation, diverticulosis, tumor location, tumor size, and whether the tumor site was tattooed. We also collected information about the time since completion of training of each endoscopist, as well as physician specialty (gastroenterology or surgery). Data collected from surgical pathology reports included tumor location, depth of tumor invasion, and presence of lymphovascular invasion. Endoscopic and surgical tumor locations were categorized by colon segments defined as cecum, ascending, hepatic flexure, transverse, splenic flexure, descending, sigmoid (including the rectosigmoid junction), and rectum. We choose to divide the colon into eight segments as these are the commonly used terms when endoscopists label specimens. The right colon was defined as the cecum, ascending colon, and hepatic flexure. The left colon was defined as transverse colon and distal. Data collected from the medical record included patient age, patient gender, patient BMI, and tumor stage. For each tumor that was discordant on endoscopic and surgical reports, we determined the preoperative planned surgical procedure and the actual surgical procedure performed.

Statistical Analysis

The primary outcome was to determine the accuracy of endoscopic colon cancer location compared to surgical location. The percentage of discordance by more than one colonic segment and discordance of right versus left colon was calculated. For univariate analysis, categorical variables (including patient, tumor, procedural, or endoscopist factors) were analyzed using Chi-squared test and reported as proportions. All continuous variables were analyzed by Kruskal–Wallis and were reported as mean values with standard deviations. Multivariate analysis using forward stepwise logistic regression was performed to determine factors that predict discordant colon cancer localization. A two-sided p value of <0.05 was considered statistically significant. All statistical analyses were performed using SAS version 9.3 (SAS Institute Inc.).

Results

There were 778 surgically resected colon cancers during the study period. Of this group, 110 patients had a colonoscopy performed within 6 months prior to surgical resection of the cancer. No cases were noted to have synchronous colon cancers on endoscopy or surgical resection.

Study Population

Characteristics of the study cohort are listed in Table 1. The mean age of patients at the time of colonoscopy was 61.6 years with a similar gender distribution (males: 51.9%) and a mean BMI of 28.0. Of patients where preparation quality was recorded ($n = 93$), the majority had an adequate colonoscopy preparation (82.8%). Cecal intubation rate for our cohort was 75.5%. Of cases where

Table 1 Characteristics of patients, colonoscopies, tumors, and endoscopists

Characteristics of patients ($n = 110$)	
Age, mean (SD)	61.6 (15.3)
Male, *n* (%)	57 (51.9)
BMI, mean (SD)	28.0 (5.85)
Characteristics of colonoscopies ($n = 110$)	
Preparation quality, *n* (%)	
Excellent	13 (11.8)
Good	64 (58.2)
Fair	14 (12.7)
Poor	2 (1.8)
Not recorded	17 (15.5)
Cecum reached, *n* (%)	83 (75.5)
Obstructed	21 (19.1)
Aborted	6 (5.5)
Diverticulosis, *n* (%)	40 (36.4)
Fellow involvement, *n* (%)	22 (20.0)
Tattoo placed, *n* (%)	55 (50.0)
Characteristics of tumors ($n = 110$)	
Tumor size, mean (SD), *mm*	35.9 (22.5)
Depth of invasion, *n* (%)	
Submucosa	17 (16.8)
Muscularis propria	40 (22.8)
Subserosa	48 (7.9)
Pericolonic tissue	85 (36.6)
Visceral peritoneum	16 (15.4)
Lymphovascular invasion, *n* (%)	38 (38.0)
Characteristics of endoscopists ($n = 34$)	
Median months in practice at time of colonoscopy, *n* (range)	93.5 (2–447)
Specialty, *n* (%)	
Gastroenterologist	29 (85.3)
Surgeon	5 (14.7)
Type of practice, *n* (%)	
Academic	25 (73.5)
Community	9 (26.5)

SD standard deviation, *BMI* body mass index

the cecum was not reached, twenty-one were because of an obstructing tumor, five were because of looping, one was because of diverticulosis, and one was because of patient discomfort. Six of the cases that did not reach the cecum went beyond the site of the tumor, but could still not reach the cecum due to looping ($n = 3$), switching to a gastroscope in order to traverse the partially obstructing tumor ($n = 1$), diverticulosis ($n = 1$), or patient discomfort ($n = 1$). Half of the tumors had a tattoo placed at the time of endoscopy. Tumors had a mean size of 35.9 mm with lymphovascular invasion in 38.0%. There were 34 endoscopists included in our study. They were primarily gastroenterologists (85.3%) in academic practice (73.5%) and were highly experienced with a median of 93.5 months in practice at the time of the colonoscopy. Twenty percent of the colonoscopies had fellow involvement.

Colon Cancer Localization

Discordant colon cancer localization was seen in 29.1% (32/110) of lesions between endoscopic and surgical pathology reports (Table 2). These included seven cases (6.4%) of discordance by more than one colonic segment. One lesion in the cecum was endoscopically labeled as transverse colon in the setting of an incomplete colonoscopy that could not advance beyond the lesion. Two lesions in the ascending colon were endoscopically labeled as transverse colon.

Table 2 Comparison of surgical and endoscopic tumor location

	Endoscopic tumor location, *n* (%)	Surgical tumor location, *n* (%)	Endoscopic location inaccurate compared to surgical location, *n* (%)	Endoscopic location inaccurate by >1 colonic segment compared to surgical location, *n* (%)
Overall	110	110	32 (29.1)	7 (6.4)
Right	29	33	14 (42.4)[a]	3 (9.1)
Cecum	10 (9.1)	12 (10.9)	3 (25.0)	1 (8.3)
Ascending	11 (10.0)	19 (17.3)	10 (52.6)	2 (10.5)
Hepatic flexure	8 (7.3)	2 (1.8)	1 (50.0)	0 (0)
Left	81	77	18 (23.4)[a]	4 (5.2)
Transverse	12 (10.9)	9 (8.2)	2 (22.2)	2 (22.2)
Splenic flexure	3 (2.7)	4 (3.6)	2 (50.0)	1 (25.0)
Descending	5 (4.6)	2 (1.8)	1 (50.0)	0 (0)
Sigmoid	40 (36.4)	35 (31.8)	5 (14.2)	1 (2.9)
Rectum	21 (19.1)	27 (24.6)	8 (29.6)	0 (0)

[a] Percent discordance of right versus left: $p = 0.04$

Two lesions in the transverse colon were endoscopically labeled as descending colon. One lesion at the splenic flexure was endoscopically labeled as transverse colon.

There were 13 cases (40.6%) of discordant lesions surgically identified in the sigmoid colon and rectum. The eight discordant lesions surgically localized to the rectum were endoscopically noted to be in the rectosigmoid ($n = 4$) and sigmoid ($n = 4$). Of the five discordant lesions surgically localized to the sigmoid, endoscopic localization was noted to be in the rectum ($n = 2$), descending colon ($n = 2$), and the splenic flexure ($n = 1$).

Changes in Surgery Due to Discordant Location

Among the discordant cases, we identified 10 cases in which the planned surgical procedure was changed or the extent of the surgery was lengthened intraoperatively. There were three major changes to surgical resections: (1) a planned right hemicolectomy changed to a left hemicolectomy; (2) a planned transverse colectomy changed to a right hemicolectomy; and (3) a planned sigmoid colectomy changed to an extended left colectomy. There were seven minor changes to surgical resections: (1) five planned right hemicolectomies changed to extended right hemicolectomies; (2) a planned left segmental resection changed to a transverse colectomy; (3) a planned sigmoid colectomy changed to descending and sigmoid resection.

Analysis of Factors Associated with Discordant Tumor Localization

On univariate analyses, right-sided colon lesions were associated with increased localization inaccuracy (43.8 vs 24.4%, $p = 0.04$) (Table 3). On multivariate analysis after controlling for age, gender, BMI, polyp size, prep quality, complete colonoscopy, fellow involvement, and months of endoscopist experience, right-sided colon lesions remained independently associated with discordance (OR 1.74, 95% CI 1.03–2.93, $p = 0.04$). When including the transverse colon with the right colon instead of left colon, right-sided colon lesions continue to demonstrate higher likelihood of discordance (OR 1.55, 95% CI 0.96–2.52, $p = 0.08$), although no longer statistically significant.

Discussion

In this multicenter study that included both academic and community hospitals, endoscopic colon cancer localization was inaccurate in almost thirty percent of cases when compared to surgical location. Right-sided colon cancers were significantly more likely to be inaccurately localized during colonoscopy with no other patient, tumor, procedural, or endoscopist factors associated with inaccurate endoscopic localization. There were three cases during which the presurgical planned procedure was majorly changed at the time of surgery and some patients going for surgery ended up with a different length of colon resected than was initially planned. These altered surgical procedures underscore the importance of accurate colon cancer identification prior to surgery.

Prior studies have shown a range of colonoscopic localization accuracy. The largest study to date assessed 400 colon cancers identified on colonoscopy and resected at a group of community hospitals from 1999 to 2006 [4]. This study found a 12% rate of inaccurate colonoscopic localization when dividing the colon into four segments (right, transverse, left, and rectum) and more than half of these inaccurately localized lesions required modifications during surgical resection. Another large study assessed 374

Table 3 Predictors of inaccurate endoscopic tumor localization

Predictors, *n* (%)	Univariate			Multivariate		
	Accurate ($n = 78$)	Inaccurate ($n = 32$)	*p* value	OR	95% CI	*p* value
Age, mean (SD)	57.6 (16.1)	57.7 (13.1)	0.70	1.02	0.98–1.05	0.36
Male	40 (51.3)	17 (53.1)	0.86	1.13	0.42–3.02	0.81
BMI > 25	30 (38.5)	13 (40.6)	0.83	1.50	0.55–4.07	0.43
Right-sided tumor[a] ($n = 33$)	19 (24.4)	14 (43.8)	0.04	1.75	1.04–2.94	0.04
Polyp size ≥10 mm	36 (46.2)	13 (40.6)	0.60	1.14	0.40–3.19	0.81
Prep quality adequate, *n*/total (%)	13/66 (19.7)	3/27 (11.1)	0.32	0.53	0.13–2.24	0.39
Cecum reached	57 (73.1)	26 (81.3)	0.37	1.11	0.25–4.91	0.89
Months in practice, median (range)	139.4 (2–447)	188.8 (14–447)	0.09	1.00	1.00–1.01	0.21
Fellow involvement	16 (20.5)	6 (18.8)	1.00	0.77	0.23–2.66	0.68

[a] By surgical location

colon cancers resected by a single surgeon and found only 4% had discordant colonoscopic and surgical locations when dividing the colon into six segments (ileum, ascending, transverse, descending, sigmoid, and rectum) from 1991 to 2008 [5]. Of these discordant cases, 73% required a modification of the planned surgical procedure. Bryce et al. [8] reported a prospective, multicenter study conducted from 2011 to 2012 with a 79.3% endoscopic localization accuracy rate among 111 cases. Nine colonic segments (cecum, ascending, hepatic flexure, transverse, splenic flexure, descending, sigmoid, rectum, and anastomosis) were used in this study. Incomplete colonoscopy was the only significant factor that influenced inaccurate colonoscopic localization.

Compared to these prior studies, ours has a number of strengths. Our study was multicenter including both academic tertiary-care centers and community hospitals. We conducted a multivariable analysis evaluating factors that predict inaccurate localization. We accounted for a variety of factors that have been previously evaluated, including complete colonoscopy, but also assessed new factors, including tumor location, BMI, and endoscopist experience.

Our study adds to the current body of the literature, as ours is the first to show that right-sided colon lesions have a high rate of inaccurate localization. Prior studies have shown mixed results on where in the colon endoscopic inaccuracy is most common. One prior study found a significantly increased rate of endoscopic localization inaccuracy with tumors in the descending colon and cecum after controlling for other factors [6]. In contrast to our results, Louis et al. [4] reported no difference in endoscopic and surgical discrepancies between the right and left colon. However, major discrepancies in endoscopic localization that required alteration in the surgical resection were more likely to be present in the left colon, which they attributed to a larger selection of surgical options to treat left-sided compared to right-sided lesions. When we reanalyzed our data to include transverse colon with the right colon instead of with the left colon, there was still a trend more inaccuracy of localization in the right colon though this was no longer statistically significant. This may be due to sample size. However, our data still demonstrate that more major intraoperative modifications were needed for right-sided colon cancers. Endoscopists need to better identify landmarks including the appendiceal orifice, ileocecal valve, and hepatic flexure to localize the right colon.

One-quarter of our cases had an incomplete examination due to obstructing tumor or aborted procedure due to looping or patient discomfort. This may have increased our rate of inaccurate localization by colonoscopy. However, in contrast to prior studies [6, 8], we did not find incomplete colonoscopy as a predictor of inaccurate endoscopic tumor localization.

The largest number of inaccurately endoscopically localized tumors in our study was in the rectum and sigmoid (40.6%). Surgical landmarks for identification of the rectosigmoid junction include the point at which the taenia coli coalesce to form the outer longitudinal smooth muscle layer of the rectum, peritoneal reflection, and sacral promontory [9], though surgical definitions vary between providers [10] and landmarks vary between patients [11]. Endoscopic landmarks that delineate the rectosigmoid junction are more difficult to identify and are not standardized. The significance of this finding is confirmed in our study with two patients who had inaccurately localized tumors identified in the rectum or sigmoid that required extended resections compared to that planned preoperatively based on the endoscopic tumor localization.

Endoscopic localization in the rectum can be improved by using the anal verge (not the buttocks or dentate line) as the distal landmark for measurements as well as by using rigid (not flexible) proctoscopy [12, 13]. A distance of 12 cm from

the anal verge is defined as the rectum on rigid proctoscopy based on local recurrence rates proximal to this distance being more similar to colon cancer [14]. More recent data suggest a gender differential for distance to the sacral promontory with a median distance of 16 cm in women and 18 cm in men [11]. Endoscopists should also try to identify the valves of Houston, three lateral curves which delineate the lower, middle, and upper rectum, and note location of the tumor in relation to these landmarks in the report.

Colonoscopies in our study were performed without the use of endoscopic imaging technology to help with localization, but this technology may improve accuracy. A 2011 English study found that colon cancer location was accurately described in greater than 93% of cases when colonoscopy was performed with aid of a endoscopic imaging system [15]. However, other work has found that magnetic endoscopic imaging did not significantly improve colonic tumor localization [8]. Further trials of magnetic endoscopic imaging are needed to determine whether this will aid in accurately endoscopically localizing colorectal tumors.

Only 20% of our cases involved tattoo placement. Prior literature suggests this is a safe and effective technique. A study evaluating patients who underwent laparoscopic colorectal tumor resections showed that endoscopic tattooing had a higher accuracy for tumor localization compared to colonoscopy alone (97.9 vs 88.7%) [16]. Another study reported decreased operative times and blood loss in patients who had preoperative tattoos placed for localization [17]. Until we find ways to improve endoscopic localization accuracy, tattoos and preoperative imaging may be helpful in guiding surgical excision.

Our study has several limitations. We divided the colon into eight segments for analysis. Dividing the colon into fewer colonic segments may have decreased our rates of endoscopic localization inaccuracy. However, for our analysis of predictors of endoscopic localization inaccuracy, we looked at only right versus left colon and found this to be a significant predictor. One-quarter of our cohort did not have a complete examination to the cecum, and endoscopist experience in our study had a large variance. Though these could effect localization accuracy, neither factor was an independent predictor on multivariate analysis. Finally, this was a retrospective study that assessed only patients who underwent surgical resection of colon tumors identified on colonoscopy. Accuracy may be skewed by patients who were found to have a colonic tumor that did not undergo surgical resection. Colonoscopic accuracy may differ for other, non-malignant findings including polyps.

In conclusion, this multicenter center study demonstrates that endoscopic localization of colon cancers is often inaccurate. This inaccurate localization can lead to intraoperative changes to surgical planning, particularly in the right colon. Endoscopists need to better assess anatomical landmarks in order to more accurately localize pathology such as colon cancers identified during colonoscopy.

Compliance with ethical standards

Conflict of interest None.

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