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Variation of agreement in polyp size measurement between CT colonography and pathology assessment: clinical implications

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Abstract

Background and Aims—Clinical management of polyps discovered by computed tomographic (CT) colonography depends on polyp size. However, size measured by CT colonography is an estimate, and its agreement with other measures is not well characterized. We hypothesized that size measurement by CT colonography varies substantially compared to measurement by other methods.

Methods—We performed a secondary data analysis of a multicenter study of CT colonography in comparison to colonoscopy. Polyp size was determined by CT colonography, at colonoscopy, and measurement pre-fixation with a ruler. Agreement was assessed using descriptive statistics and Bland-Altman methodology.

Results—600 trial participants completed both tests. 95% limits of agreement indicated that estimates of size by CT colonography were between 52% lower to 64% higher than pre-fixation polyp size estimates. 95% limits of agreement stratified by categories of clinical importance indicated that estimates of size by CT colonography were between 44% lower to 84% higher for polyps ≤ 0.6 cm, 44% lower to 44% higher for polyps 0.6 to 0.9cm, and 48% lower to 22% higher for polyps ≥ 0.9 cm compared with pre-fixation estimates. Analysis of participants with one identified polyp in the same colon segment demonstrated that categorization based on CT colonography measurement (i.e., <0.6 cm, 0.6 to 0.9cm, or >0.9 cm) differed from pre-fixation measurement for 43% of participants.

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Conclusions—Polyp size estimation by CT colonography varies from pre-fixation and colonoscopic measures of size. Future studies should clarify whether size estimation by CT colonography is sufficiently reliable as a primary factor to guide clinical management.

Introduction

Colorectal cancer is diagnosed in an estimated 150,000 persons per year in the United States, and accounts for over 50,000 deaths per year¹. Prevention of colorectal cancer by early detection and removal of adenomatous polyps, which are thought to be the interval lesion through which most colorectal cancers develop, is the main focus of established cancer screening strategies such as fecal occult blood testing, flexible sigmoidoscopy, and colonoscopy^{2, 3}. Mortality benefit, as well as a shift towards detection of earlier stage lesions, have been demonstrated by some of these modalities^{4–9}.

Computed tomographic (CT) colonography is a relatively new potential colorectal cancer screening modality that, because it is non-invasive, has been proposed as an added option. While some data suggest that the sensitivity of CT colonography is high enough to warrant its use as a colorectal cancer screening strategy¹⁰, other data suggest that CT colonography, as it is currently most commonly performed, does not have adequate sensitivity^{11, 12}. Additionally, prognostic mathematical and cost-effectiveness models have identified other important factors that may ultimately determine the clinical and cost-effectiveness of CT colonography for colorectal neoplasia screening, including the following variables: 1) improvement in adherence to colorectal cancer screening based on availability of CT colonography, 2) duration of follow up interval after normal or equivocal CT colonography, 3) referral threshold for colonoscopic follow-up based on polyp size, and 4) the sensitivity and specificity of CT colonography for polyps $\geq 5\text{mm}$ and $\geq 1\text{cm}$ in size^{13–17}.

Though the sensitivity and specificity of CT colonography for colonic polyps at various size thresholds has received careful analysis in each of the published multicenter trials^{10–12}, analysis of the measurement error associated with polyp size measurement has undergone limited study^{10, 18–20}. Because CT colonography cannot evaluate polyp histology, the assessment of current and future risk for colorectal cancer (and patient management based on CT colonography findings) is fundamentally based on polyp size²¹. Indeed, management strategies have been actively debated^{22–26}, and it is clear that it is important to understand the characteristics of the seminal measure that determines clinical management of patients, namely polyp size measurement by CT colonography.

In this study, we have hypothesized that there is variation in polyp size measurement by CT colonography in comparison to size estimation by pre-fixation measurement and at time of colonoscopy. Here, we present an additional analysis of one of the large multicenter trials that included polyp size measurement by 1) CT colonography, 2) colonoscopy, and 3) pre-fixation measurement of removed polyps¹². Our results demonstrate polyp size estimation by CT colonography is highly variable compared to other measurement methods. This limitation raises a major concern when using polyp size to triage patients for management, and calls into question use of size measurements alone to guide clinical management of polyps detected at CT colonography.

Materials and Methods

Details of the: “Computed Tomographic Colonography (virtual colonoscopy): A multicenter comparison with standard colonoscopy for detection of colorectal neoplasia,” trial have been published previously; a brief summary of methods follows^{12, 27}. This trial was a multicenter study of 615 subjects aged 50 or older referred for clinically indicated colonoscopy from 2000

to 2003. All subjects underwent CT colonography immediately prior to colonoscopy. The protocol was approved by institutional review boards at each participating site; all participants provided written, informed consent. By protocol, segmental unblinding was employed to allow for immediate re-examination of a colonic segment if discrepancies in polyp identification were detected between the two procedures. Attempt was made to remove all polyps detected by colonoscopy. Polyp size was measured by computer software for CT colonography, comparison to open biopsy forceps prior to removal for colonoscopy, and ruler measure pre-fixation of resected polyps. Pre-fixation size measurement was considered the reference standard²⁸.

Outcomes

The outcome measures for this study were the recorded polyp sizes determined by CT colonography, colonoscopy, and pre-fixation pathology. The primary analysis assessed agreement between polyp size measurement by CT colonography and pre-fixation pathology measurement. Secondary analyses assessed agreement between: 1) biopsy forceps and pre-fixation pathology measurements; 2) both CT colonography and biopsy forceps with pre-fixation size, stratified by three polyp size thresholds believed to be of clinical significance²¹: <0.6 cm, 0.6 to 0.9cm and ≥ 1 cm; 3) both CT colonography and biopsy forceps with pre-fixation pathology for polyps with advanced histology, defined as villous histology, high grade dysplasia, or cancer; and, 4) CT colonography and pre-fixation size for subjects who only had one polyp identified and measured in the same colonic segment (rectum/sigmoid colon, descending colon/splenic flexure, transverse colon/hepatic flexure, ascending colon, or cecum).

Data analysis

The Bland-Altman method was used to assess agreement between measurement methods^{29–31}. In Bland-Altman analysis, the primary characteristic of interest is the 95% limits of agreement. This provides an assessment of the true variation between two measuring procedures, which is not evaluable by simply considering the average difference between the measures of interest, or correlation coefficients. Because pre-fixation polyp size was considered the reference standard for polyp size, pre-fixation size, rather than an average of pre-fixation polyp size and CT colonography measurement, was used as the comparator point^{28, 32, 33}. Specifically, to calculate the average difference between two measurement techniques and the corresponding 95% limits of agreement, the measurement by the comparator of interest (e.g. size by CT colonography measurement) was subtracted from the reference method of interest (pre-fixation or biopsy forceps), eg: (pre-fixation size – CT colonography size) $\pm 1.96 \times$ (standard deviation of differences). In all analyses, model checking with histograms and Bland-Altman plots by the method of Bland and Altman was performed. If assumptions of Bland-Altman analysis were unmet, then data transformations were performed³¹.

Role of funding source

The funding source had no role in the design or execution of the study.

Results

Details of the characteristics of the study population have been published previously¹². In brief, the mean age of subjects was 61 $\pm$ 8.34 years; 55% were women, and 87% were White. Indications for colonoscopy included hematochezia, presence of fecal occult blood, change in stool habit, abdominal pain, and surveillance after prior polypectomy. Six-hundred of 615 enrolled participants underwent CT colonography followed by colonoscopy.

Eight-hundred twenty-seven lesions were detected among 308 of the 600 participants. Of the 827 lesions, 654 were 0.1 to 0.5 cm, 119 were 0.6 to 0.9 cm, and 54 were 1 cm or more in size. Eight-hundred and five lesions were detected by colonoscopy, of which 105 lesions were detected by CT colonography. Of these 105 polyps detected by both CT colonography and colonoscopy, 50 were 0.1 to 0.5 cm, 27 were 0.6 to 0.9 cm, and 28 were 1 cm or more in size.

For the primary analysis, both CT colonography measurement and pre-fixation pathology measurement were available for 82 of 105 polyps detected by CT colonography and confirmed by colonoscopy. For the comparison of CT colonography to open biopsy forceps at colonoscopy, both measurements were available for 94 polyps detected by CT colonography. For comparison of colonoscopic measurement to pre-fixation size measurement, both measurements were available for 666 of 827 lesions detected by colonoscopy. Lastly, for the “one-polyp” analysis of agreement of CT colonography with pre-fixation size measurement, pre-fixation size was available for 111 participants out of 136 with only one polyp, 25 of whom had identification of their polyp with CT measurement. Polyps from these 25 participants included 4 normal biopsies, 8 hyperplastic polyps, 10 tubular adenomas, 2 tubulovillous adenomas, and 1 adenocarcinoma. Of these 25 participants, 14 had polyps that were reported by both CT and colonoscopy as being in the same segment of the colon.

Figure 1a illustrates that polyp size measured by CT colonography is progressively underestimated with increasing pre-fixation polyp size. A histogram of the frequency of the differences in polyp size was right skewed and non-normally distributed (Figure 1b). Because the data show a systematic trend towards increasing variability with increasing size of the measurement in question, Bland-Altman 95% limits of agreement were based on the ratio of the CT relative to the pre-fixation polyp size rather than on the average difference of the two measurements, as described by Bland-Altman^{30, 31}. Figure 1c provides an accurate interpretation of agreement in which the ratio of polyp measurement by CT colonography to pre-fixation size is plotted against the average polyp size. Ninety-five percent limits of agreement indicate that most estimates of size by CT colonography were between 52% lower to 64% higher than pre-fixation polyp size. The range of ratios were 0.33 to 1.67; 32% of the ratios of polyp size by CT to size by pre-fixation were 1, while 38% were greater than 1, and 30% less than 1.

For open biopsy forceps measurement at colonoscopy comparison to pre-fixation pathology, the ratio of the two measurements ranged from 0.22 to 5.0; 26% of the colonoscopy measurements were less than the pre-fixation measurements and 27% were greater than pre-fixation size. The 95% limits of agreement indicated that most size estimates by colonoscopy were between 90% lower to 2 times higher than pre-fixation estimates. The ratio of polyp size estimate measurements with corresponding 95% limits of agreement, stratified by three categories of potential clinical importance are presented in Table 1 for both CT colonography and colonoscopy measurements of size compared to pre-fixation. Figure 2 illustrates 95% limits of agreement for CT colonography compared to pre-fixation for polyps 0.6 to 0.9 cm in pre-fixation size. Six of these 25 polyps (24%) would have been placed in a different polyp reference category by CT colonography compared to pre-fixation (less than 0.6cm or greater than 0.9cm) and are highlighted.

Of the 41 identified lesions with advanced histology, 17 lesions had both pre-fixation and CT colonography measurements and 32 had both open biopsy forceps and pre-fixation measurements. For the 17 advanced lesions measured by pre-fixation and CT colonography, two contained adenocarcinoma, while 15 harbored villous pathology. Ninety-five percent limits of agreement suggest that most polyps were estimated by CT colonography to be between 38% lower to 32% higher than pre-fixation size. Of the 32 advanced lesions measured by both colonoscopy and pre-fixation, four contained adenocarcinoma, 27 villous pathology, and one

contained high-grade dysplasia. For colonoscopic measurements of polyp size compared to pre-fixation, 95% limits of agreement indicated that most estimates by colonoscopy were between 25% lower to 31% higher than pre-fixation size. Table 2 presents 95% limits of agreement for comparison of CT colonography relative to open biopsy forceps, stratified by size: 95% limits of agreement suggested that most CT colonography estimates were 68% lower to 76% higher than the open biopsy forceps polyp size.

Figure 3 presents a plot of the ratio of polyp size measurement by CT colonography to pre-fixation estimate for the analysis of participants with only one polyp measured by CT colonography and pre-fixation and identified in the same location of the colon. Six of 14 participants (43%) with one polyp were categorized by pre-fixation measurement into a polyp reference category different from that identified by measurement at CT colonography alone.

Discussion

Our results indicate that size estimation of polyps found at CT colonography varies from other measures of polyp size. Furthermore, analyses of polyps stratified by categories of proposed clinical importance demonstrates that classification of polyps into incorrect polyp reference categories (even when estimates fall within 95% limits of agreement) may occur.

Prior work regarding the reliability of colonoscopic, as well as radiologic, measurements of polyp size merits consideration and is consistent with our findings. One study, examining polyp measurement in a training set of 16 polyps identified with multi-detector CT, employing open biopsy forceps measurement at colonoscopy as the gold standard, demonstrated wide 95% limits of agreement for CT colonography size measurement and open biopsy forceps³⁴. The authors reported variation of -0.9 to 0.5 cm, even for experienced radiologists.

Yeshwant and others¹⁸ retrospectively studied optimal modes of size measurement in a subset of 79 polyps from one of the three large multicenter trials of CT colonography¹⁰. A research assistant, trained by a radiologist, determined linear size of 79 polyps and volume of 251 polyps in conjunction with the same radiologist. Automated linear and volume measurements of 251 polyps were also taken using reading software. Size measurement by linear probe at colonoscopy was the reference standard. The main analyses included determination of mean size measurement error, as well as a confidence analysis, in which the confidence with which a given polyp would be characterized as being greater than 1 cm in size was determined. Overall, linear measurement of polyps employing a 3D display was reported to be the most accurate, with mean measurement error of -0.14 cm $\pm$ 0.68 cm, and the confidence with which a polyp would be called greater than 1 cm for polyps actually 1 to 1.2 cm in size ranging from 50 to 75% and for polyps actually 0.6 to 0.9 cm in size ranging from 0 to 15%. Fractional differences for linear 3D measurements averaged 21% $\pm$ 22.

More recently, Burling and others reported an analysis of measurement methods, including automated polyp measurement applied by a radiologist and a radiology technician, to a study set of 50 polyps from 33 patients. Measurements obtained by different viewing modes of CT colonography were compared to measurements obtained by either comparison to open biopsy forceps or linear probe at colonoscopy. For all 6 measurement methods employed, Bland-Altman analysis suggested variability of -0.3 cm to 0.8 cm 95% of the time, with a reported tendency towards overestimation of polyp diameter except when using an abdominal window display¹⁹.

One group has compared polyp size measurement by CT colonography to gross pathology measurement^{20, 35}. Using a resected, sewn off colon specimen from a single patient with familial adenomatous polyposis syndrome, polyp size was measured by CT colonography, followed by caliper measurement of the polyps within the gross specimen. Two observers (a

radiologist and a radiology technician) recorded polyp size measurement using 2D and 3D views, as well as automated polyp measurement software. Optimal limits of agreement were achieved by the radiologist, with the resected colon fully-insufflated: -0.71 to 0.31 cm on 2D measurement, and -0.19 to 0.32 cm on 3D measurement. The proportion of polyps correctly categorized into groups of clinical significance ranged 75 to 100% for 8 polyps 0.1 to 0.5 cm in size, 18 to 64% for 11 polyps 0.6 to 0.9 cm in size, and was 100% for the single polyp greater than 1 cm in size. Inter- and intra-observer 95% limits of agreement suggested variability in size estimation of up to 2.5 mm.

Under experimental conditions employing a glass colon model containing 24 artificial polyps, Young and others demonstrated the optimal potential for polyp size measurements by CT colonography³⁶. Six reviewers measured these polyps employing two of three different types of CT colonography reading workstations. The three optimal methods of measurement (two dimensional axial or multiplanar analysis in lung windows, as well as three-dimensional tissue cube analysis) had small mean absolute errors ranging from 0.48 to 0.76 mm and standard deviations ranging from 0.51 to 0.79 mm. Underestimation of polyp size was consistently noted for all but two of 14 methods of measurement employed. While this analysis highlights optimal performance of CT colonography size measurement in an experimental model, results from *ex-* and *in-vivo* colon analyses^{18, 34, 35}, as well as our analysis, are consistent with our conclusion that polyp size measurements at CT colonography show insufficient agreement with polyp size measurement by colonoscopy or pathology to be considered the primary factor for risk stratification of polyps detected by this modality.

The reliability of polyp size measurement by colonoscopy also appears to be problematic. In an analysis of 100 polyps employing pre-fixation pathology as the “gold standard”, open biopsy forceps measurement was associated with a mean difference of 0.1 cm, with a 95% confidence interval for mean difference versus actual size of 0.06 to 1.4 cm²⁸. Linear probe measurement was reported to be the closest measurement to gold standard pre-fixation pathology, though the endoscopy nurse measuring pre-fixation size was not blind to investigator measurement by probe and forceps, raising the possibility of measurement bias. In a study comparing open biopsy forceps measurement to pre-fixation pathology among 31 polyps, the mean difference was 0.16 cm, and gastroenterologists consistently overestimated polyp size³⁷. In a study of 33 snared polyps, employing visual estimation alone, without requiring open biopsy forceps comparison, Shoen reported that endoscopists were within a measurement error of 0.3 cm of pre-fixation measurement only 80% of the time³². Data from a large trial that included visually estimated size measurement of 1795 patients with a single polyp found at sigmoidoscopy confirmed by colonoscopy demonstrated high variability in polyp size estimation³⁸. Utilizing *in vitro* models, two groups found consistent underestimation of polyp size by endoscopist measurement employing open biopsy forceps as a guide^{39, 40}. These studies raise a number of important points regarding polyp size variation, limitations include small sample sizes in many cases, and the absence of formal agreement assessment of agreement in others. One interpretation of these data (in conjunction with ours) is that the inherent variability of size measurement at colonoscopy supports polypectomy for all polyps encountered at colonoscopy, as is currently recommended standard practice⁴¹.

Polyp size appears to be proportional to risk for advanced neoplasia, and has been intensely studied. While the prevalence and subsequent incidence of cancer in individuals with polyps 1 cm or more in size is consistently reported to be high^{42–46}, and while the majority of reports have not identified cancer in polyps less than 0.5 cm in size^{42, 47–51}, uncertainty regarding the rate of cancer and worrisome histology in polyps sized 0.5 to 0.9 cm exists. Zero to 10% of adenomas 5 to 9 mm in size may have high grade dysplasia^{47, 48, 52–54}, with most estimates for high grade dysplasia ranging from 3 to 7%, and for invasive cancer from 0 to 2.5%^{47, 52, 54}. However, the exact prevalence of advanced histology in polyps less than 1 cm in size is

difficult to discern based on these studies, as many only included adenomas (rather than all polyps) in their calculations, and most did not include only a screening population. Nonetheless, it may be generally accepted that size is an important, but incomplete predictor of underlying histology.

Our study has potential limitations. As has been typical of the other larger multicenter trials of CT colonography for colorectal neoplasia detection, a polyp matching algorithm was employed to match polyps identified on CT colonography to those identified at colonoscopy. Because in this study, the algorithm defined a true match as a polyp identified by both CT colonography and colonoscopy in the same or adjacent segment of the colon if size estimates agreed within 50%, but did not acknowledge a match if size differed by more than 50% or location by more than 1 adjacent segment, bias, most likely towards more favorable agreement between CT colonography and pre-fixation measurement, may exist.

Compared to the study that reported the greatest sensitivity in a large number of patients¹⁰, the study from which we used data for the current analysis had lower sensitivity and specificity for detection of polyps¹². It could be argued that because readers did not detect lesions with great accuracy that they also did not accurately measure polyp size. We have considered the possibility that purported poor reader ability reflects a systematic lack of expertise that could bias the current investigation. In order to address this possibility, we considered an analysis by individual study site within the original trial. However this was not possible due to limitations in sample size at many study sites. In a post-hoc analysis of the single study site that contributed the most polyps to our main analysis, and had the highest sensitivity 42 out of the 82 polyps from the study site with the highest sensitivity for polyps greater than 6mm in size (>80%), Bland-Altman limits of agreement for polyp size estimation by CT colonography were not substantially different from our overall results (95% limits of agreement 47% lower to 50% higher than pre-fixation size). Furthermore, we are unaware of data linking lack of ability to detect lesions with any type of lack of ability to measure polyps with electronic tools available for current workstations.

It is important to emphasize that although we found measures of polyp size by CT colonography to vary substantially compared to pre-fixation polyp size, it is possible that in some settings, CT colonography may more accurately size lesions. Use of multislice CT scanners may reduce polyp distortion, and barium and iodine stool and fluid tagging may improve polyp detection and characterization⁵⁵. Additionally, improved imaging reconstruction software may be associated with improved sensitivity for polyps and improved polyp characterization. In one study of a subset of 79 polyps from an earlier published cohort, the authors noted that 3D reconstruction appeared to be more accurate than 2D reconstruction for size estimation, and that measurements made in two dimensions are inherently inaccurate because they require the reader to choose an optimal reading frame for measurement¹⁸. Choosing an optimal reading frame requires that the reader recognize the plane of largest dimension for the polyp, and, if not optimally applied, may add to measurement error. Size analysis with 3D reconstruction was not performed in our study, perhaps resulting in less favorable estimates than may be expected with improvements in CT colonography software. Overall, both technology and reader related factors may affect estimates of agreement of polyp size measurement by CT colonography with pre-fixation measures. Nonetheless, it is notable that our estimates of the agreement of polyp size measurement by CT colonography with pre-fixation and colonoscopic measurement are similar to those from smaller studies employing more experienced readers and improved technology^{18, 19, 34}.

We attempted to explore potential bias with our analysis of agreement of CT colonography and pre-fixation polyp size for participants with only one polyp identified in the same segment. Of 14 polyps with perfect segmental match, 6 (43%) would have been classified into a size

category of proposed clinical relevance different than that indicated by pre-fixation pathology (2 underestimated; 4 overestimated). Furthermore, in a post-hoc analysis, we also performed a “one segment” analysis in which agreement was determined for those polyps which had no other polyps present in the same segment at colonoscopy. Of the 82 polyps identified by colonoscopy and CT, 54 polyps did not have a polyp in the same segment. The 95% limits of agreement suggested that estimates of size by CT were 63% lower to 71% higher than pre-fixation estimates. Thus, both “one polyp” and “one segment” analyses are consistent with our overall observation that polyp estimation by CT colonography varies compared to other measures. The individual measuring pre-fixation size was not by protocol blinded to the measurement as determined by comparison to open biopsy forceps; this may have biased our estimation of size by colonoscopy favorably, and may have had a positive or negative impact on limits of agreement determination for CT colonography with pre-fixation size. Polyps may shrink after electrocautery and removal^{28, 32, 37}; despite this, a trend towards underestimation of polyp size by CT colonography compared to pre-fixation size with increasing polyp size was observed. Lastly, our estimates of the agreement of CT colonography measurements compared to open biopsy forceps may be biased in favor of colonoscopy measurement, given that in many cases, the same biopsy forceps used for measurement may have been used for polypectomy. Despite this, significant variation between colonoscopic and pre-fixation measurement was noted.

The finding that the measurement of polyp size by CT colonography has substantial variation in agreement with pre-fixation pathology measurement has several important clinical implications. First, current recommendations for management of polyps detected by CT colonography rely heavily on estimates of polyp size. A consensus statement recommended that polyps less than 0.6 cm not be reported or resected, that patients with 1 to 2 polyps 0.6 to 0.9 cm be followed by a subsequent surveillance CT colonography in up to three years or be referred for colonoscopy, and that patients with 3 or more polyps 0.6 to 0.9 cm or any polyp ≥ 1 cm be referred for colonoscopy²¹. However, our analyses suggest that misclassification of a hypothetical polyp 0.7 cm in size as greater than 0.9 cm, or less than 0.6 cm using CT colonography may occur with moderate frequency. The degree to which such misclassification may occur leads us to speculate that polyp size estimation by CT colonography may be insufficiently reliable to be used as a primary factor to guide clinical management. This, in context with the fact that histology offers complimentary (if not more prognostic) risk information and, in consideration of recent modeling data which suggests excess cancer risk in patients with small polyps triaged to surveillance by CT colonography⁵⁶, raises the possibility that individuals with polyps suspected on CT colonography examination should be referred for diagnostic colonoscopy, with polypectomy if polyps are confirmed. In context of clinical investigation, our findings call into question the reliability of polyp matching algorithms that do not allow matching of polyps detected at CT and colonoscopy if size estimation differs by more than 50%. Removing size as an important criterion, or improving size estimation, might result in more favorable estimates of sensitivity for polyps by CT colonography. Future studies of CT colonography should continue to pursue novel methods of size estimation that may be more accurate and easier to follow over time, such as volume measurement⁵⁷ and use of optimal viewing modes³⁶, and place these advances in context of other clinical assessments of risk for colorectal cancer to more precisely delineate which individuals with polyps detected by CT colonography may forgo colonoscopy.

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Abbreviations

CT, computed tomographic.

Figure 1.

Figure 1a. Size difference for polyps measured by CT and pre-fixation (n=82). Plot of average per polyp difference in size, as measured at CT colonography and pre-fixation, by the average size recorded by the two techniques. Multiple polyps are represented by several points. See text for details of analysis. Solid line = average difference, dashed lines = 95% limits of agreement.

Figure 1b. Frequency of size variation differences between CT colonography and pre-fixation (n=82). A right skewed distribution is present.

Figure 1c. Ratio of polyp size measurement by CT colonography to pre-fixation (n=82). 95% limits of agreement by CT colonography 52% lower to 64% higher than pre-fixation size. Solid line = average ratio, dashed lines = 95% limits of agreement.

Figure 2. Ratio of polyp size measured by CT relative to pre-fixation 0.6 to 0.9cm in size (n=25)
 Dark circles indicate underestimation of size category (placed in <0.6cm group); triangles indicate overestimation of size category (placed in >0.9cm group). (5 cases underestimated; 1 case overestimated). Solid line = average ratio, dashed lines = 95% limits of agreement.

Figure 3. Ratio for individuals with one same segment polyp measured by CT relative to pre-fixation (n=14)

Plot of ratio, as measured at CT colonography relative to pre-fixation, by the average size recorded by the two techniques for participants with only one colonic polyp identified and measured in the same colonic segment. Dark circles indicate underestimation of size category by CT; triangle indicates overestimation of size category by CT. Solid line = average ratio, dashed lines = 95% limits of agreement.

Table 1

Agreement of CT colonography and Open Biopsy Forceps with Pre-fixation Poly Size Measurement

CT Colonography				
	N	95% limits of agreement	Average Ratio (CT/Prefix)	Average Absolute Difference in cm (SD) *
Overall	82	(0.48, 1.64)	1.06	0.15 (0.20)
Polyp size <0.6cm	37	(0.56, 1.84)	1.20	0.10 (0.08)
Polyp size 0.6 to 0.9cm	25	(0.56, 1.44)	1.00	0.11 (0.11)
Polyp size >0.9cm	20	(0.52, 1.22)	0.87	0.30 (0.34)
Open Biopsy Forceps				
	N	95% limits of agreement	Average Ratio (Forceps/Prefix)	Average Absolute Difference in cm (SD) **
Overall	666	(0.10, 2.07)	1.09	0.10 (0.15)
Polyp size <0.6cm	521	(0.05, 2.17)	1.11	0.09 (0.12)
Polyp size 0.6 to 0.9cm	107	(0.28, 1.66)	0.97	0.17 (0.18)
Polyp size >0.9cm	38	(0.57, 1.47)	1.02	0.19 (0.25)

* CT - Pre-fixation Size

** Colonoscopy Forceps - Pre-fixation Size

Table 2
Comparison of CT Colonography to Open Biopsy Forceps

	N	95% limits of agreement	Average Ratio (CT/Forceps)	Average Absolute Difference in cm (SD)
Overall [‡]	94	(0.32, 1.76)	1.04	0.20 (0.26)
Polyp size <0.6cm	39	(0.32, 2.12)	1.22	0.13 (0.17)
Polyp size 0.6 to 0.9cm	27	(0.55, 1.33)	0.94	0.12 (0.15)
Polyp size >0.9cm	28	(0.46, 1.36)	0.91	0.39 (0.34)

[‡] size categories based on pre-fixation size