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Differences between genders in colorectal morphology on CT colonography using a quantitative approach: a pilot study

Charles N. Weber [a], Jason A. Poff [b], Anna S. Lev-Toaff [c,1], Marc S. Levine [c], Hanna M. Zafar [c,*]

[a] Massachusetts General Hospital, Department of Radiology, Boston, MA, United States
[b] Greensboro Radiology Medical Imaging Professionals, Greensboro, NC, United States
[c] Hospital of the University of Pennsylvania, Department of Radiology, Philadelphia, PA, United States

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ABSTRACT

Purpose: To explore quantitative differences between genders in morphologic colonic metrics and determine metric reproducibility.
Methods: Quantitative colonic metrics from 20 male and 20 female CTC datasets were evaluated twice by two readers; all exams were performed after incomplete optical colonoscopy. Intra−/inter-reader reliability was measured with intraclass correlation coefficient (ICC) and concordance correlation coefficient (CCC).
Results: Women had overall decreased colonic volume, increased tortuosity and compactness and lower sigmoid apex height on CTC compared to men ($p < 0.0001$,all). Quantitative measurements in colonic metrics were highly reproducible (ICC = 0.9989 and 0.9970; CCC = 0.9945).
Conclusion: Quantitative morphologic differences between genders can be reproducibility measured.

1. Introduction

Incomplete optical colonoscopy (OC) has been reported in up to 20% of patients who undergo colon cancer screening [1] and is more common in women than in men [2–5]. Higher rates of incomplete OC in women are thought to reflect differences in colonic morphology, including colonic length and tortuosity, based on subjective visual analysis and endoscopic experience [5–8]. However, differences in morphology between genders have been difficult to measure quantitatively, as the colon can be distended in three dimensions, and the cecum, sigmoid, and transverse colon are variably mobile, depending on the presence and extent of various colonic mesenteries. A quantitative, reproducible method for assessment of colonic morphology would permit detailed evaluation of differences between men and women with incomplete OC. We therefore performed a pilot study using CT colonography (CTC) to explore differences between men and women for specific colonic metrics and also to determine the reproducibility of CTC for these metrics by measuring intra- and inter-reader reliability.

2. Materials and methods

We identified 260 patients in our computerized database who underwent CTC at out institution during a 4-year period between February 2008 and April 2012. Further review of patient records revealed that 176 (68%) of these 260 patients underwent CTC after incomplete OC (Fig. 1). The CTC software used for our study requires a continuous column of gas to produce a satisfactory centerline. Therefore, thirty-four patients were excluded from analysis on preliminary review by two trained readers because of colonic underdistention in 20 (underdistention was defined as one or more collapsed colonic segments such that a satisfactory centerline could not be generated), excessive fluid in ten (excessive fluid was defined as fluid occupying at least 50% of the colonic lumen), intestinal malrotation in two, technical error in two and partial colectomy in one. Of the remaining 141 patients (29 men and 112 women), the first 20 consecutive men and 20 consecutive women in this group were selected for this pilot.

Standard CTC preparation and technique were used for all patients (Appendix A). Quantitative assessment was performed on a customized Siemens Leonardo workstation (Leonardo, Siemens Medical Solution; Forchheim, Germany). Using the software's interface, extra-colonic gas-containing structures were removed, and an automated centerline was generated. Overall centerline length was then manually refined by the reader, with the colon divided into six segments (rectum, sigmoid colon, descending colon, transverse colon, ascending colon, and cecum) in standard fashion using a 3D colon view (surface rendering

* Corresponding author at: Hospital of the University of Pennsylvania, Department of Radiology, 1 Silverstein Bldg., 3400 Spruce Street, Philadelphia, PA 19104, United States.
E-mail address: hanna.zafar@uphs.upenn.edu (H.M. Zafar).
[1] Deceased.

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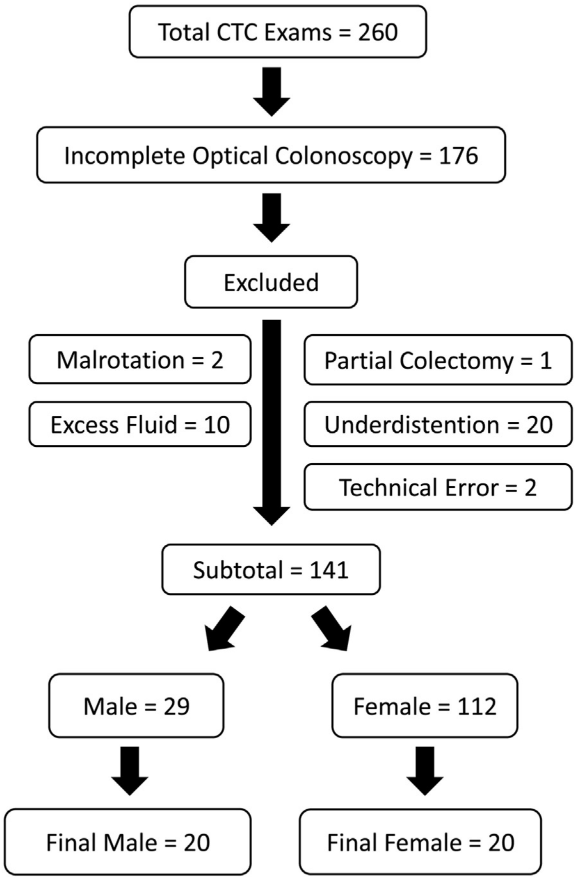

Fig. 1. Patient selection. Among 260 total CTC exams, 176 patients were referred for incomplete optical colonoscopy. Those with non-native anatomy (i.e., malrotation or partial colectomy), excess colonic fluid at exam, inadequate colonic distention, and technical errors with the software, were excluded. Of the remaining 141 exams, the first twenty consecutive CTC studies on men and women were selected for analysis.

view) and 2D multiplanar reformation (MPR). Once segmentation was complete, specific morphologic metrics were automatically derived by the software, including length (in millimeters [mm]), volume (in liters [L]), tortuosity, and compactness (in millimeters squared [mm^2]) for the colon overall and also for each individual colonic segment; tortuosity of the rectum was not evaluated because this segment is rarely if ever tortuous. Luminal volumes were calculated utilizing a simultaneous multi-label region growing algorithm which uses 1 mm increments of the centerlines as seeds and layers radially with voxels from each seed until the colon wall is reached. Tortuosity was defined as the number of high curvature points (HCPs) in the overall colon and each colonic segment, respectively. A high curvature point was defined by an algorithm utilizing mathematical criteria to identify acute bends in the colon that incorporated 80 mm limbs flanking proximal and distal to each 1 mm increment of the centerline (Fig. 2). Compactness was defined as the volume of the axis-aligned bounding box containing the centerline divided by the length of the centerline (Fig. 3); this metric accounted for differences in colon length and abdominopelvic cavity size between patients rather than using patient height to account for these differences [9]. The final metric, sigmoid apex height (in millimeters [mm]), was defined as the craniocaudal distance of the sigmoid apex (i.e., the most superior portion of the sigmoid colon), relative to the lumbosacral junction (LSJ), a fixed point (Fig. 4). Both the sigmoid apex and LSJ were designated manually using 2D MPR views. Positive and negative values were generated based on whether the sigmoid apex was located cranial or caudal to the lumbosacral junction, respectively.

CTC datasets were primarily assessed on supine views in 33 patients (including 15 men and 18 women) and on prone views ($n = 5$) or lateral decubitus views ($n = 2$) in seven patients (including five men and two women) in whom the supine view was suboptimal. The datasets were each interpreted twice by two trained readers at different time points, with a minimum 4-week interval between sessions. The quantitative data were compared by gender with the student's *t*-test (Table 1). Reproducibility was assessed by measurement of intra- and inter-reader reliability using the intraclass correlation coefficient (ICC) and the concordance correlation coefficient (CCC), respectively, with calculation of 95% confidence intervals (CI). Statistical analyses were performed with MedCalc Statistical Software 12.5.0.0 (MedCalc Software; Mariakerke, Belgium).

Our institutional review board approved all aspects of this retrospective study and did not require informed consent from any patients included in our study. This investigation was compliant with the Health Insurance Portability and Accountability Act.

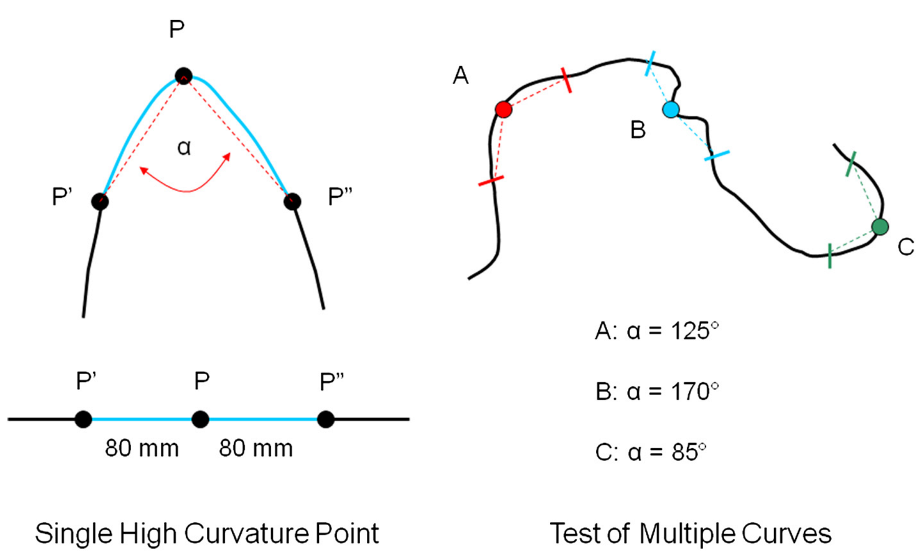

Fig. 2. Tortuosity. When the angle α between points P′, P, and P″ is smaller than 90° (left), point P is designated a high curvature point and included into the tortuosity score. Points P′ and P″ are selected by moving 80 mm antegrade or retrograde along the centerline from point P. To prevent over- and under-calling tortuosity, the flanking limbs about each point on the centerline are incorporated into the algorithm to ensure consistency. In a test of multiple curves (right), Points A and B represent a broad, lengthy bend and a small local undulation, both considered less likely to impede passage of an endoscope, and are therefore not included in the tortuosity score. Point C meets the criteria for a high curvature point (α < 90°) and is included in the tortuosity score.