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Determination of Normal Distribution of Distended Colon Volumes to Guide Performance of Colonic Imaging With Fluid Distention

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The purpose was to determine the normal distribution of distended colon volumes as a guide for rectal contrast material administration protocols. All computed tomography colonography studies performed at Emory University Hospital, Atlanta, Georgia, between January 2009 and January 2015, were reviewed retrospectively. In total, 85 subjects were included in the analysis (64% [54 of 85] female and 36% [31 of 85] male). Mean patient age was 65 years (range: 42-86 y). Distended colon volumes were determined from colon length and transaxial diameter measurements made using a 3-dimensional workstation. Age, sex, race, height, weight, and body mass index were recorded. The normal distributions of distended colon volumes and lengths were determined. Correlations between colonic volume and colonic length, and demographic variables were assessed. Mean colon volume was 2.1 L (range: 0.7-4.4 L). Nearly, 17% of patients had a distended colonic volume of >3 L. Mean colon length was 197 cm (range: 118-285 cm). A weak negative correlation was found between age and colonic volume ($r = -0.221$; $P = 0.04$). A weak positive correlation was found between body mass index and colonic length ($r = 0.368$; $P = 0.007$). Otherwise, no significant correlations were found for distended colonic volume or length and demographic variables. In conclusion, an average of approximately 2 L of contrast material may be necessary to achieve full colonic opacification. This volume is larger than previously reported volumes (0.8-1.5 L) for rectal contrast material administration protocols.

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Introduction

Colonic opacification with rectally administered contrast material is performed in the setting of penetrating trauma to evaluate for colonic injury. Protocols with contrast material volumes ranging from 800-1500 mL have been described.[1-3] Adequate distention of the colon is important to evaluate for injury, and opacification of the proximal colon may be especially challenging if adequate volumes of rectal contrast material are not administered.

That adequate colonic opacification is not always achieved and has been cited as a problem in the surgical literature.[4] Given the radiation concerns related to repeat scanning and logistical hurdles to readministration of additional rectal contrast material, adequate colonic distention on the first attempt is desirable. In our practice, we noted that the volume of rectal contrast material administered varied somewhat based on the radiologist of the day. We therefore decided to determine the range of distended colonic volumes at computed tomography (CT) imaging to serve as a guide for rectal administration of contrast material.

Materials and Methods

Institutional Review Board approval was obtained, and a waiver of informed consent was granted for this Health Insurance Portability and Accountability Act compliant study.

To determine the normal distribution of maximally distended colonic volumes, we retrospectively evaluated CT colonography (CTC) studies. All CTC studies performed at our institution between 2009 and 2015 were reviewed. Patient age, sex, race, body mass index (BMI), height, and weight were recorded. Age and sex were obtained from the image annotations. Race, BMI (BMI = weight (kg)/height (m^2)), height, and weight were recorded from the electronic medical record. Whether each patient had undergone a prior colonic resection before CTC also was recorded.

CTC Technique

CTC studies were performed after a bowel cleansing regimen. The colon was insufflated with carbon dioxide using an automated pump (Protocol Colon Insufflator, EZ EM; Lake Success, NY). Carbon dioxide was insufflated until the patient reported feeling significant distention, and a scout view was obtained in the supine position to verify adequate global colonic distention. Axial images were then acquired.

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Volume Calculation

Studies were reviewed using the Viatronix 3D Viewer (V3D Colon, Viatronix Inc.; Stony Brook, NY). This software produces a 3-dimensional rendering of the colon with a fly-through view along the colonic lumen. The software also generates a centerline through the colonic lumen, which allows for direct measurement of the distance from the anus to any location in the colon.

For consistency, the supine data set was used for the colonic volume calculation. Underdistended colons were defined as colons with multiple segments in which the colonic walls were collapsed and were in contact. Exclusion criteria were studies that did not include a supine data set and studies in which the colon was underdistended.

For each CTC study, the total length of the colon was determined by measuring the distance of the centerline from the cecal tip to the anus. The colon was then divided into 5 equidistant segments based on total length. A total of 2 transaxial measurements were made at the midpoint of each segment. The first diameter measurement was made to encompass the largest transaxial diameter, and the second measurement was made perpendicular to the first measurement. Total colon volume (V) was then calculated based on the mean of the transaxial diameters using the formula for a cylinder, $V = \pi r^2 L$, where r = radius and L = length.

Statistical Analysis

Statistical analysis was performed using the *R* software package (3.2.0). The 2-sample t test was used to compare mean colon volumes and lengths based on sex, age, and race. Pearson correlation coefficients were computed for colon volumes and height, weight, BMI, and age. Pearson correlation coefficients also were computed for colon length and height, weight, BMI, and age.

Results

In total, 95 CTC examinations were initially identified. A total of 6 studies were excluded as they did not include a supine data set, and 4 studies were excluded as the colon was underdistended, resulting in a final study population of 85 CTC examinations. CTC examinations were from 85 subjects (64% [54 of 85] female; 36% [31 of 85]) male). Mean patient age was 65 years (range: 42-86 y). Information regarding race was available for 66 subjects of whom 70% (46 of 66) were white, 29% (19 of 66) were African-American, and 1% (1 of 66) were Asian. Subject age, weight, height, and BMI are reported in Table 1. A total of 2 patients had undergone a prior colonic resection before the CTC study (a 56-year-old patient and a 75-year-old patient).

The distribution of distended colonic volumes and lengths are reported in Figures 1 and 2. Mean distended colon volume was 2.1 ± 0.9 L (range: 0.7-4.4 L) (Fig. 3). Mean distended colon length was 197 ± 35 cm (range: 118-285 cm).

Comparisons of distended colonic lengths and volumes based on sex, age, and race are reported in Table 2. Patients > 60 years of age had smaller colon volumes than patients ≤ 60 years of age (mean = 2.0 L vs 2.4 L; $P = 0.04$). No difference was found for distended colonic volume or length based on sex or race.

Table 1
Patient demographics.

	Mean ± SD	Range
Age, y	65 ± 9	42-86
Weight, kg	157 ± 28	83-198
Height, cm	90 ± 37	48-191
Body mass index*	28.5 ± 7.4	17.0-59.9

*Body mass index = weight (kg)/height (m^2).

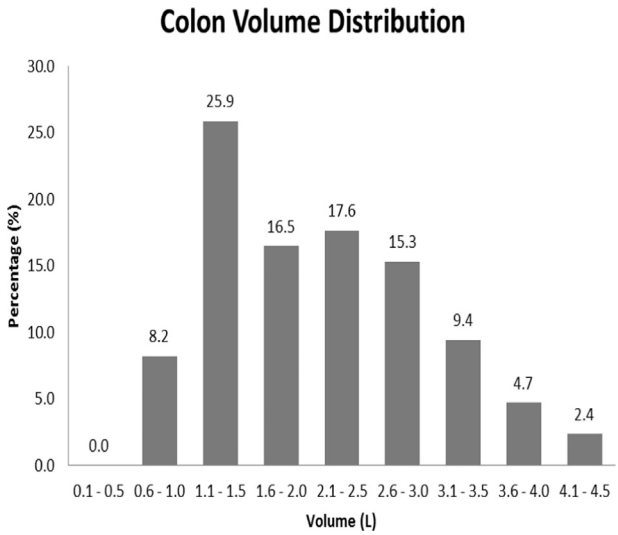

Fig. 1. Distribution of distended colonic volumes with volume (L) on the x axis and percentage of patients (%) on the y axis.

Correlation coefficients for distended colonic volumes and colonic lengths are reported for age, BMI, height, and weight in Table 3. A weak negative correlation was found between age and distended colon volume ($r = -0.221$; $P = 0.04$). A weak positive correlation was found between BMI and colon length ($r = 0.368$; $P = 0.007$). No statistically significant correlation was found between distended colonic volume or length, and the other demographic variables. Box plots of colonic length and volume based on subject age and BMI are reported in Figure 4.

Discussion

The mean distended colonic volume of 2.1 L and maximum colonic volume (4.4 L) are substantially higher than previously reported volumes (0.8-1.5 L) for rectal contrast material administration protocols.[1-3] These results suggest that protocols for rectal administration of contrast material should be modified to include 2 L as a starting point, especially if a proximal colonic site

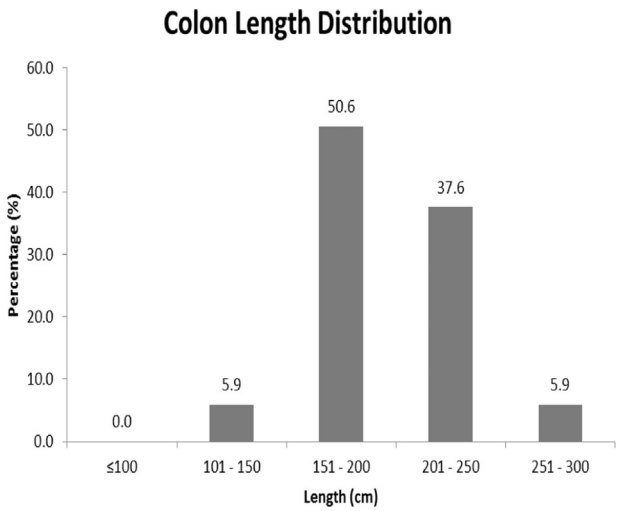

Fig. 2. Distribution of distended colonic lengths with volume (L) on the x axis and percentage of patients (%) on the y axis.

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