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Anatomic Classification of the Endoscopic Appearance of the Normal Appendiceal Orifice: A Novel Tool for Recognition and Documentation of Cecal Intubation

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Abstract

Complete colonoscopy for cancer screening requires cecal intubation. Failure to reach and examine the cecum may result in missed right colon pathology. We developed and validated a novel classification scheme for the endoscopic appearance of the normal appendiceal orifice (AO). We analyzed 1,456 AO images and grouped them into four categories based on distinguishing features: 'diverticuloid', 'umbilicoid', 'crescent' and 'linear'. An expert panel classified the images and modified these categories, combining crescent and linear categories into 'curvilinear'. A 100-image subset was classified twice by a validation cohort consisting of gastroenterology faculty and fellows. Inter-observer agreement among the expert panel, and intra- and inter-observer agreement among the validation cohort were analyzed using Fleiss' kappa statistic. The distribution of AO images was 67% curvilinear, 19% umbilicoid and 10% diverticuloid; 85 images (4%) were not classifiable. There was substantial inter-observer agreement among the expert panel (kappa, 0.72). Inter-observer agreement among the validation cohort was moderate (kappa, 0.53 and 0.55 for the first and second viewing, respectively). Intra-observer kappa values among the validation cohort were 0.69 for the overall classification, 0.65 for diverticuloid, 0.70 for umbilicoid and 0.70 for curvilinear, indicating substantial agreement. This simple, validated classification scheme for the endoscopic appearance of the normal AO can be used both as a research and clinical tool to measure endoscopic quality, improve cecal examination and document successful cecal intubation.

Keywords

quality assurance; colonoscopy; classification; endoscopy; cecal intubation; appendiceal orifice; outcome measures

INTRODUCTION

Colonoscopy is the preferred screening method for colorectal cancer, the second leading cause of cancer death in the United States (Baxter et al., 2009). Nonetheless, the efficacy of colonoscopy is highly dependent on the quality of the examination. Quality assurance was the subject of many recent investigations (Aslinia et al., 2006; Faigel et al., 2006; Cotton et al., 2006; Rex et al., 2006; Lieberman et al., 2007). Several studies indicate a lower neoplasia detection rate in the proximal colon, particularly the cecum and ascending colon (Brenner et al., 2006; Singh et al., 2007; Bressler et al., 2007; Baxter et al., 2009). Although other factors may play a role, failure to examine the proximal colon completely, including cecal intubation, is considered a major contributor to this endoscopic shortcoming (Brenner et al., 2006; Singh et al., 2007; Bressler et al., 2007; Baxter et al., 2009). Hence, it is not surprising that benefits of colonoscopy for reduction of mortality from proximal colon cancer correlate with endoscopic skills and practice (Baxter et al, 2011; Rex, 2011).

During endoscopy, the cecum is recognized by key anatomical landmarks; the appendiceal orifice and ileo-cecal valve. Because they are verifiable, photographic and video documentation of cecal intubation are advantageous compared to written statements alone. Correct identification of cecal landmarks and standardized documentation of cecal intubation are likely to reduce the rate of incomplete colonoscopy. Despite the importance of proper recording of cecal intubation, there is no validated and widely accepted method of photo-documentation.

The U.S. Multi-Society Task Force on Colorectal Cancer suggests that visualization of both the lips of the ileo-cecal valve and the appendiceal orifice can verify cecal intubation with complete certainty (Rex et al., 2002). The Task Force recommends that cecal intubation be achieved in at least 90% of cases and in at least 95% of colorectal cancer screening colonoscopies. All procedure reports are expected to include photo-documentation of cecal landmarks (Rex et al., 2002). Nonetheless, even to experienced endoscopists, sometimes folds and diverticuli in the proximal or mid colon may, at first glance, mimic the appearance of the ileo-cecal valve and AO.

In the course of evaluating the quality of colonoscopy practice at our institution (Aslinia et al., 2006), it became apparent that, in contrast to surgical and pathological classification of appendiceal anatomy, there is no validated classification for the endoscopic appearance of the AO. Classification schemes for normal and pathological endoscopic findings (e.g. esophagitis, Barrett's esophagus, and stigmata of hemorrhage from bleeding peptic ulcers) have advanced clinical care and research by facilitating recognition and grading of these findings. These considerations prompted the current study to define and classify the endoscopic appearance of the normal AO.

PATIENTS AND METHODS

Image collection

This study was approved by the Institutional Review Board of the University of Maryland School of Medicine. To identify studies that included normal AO images, we reviewed electronic reports of 12,911 consecutive colonoscopies performed between March 1, 1999 and November 30, 2008. March 1999 was chosen as the start date because our electronic documentation software “ProVation” (ProVation Medical Inc., Minneapolis, MN) was implemented in mid-February 1999. This electronic database contains all endoscopic procedures performed at the University of Maryland Medical Center from March 1999 onwards. Of 12,911 reports, 2,549 included AO images. Of these, we excluded 1,093 images for one or more of the following reasons: distorted or out-of-focus image, unidentifiable AO or image obscured by stool or cecal pathology (including prior appendectomy). The resulting 1,456 images of the AO were included for analysis (Figure 1).

Image classification by expert panel

Based on distinguishing features, images were initially grouped into four categories by the first and senior authors:

1. Diverticuloid: wide-open orifice without adjacent surrounding folds.
2. Umbilicoid: closed orifice with two or more surrounding circular or nearly circular folds.
3. Crescent: curved orifice forming at least one-fourth of a circle or oval with limited or no surrounding folds.
4. Linear: orifice is a straight line with limited or no surrounding folds.

This classification was reviewed and revised by an expert panel consisting of senior endoscopists, three in academic and one in private practice. Their average duration of endoscopic practice after completion of gastroenterology fellowship was 31.5 years (range, 29 to 36 years).

Each member of the expert panel was individually shown and asked to classify all 1,456 images. Images were labeled according to the classification chosen by at least three of four experts. When three out of four experts were not able to agree on classification, the image was relegated to a fifth group- ‘uncategorized’ (85 images).

Inter-observer agreement was calculated based on the four-group classification, excluding uncategorized images. Because of overlap between the linear and crescent categories, after reviewing all 1,456 images, the panel recommended merging crescent and linear into one category, curvilinear; curved or straight orifice with limited or no surrounding folds (Figure 2). This resulted in a three-category classification scheme. The final distribution of images was 10% diverticuloid, 19% umbilicoid, 65% curvilinear and 6% uncategorized.

Validation cohort

The three-group classification scheme was subsequently validated by 12 faculty gastroenterologists and 10 fellows from the Division of Gastroenterology and Hepatology at the University of Maryland Medical Center. The validation cohort reviewed a 100-image subset of the original 1,456 images. The subset was created by stratified random sampling within each of the three categories and the 85 uncategorized images. The stratified sampling assured that the frequency of the three categories and the uncategorized images in the 100-image subset would be the same as that seen in the original 1,456 images. Members of the validation cohort reviewed the 100 images at two separate viewing sessions, one week apart. Images were presented in random order at both the first and second viewing sessions, allowing us to determine both inter- and intra-observer agreement.

The validation cohort was introduced to the three-group AO classification during a 10-minute tutorial at which the cohort was shown 40 images representing typical examples of each category. The tutorial was designed to be compatible with computer-based training. None of the 40 tutorial images were included in the 100-image subset used for testing. In both sessions, reviewers had 10 seconds to classify each image.

Statistical methods

Inter- and intra-rater agreement of the categorization of AO images was quantified using Fleiss' kappa (K) (Fleiss, 1971). Fleiss' kappa is the quotient of agreement achieved beyond that due to chance divided by maximal agreement attainable beyond that due to chance. Values approximating one indicate that the achieved agreement approaches the maximal value obtainable; values closer to zero indicate that the achieved agreement is small compared to maximal possible agreement. To qualify kappa, we used the categories of agreement proposed by Landis and Koch (1977): less than 0, no agreement; 0 to 0.20, slight agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; 0.81 to 1.00, almost perfect agreement. We accepted the kappa from the four-category classification rating of the expert panel (0.72) and tested the validation cohort using the three-category classification system.

RESULTS

Expert panel

The original analyses to determine inter-observer agreement among the experts using the four-category classification revealed a Fleiss' kappa value of 0.72 ($p < 0.0001$); this represents substantial agreement. Among the expert panel, overall kappa for assessment of the endoscopic appearance of the AO using the three-category classification was also substantial (kappa=0.73; $p < 0.0001$). The difference in kappas for the two classifications was not statistically significant (Table 1). Using either classification scheme, inter-observer agreement for individual categories and overall classification was 'substantial' to 'almost perfect'.

To assess changes in AO appearance over time, 70 paired AO images from a subset of patients with at least two procedures performed at least three year apart were reviewed by

our 'masked' expert panel. Intra- and inter-observer kappas for agreement in AO classification over time were 0.21 (fair) and 0.43 (moderate), respectively (all $p < 0.0001$). In particular, the fair intra-observer kappa indicates that, using our classification scheme, AO appearance is not static and can change over time.

Validation cohort

In the first session, inter-observer kappas for assessment of AO appearance showed moderate agreement: 0.54 for curvilinear, 0.48 for diverticuloid, 0.56 for umbilicoid and 0.53 for overall classification (all $p < 0.0001$). For the second session, the values were 0.56 for curvilinear, 0.52 for diverticuloid, 0.57 for umbilicoid and 0.55 for overall classification, again representing moderate agreement (all $p < 0.0001$, Table 2). Although these values indicate incremental improvement in ratings, the observed differences in kappas for the two classification sessions were not statistically significant.

Table 3 summarizes kappa values for intra-observer agreement within the validation cohort. We observed substantial intra-observer agreement for individual categories as well as for the overall classification.

Kappa values were subsequently stratified based on reviewer gender and seniority (gastroenterology faculty vs. fellow). Gender and academic position did not significantly affect either intra- or inter-observer agreement (data not shown).

DISCUSSION

A key quality assurance measure for colonoscopy is achievement and documentation of cecal intubation. Despite the importance of achieving and documenting cecal intubation (Rex et al., 2002; Rex et al., 2006; Lieberman et al., 2007; Rex et al., 2009) and regardless of anatomical landmarks used to identify the cecum (Cirocco and Rusin, 1993; Cirocco and Rusin, 1995; Marshall and Brown, 1996; Thuraisingam et al., 2008), cecal intubation is frequently not supported by objective evidence (Thomas-Gibson, 2008). Moreover, photo-documentation of the ileo-cecal valve alone does not prove cecal intubation (i.e. that the colonoscope was passed proximal to the ileo-cecal valve). The U.S. Multi-Society Task Force on Colorectal Cancer recommends photo-documentation of cecal landmarks (Rex et al., 2002). The European Society of Gastrointestinal Endoscopy (ESGE) also recommends capturing at least two images to document complete colonoscopy; the ileo-cecal valve, referred to as a fixed reference point, and the cecum with visualization of the appendiceal orifice. ESGE recommendations indicate that the cecum image confirms that the portion proximal to the ileo-cecal valve was examined (Rey et al., 2001). A combination of photographs is more convincing than a single photograph of the ileo-cecal valve, AO, the cecum from just distal to the ileo-cecal valve, or the terminal ileum (Rex, 2000). However, there is evidence that as a single image, a photograph of the cecum just distal to the ileo-cecal valve is most convincing to document complete colonoscopy, especially when the valve lips or notch are visible (Rex, 2000). An AO appearance with surrounding triangular folds (diverticuloid in our classification) and a crescent-shaped orifice (curvilinear) are associated with a high score for convincing other endoscopists of cecal intubation (Rex, 2000).

Several classifications for the pathological appearance of the appendix have been proposed. In 1910, Moschcowitz (1910) proposed the first classification of appendiceal intussusception, modified by McSwain (1941) and later by Langsam (1984). Two classifications of congenital abnormalities of the appendix were proposed (Cave, 1936; Wallbridge, 1963). A surgical classification of acute appendicitis was introduced by Schullinger (1936) and Bower (1939). Nonetheless, until now, no classification scheme for the endoscopic appearance of the normal AO has been available.

The current classification of the appearance of normal AO was proposed for several purposes: (1) To define variations in the endoscopic appearance of a key landmark of cecal intubation; (2) To create a teaching and quality assurance tool to attract endoscopists' attention to the AO during colonoscope insertion; (3) To encourage endoscopists to visualize the AO which is not as readily accessible as the ileo-cecal valve during colonoscope insertion, thereby requiring intubation of the caput cecum and thorough examination of the cecum; and, (4) To add consistency in documenting AO appearance using a validated nomenclature that can be used to compare the endoscopic appearance of the AO in health and disease. For example, the AO image in Figure 3 is not readily classifiable by our proposed scheme; biopsies revealed mucinous adenocarcinoma of the appendix.

The proposed three-category AO classification is easy to remember and little time (fewer than 10 seconds per image) was needed for either experienced endoscopists or trainees to categorize the AO. A brief tutorial can introduce the classification to endoscopists in five to ten minutes. Moreover, this classification has now been formally validated. Regarding inter- and intra-observer agreement, the ideal kappa value, 1.0, represents perfect agreement. Many endoscopic measures in common use do not achieve this ideal. Examples include the Los Angeles classification of esophagitis ($K=0.49$ to 0.65) (Rath et al., 2004), endoscopic ultrasound features of chronic pancreatitis ($K=0.41$ to 0.51) (Wallace et al., 2001) and recognition of stigmata of hemorrhage from bleeding peptic ulcers ($K = 0.34$ to 0.66) (Lau et al., 1997). Hence, kappas in our study, ranging from 0.48 to 0.72 for examination by our expert panel and validation cohort for a series of AO images, are either equivalent or superior to those for commonly-used endoscopic classifications.

Substantial to almost-perfect inter-observer agreement among the experts, moderate inter-observer agreement and substantial intra-observer agreement within the cohort validated the current classification for use in routine clinical practice. Possible reasons for the difference in kappa values between the experts and validation cohort include the larger number of images reviewed by experts (1496 vs. 240), experts' research interest in the subject and the larger number of reviewers in the validation cohort (22 vs. 4). Moreover, in the validation cohort, the lack of a significant difference in kappa values between faculty and fellows indicates that learning this classification scheme does not require more than a brief tutorial. That is, it has a relatively short learning curve.

Use of this new classification scheme is likely to advance the quality of colonoscopy and not merely add another layer of documentation: (1) It provides a tool to distinguish a normal from abnormal AO; (2) It is an intervention that will help teach endoscopists to recognize the AO (e.g. distinguish a diverticuloid AO from a cecal diverticulum); and (3) It requires

intubation of the caput cecum, thereby improving cecal examination for neoplasia and other lesions.

Our study had several strengths; a large sample of images, four experts classifying every image and 22 reviewers in the validation cohort. This classification scheme introduced the distinctive and descriptive aspects of the endoscopic view of the AO in a simple and memorable way. In reviewing and selecting images for further analysis, we were careful to ensure that these were, in fact, photographs of the AO. It is very unlikely that photographs taken by experienced board-certified gastroenterologists, who used additional criteria for cecal intubation (e.g. ileal intubation and images of the ileo-cecal valve), and vetted by our expert panel, were not of the AO. A limitation of our study design was the use of still images; we acknowledge that the view of the AO may change depending on the angle of approach, patient position and the degree of colonic distention. Snapshots of the AO cannot assess these parameters. This is likely why we observed only ‘fair’ intra-observer agreement for paired AO images taken several years apart from the same person. Nonetheless, for colonoscopy still images of the AO remain the current standard-of-practice for image documentation (Rex, 2000).

In conclusion, we propose a simple and validated classification for the endoscopic appearance of the normal AO. Applying this classification at colonoscopy and in preparing procedure reports is likely to provide greater assurance of cecal intubation and examination, encourage capture of AO images for documentation, improve standardization of colonoscopy reports and increase detection of cecal pathology.

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Figure 1.

Flow diagram for the study. After reviewing reports of 12,911 consecutive colonoscopies, 2,549 AO images were chosen. We excluded 1,093 images for the following reasons: distorted or out-of-focus image, unidentifiable AO or image obscured by stool or cecal pathology. As a result, 1,456 AO images were analyzed and grouped into four categories. An expert panel reviewed and classified the images and modified the criteria to combine crescent and linear into curvilinear. From these 1,456 images, 100 were selected at random for classification by the validation cohort.

Figure 2.

Representative images for each category of the proposed classification of the endoscopic appearance of the appendiceal orifice. Each row shows four representative AO images for each category; diverticuloid (a-d), umbilicoid (e-h), and curvilinear (i-l).

Figure 3.
Endoscopic image of the appendiceal orifice in a patient with mucinous adenocarcinoma of the appendix.

TABLE 1

Fleiss' kappa statistics for interobserver agreement based on the initial (four-group) and three-group classification of the endoscopic appearance of the appendiceal orifice by the expert panel

AO category	Four-group classification Kappa (95% CI)	Three-group classification Kappa (95% CI)
Diverticuloid	0.72 (0.71, 0.73)	0.72 (0.71, 0.73)
Umbilicoid	0.84 (0.83, 0.85)	0.84 (0.83, 0.85)
Crescent	0.67 (0.66, 0.68)	0.80 (0.79, 0.81)
Linear	0.67 (0.66, 0.68)	-
Overall	0.72 (0.70, 0.74)	0.73 (0.71, 0.75)

TABLE 2

Fleiss' kappa statistics for interobserver agreement based on the three-group classification of the endoscopic appearance of the appendiceal orifice by the validation cohort

AO category	First session Kappa (95% CI)	Second session Kappa (95% CI)
Diverticuloid	0.48 (0.46, 0.50)	0.52 (0.50, 0.54)
Umbilicoid	0.56 (0.54, 0.58)	0.57 (0.55, 0.59)
Curvilinear	0.54 (0.52, 0.56)	0.56 (0.54, 0.58)
Overall	0.53 (0.50, 0.56)	0.55 (0.52, 0.58)

TABLE 3

Fleiss' kappa statistics for intra-observer agreement based on the three-group classification of the endoscopic appearance of the appendiceal orifice by the validation cohort

AO category	First session Kappa (95% CI)
Diverticuloid	0.65 (0.45, 0.85)
Umbilicoid	0.70 (0.50, 0.90)
Curvilinear	0.70 (0.50, 0.90)
Overall	0.69 (0.55, 0.83)