Association Between Visual Gaze Patterns and Adenoma Detection Rate During Colonoscopy: A Preliminary Investigation

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OBJECTIVES: Eye gaze tracking (EGT) technology follows a person’s gaze and records the resulting visual gaze pattern (VGP). Adenoma detection rate (ADR) is a validated measure of colonoscopy quality. Higher ADRs are associated with prolonged withdrawal times and other endoscopic maneuvers that allow a better visualization of the mucosa; however, the influence of VGP has yet to be explored. We aim to quantify the VGP for endoscopists observing colonoscopy videos and describe the association between VGP and ADR. Furthermore, we will evaluate the relationship between VGP and the endoscopists’ years of experience.

METHODS: Eleven endoscopists watched three videos while their VGP was recorded. The videos corresponded to 3 min of three different colonoscopy withdrawals. We divided the screen into a 3×3 grid of nine segments: eight peripheral and one central. We compared percent of gaze time (GT) in the central vs. peripheral segments using a paired t-test. VGP with ADR and years of practice were evaluated using Pearson’s test.

RESULTS: Subjects spent more GT in the screen’s central segment (65 vs. 33%, P<0.001). ADR was significantly associated with increased percentage of central GT (r=0.67, P=0.024) and increased mean GT in the central segment (r=0.70, P=0.017). There was negative correlation between endoscopists’ years of practice and the percentage of central GT (r=−0.67, P=0.025), but no correlation between years of practice and percentage of peripheral GT (r=0.24, P=0.47).

CONCLUSIONS: This reveals an association between a centrally focused VGP and ADR. Future steps include confirming in a larger sample and exploring if VGP can retrain low ADR endoscopists to perform higher quality colonoscopies.

INTRODUCTION

Eye gaze tracking (EGT) technology makes it possible to follow a person’s gaze and record the resulting visual gaze pattern (VGP) of saccadic eye movements and fixations. These eye movements can be mapped and analyzed to detect potential deviations from the expected target of interest.

Research studies have found differences in VGP when comparing subjects of different experience levels performing a given task (1–4). Studies performed with automobile drivers have confirmed that certain gaze patterns are more often present in experienced drivers than in novices, and that certain visual skills could be associated with a reduction in the likelihood of being involved in a motor vehicle accident (1,3). Furthermore, less experienced individuals can be successfully trained to acquire these specific patterns of eye movement (1,3).

The applications of this technology to medicine, particularly to improve quality, are vast. EGT has been used for radiologists as a way to improve diagnostic yield (4,5). Moreover, EGT has even been incorporated as part of the surgical curriculum in certain academic centers as a method to monitor the progress of acquiring early surgical skills by the trainees (6). One leading potential application of this technology is quality improvement of colonoscopy
procedures by improving how we examine the colon and detect precancerous polyps.

Adenoma detection rate (ADR) is a widely accepted measure of colonoscopy quality and has been recently validated as an independent predictor of the risk of interval cancer after screening colonoscopy (7). To date, prolonged withdrawal time, adequate bowel preparation, and optical factors that improve the visualization of the mucosa are recognized features associated with the quality of colonoscopy performance as measured by higher ADRs (8,9). However, there is currently no data on the potential influence of VGP on ADRs. Our primary hypothesis is that certain VGPs are associated with higher ADRs, particularly the extent to which the endoscopists focus on the central portion of the video monitor vs. the peripheral portion.

The aims of our preliminary study are to quantify the VGP for endoscopists observing standardized colonoscopy videos and describe the association between VGP and ADR. In addition, we aim to evaluate the relationship between VGP and endoscopists’ years of experience.

METHODS

We invited 18 senior endoscopists to participate in this study, who measured their ADR unbeknownst to them. Seven subjects were excluded from the study for different reasons: five needed bifocal lenses or had other visual problems that made it impossible to track the corneal reflect and two endoscopists were unavailable. Therefore, we included 11 endoscopists, all of whom performed between 64 and 125 colonoscopies during the study period in which ADR was measured. The median number of colonoscopies performed was 96. When comparing the 11 endoscopists who were included in the study with the 7 endoscopists who were excluded, we did not observe any noticeable differences in age, gender, or ADR (data not shown). However, the number of years of post-fellowship program completion was higher in the seven endoscopists who were excluded (Median: 22 vs. 13 years, \( P = 0.023 \)). None of the subjects were aware of the specific hypotheses (central vs. peripheral gaze) of the study and were simply asked to observe the colonoscopy as they normally would. This study was approved by the Mayo Clinic Institutional Review Board (IRB) on 29 September 2009, IRB # 09-005879.

The ADR of the 18 endoscopists invited to participate in our study was previously calculated based on the review of the charts of consecutive patients undergoing screening, diagnostic, and surveillance colonoscopy between September 2006 and December 2007. We excluded patients with family history of polyposis syndrome, incomplete colonoscopy, or multiple colonoscopies. Thus, we reviewed endoscopic and pathology records from 2,430 patients. The estimation of the ADR was calculated for each endoscopist as the percentage of patients undergoing colonoscopy that had at least one adenomatous polyp (9).

All subjects watched three videos under similar conditions while their VGP was recorded by an eye tracking system (Applied Science Laboratories Mobile Eye, Bedford, MA). The videos were displayed on a standard high-definition endoscopy monitor and corresponded to 3 min of uncompressed high-definition segments from three normal colonoscopy withdrawals. The videos were the same and were presented in the same order to all participants. We decided a priori to analyze only the third of the three videos taped in order to decrease potential biases related with an increased awareness of the endoscopists at the beginning of the recording. This also helped to eliminate any possible learning or adjustment period that the endoscopists might experience in using the goggles in the first two videos (6 min). The endoscopists did not know which video was going to be analyzed.

The eye tracking system consisted of an eye camera and a color scene camera mounted on a pair of spectacles (Figure 1). These spectacles also included an adjustable combiner or hot mirror that is partially reflective in the near-infrared and infrared range. Therefore, this set-up reflected the eye image and cornea between the user and the eye camera. The eye camera recorded the eye being tracked, while the scene camera recorded the environment being observed by the user (the endoscopy monitor playing the colonoscopy video). The images from both cameras were combined and recorded on the same digital videotape by alternating frames, and the resulting video was transferred to a computer where the images were processed. The eye movement data were converted to a cross-hair that represents the subjects’ point of gaze on the scene video (Figure 2) (1,10).

To quantize the eye gaze data, eight black dots were applied to the frame around the endoscopy monitor, to define a 3×3 grid that subdivided the display surface of the monitor into nine equal segments: eight peripheral and one central. Then, the video from the scene camera with the superimposed crosshair was stepped frame-by-frame. The segment of fixation (as indicated by the crosshair) was tabulated using the Interact Mangold Software (Interact quick start manual v1.3. Mangold International GMBh, Arnstorff, Germany).
The software provided us with the following information: total gaze time (GT, total duration of tracking, in seconds); percent of the total GT spent in each segment of the screen or out of the screen; number of times that the gaze was directed toward each segment (number of fixations) and their mean duration in seconds or mean gaze duration. The length of time that gaze was not on the screen was also calculated.

Numerical variables were summarized with the sample median, minimum, and maximum. We compared the percent of GT in the central vs. peripheral segment of the screen using a paired t-test. Associations of visual gaze parameters with ADR and years of endoscopist practice since the completion of a Gastroenterology fellowship were evaluated using Pearson’s test of correlation. The association between ADR and years of endoscopist practice since the completion of a Gastroenterology fellowship was also examined using Pearson’s test of correlation. For all tests of correlation, Pearson’s r was estimated along with a 95% confidence interval (CI); $r^2$ was also calculated. $P$ values $\leq 0.05$ were considered statistically significant. All statistical analyses were performed using S-Plus (version 8.0.1; Insightful Corporation, Seattle, WA).

**RESULTS**

The final study group consisted of 10 males and 1 female endoscopists, where the median age at the time of VGP measurement was 48 years (min = 42 years, max = 58 years). The median length of practice since the completion of a Gastroenterology fellowship was 13 years (min = 7 years, max = 25 years). The median ADR in this group of physicians was 25% (min = 15%, max = 46%). For visual gaze parameters, the median percent of time spent in different areas of the screen was 65% (min = 54%, max = 82%) for the center of the screen, 33% (min = 16%, max = 39%) for the peripheral area of the screen, and 2.7% (min = 0.1%, max = 13.3%) not on the screen. All subjects spent more GT in the central portion of the screen compared with the periphery ($P < 0.001$).

As displayed in Figure 3, ADR was significantly associated with the increased percentage of central GT ($r = 0.67$, 95% CI: 0.12–0.91, $r^2 = 0.45$, $P = 0.024$). ADR was also significantly associated with increased mean gaze duration in the central part of the screen ($r = 0.70$, 95% CI: 0.17–0.92, $r^2 = 0.49$, $P = 0.017$), but not with the number of times that the gaze was directed toward the center of the screen ($r = -0.44$, 95% CI: -0.82 to 0.21, $r^2 = 0.20$, $P = 0.17$). We did not observe a statistically significant association between ADR and percentage of peripheral GT ($r = -0.46$, 95% CI: -0.83 to 0.19, $r^2 = 0.22$, $P = 0.15$).

We also observed a negative correlation between an endoscopist’s years of practice and the percentage of central GT ($r = -0.67$, 95% CI: -0.90 to -0.11, $r^2 = 0.44$, $P = 0.025$; see Figure 4). However, no association between the years of practice and percentage of peripheral GT was noted ($r = 0.24$, 95% CI: -0.42 to 0.74, $r^2 = 0.06$, $P = 0.47$). Of interest, although not statistically significant, there was a trend toward a lower ADR with more years of practice since the completion of a Gastroenterology fellowship ($r = -0.53$, 95% CI: -0.86 to 0.10, $r^2 = 0.28$, $P = 0.093$).
DISCUSSION

The results of our preliminary study show a positive correlation between ADR and central VGP. High adenoma detectors tended to focus on the central portion of the screen, whereas low adenoma detectors move their gaze more broadly across the screen. In addition, we found that the more experienced endoscopists spent a lower percentage of time focusing on the central VGP.

Colorectal cancer is the third leading cause of cancer death in the United States, although its incidence has significantly decreased in the last decade mostly due to the implementation of screening strategies (11). Colonoscopy and polypectomy are the hallmark in the diagnosis and prevention of colorectal cancer (8,12). Of concern, recent studies have suggested that colonoscopy screening programs do not completely prevent the risk of colorectal cancer, which may be due to the failure to detect some neoplastic lesions (8,12,13).

Continued improvement in the quality of colonoscopy is a major goal for the gastroenterology community and public at large. Indeed, several studies have been conducted with the aim of identifying quality indicators suitable of modification, such as the ADR (7). The rate of detecting adenomas can widely vary among different endoscopists (14). In our sample, the range of ADR varied threefold between the highest and the lowest detector. The reason for such variation is predominantly endoscopist dependent (15). Slowing the withdrawal time, careful washing–suction technique, and inspection behind of folds and flexures are among the most relevant factors that can increase the ADR, but it is likely that other variables not yet identified may exert an influential role as well (11).

Visual attention is important at the time of the procedure, especially when approaching small or flat lesions that could easily be overlooked. However, to date, the role of visual attention in the quality of colonoscopies has only been indirectly analyzed (16).

EGT technology was used in the article by Nodine et al. (17), to evaluate whether retrospectively visible cancers that were missing at screening mammograms would receive visual attention and could be identified in a blinded review. The results showed that up to 70% of these initial missed lesions did not attract prolonged visual attention, and most important, that only 40% of them were finally correctly diagnosed (17). This study supports the importance of eye position while tracking potential lesions during a diagnostic procedure. In a recent study by Meining et al. (18), EGT technology was applied to study gaze pattern on fixed images with white light and narrow band imaging to assess lesion detection. This paper suggests that EGT technology may be a valuable tool to assess an endoscopist’s methods for image review and offers opportunities to improve lesion detection and classification (18).

Performing a colonoscopy requires multiple object tracking, with a potential target arising anywhere along the colon and as well as anywhere on the screen. Fehd and Seiffert (19) described the resemblance between multiple object tracking patterns during an experiment. Participants tracked either 1 or 3 of 8 dots moving randomly on a black background while their eyes movements were recorded. Observers had the tendency to focus their eyes at a central point between the multiple targets (center-looking strategy) (19). A study later performed by the same researchers confirmed that the subjects remained focused on the center of a video screen, in spite of a decrease in the object speed or in the object size, or even when visibility was limited to the peripheral area. Moreover, when both techniques were directly compared in a group of individuals that were instructed to either look at the center or not at all, the center-looking strategy resulted in a better tracking performance than the target looking (20). These experiments might explain why those endoscopists with higher ADRs tend to focus on the central segment of the screen rather than looking at the periphery.

However, the second finding of our study was surprising. We found that among highly experienced endoscopists, this central gaze pattern was less prevalent, showing a strong negative correlation with the years of experience. This could be attributed to visual and/or attention changes related to age. A significant restriction in peripheral vision often occurs with aging and is exacerbated under conditions of divided attention (21,22).

There is a lack of data to support that endoscopists of more advance age and experience present significantly lower ADR. However, the study by Kaminski et al. (7) analyzed data from 186 endoscopists according to their ADR. The results showed that those with less years of experience were more likely to present higher ADR (46.2% of endoscopists with <5 years of experience presented ADR > 20% vs. 19.2% of those with >10 years) (7). In our sample, we also found a moderate negative correlation between years of experience and ADR, but these data were not statistical significant.

It could also be possible that these findings are related to the small sample size of our study and to the individual characteristics of our endoscopists. Some endoscopists have low ADR even as they gain experience (23), although it is still unknown if this rate could be modified with specific training that changes their VGPs or by other methods.

One of the limitations of our study is the use of offline videos to evaluate VGP. Performing a colonoscopy involves both manual and visual coordination and it is possible that some endoscopists position the endoscope differently. Some may position the endoscope more centrally and thus visually “scan” the entire screen. Whereas other endoscopists move the endoscope throughout the colon lumen and thus place all segments within the central screen. Due to the complexity of these variables, we chose to use a more controlled environment for this initial study. A second study limitation is the reliance on retrospective data for determining ADR. The visual gaze parameters that were measured may not have corresponded to the endoscopist’s visual gaze during the colonoscopies from which ADR was calculated. Future studies will require measurement during actual cases to determine if the central gaze focus remains associated with higher ADR. Finally, due to the small sample size, the ability to detect associations was low, and we cannot conclude that a no true association exists based on the lack of a statistically significant P value in this study. The small sample size also did not allow for the adjustment of potential confounding variables in multivariable analysis; larger studies are required to better evaluate associations of VGPs with ADR.

In summary, in this pilot study there appears to be an association between a center-looking VGP and ADR. If confirmed in a larger
sample, these data can be used to retrain low ADR endoscopists and test whether this improves colonoscopy quality.

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CONFLICT OF INTEREST

Guarantor of the article: Michael B. Wallace MD, MPH.

Specific author contributions: Cristina Almansa: study concept and design, acquisition of data, analysis and interpretation of data, and drafting of the manuscript; Muhammad W. Shahid: study concept and design, acquisition of data, and technical support; Michael Heckman: statistical analysis and critical review of the manuscript; Susan Preissler: study concept and design and technical support; Michael B. Wallace: study concept and design, analysis and interpretation of data, and critical review of the manuscript.

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Study Highlights

WHAT IS CURRENT KNOWLEDGE

✓ Adenoma detection rate (ADR) is a validated measure of colonoscopy quality.
✓ ADR can vary among different endoscopists reflecting differences among colonoscopy performance.
✓ Prolonged withdrawal time and other endoscopic maneuvers that allow a better visualization of the mucosa have been related with higher ADR.

WHAT IS NEW HERE

✓ Visual gaze patterns (VGP) may have a role in the ADR.
✓ Endoscopists with higher ADR spend more time looking at the center of the screen.
✓ There is seem to be a negative correlation between years of experience and central VGP.

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