Title: Evaluation of a novel tablet application for improvement in colonoscopy training and mentoring

Short Title: Tablet application improves colonoscopy training

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ABSTRACT

Background and Aims: Endoscopic training can be challenging for the trainee and preceptor. Frustration can result from ineffective communication regarding areas of interest. Our team developed a novel tablet application for real-time mirroring of the colonoscopy exam that allows preceptors to make annotations directly on the viewing monitor. The potential for improvement in team proficiency and satisfaction is unknown.

Methods:

Application: Mirrors the on-screen endoscopic image to an Android tablet and permits real-time annotation directly on the in-room endoscopic image display. Preceptors can also "freeze-frame" an image and provide visual on-screen instruction (telestration).

Study Design: Trainees, precepted by a GI attending, were 1:1 randomized to perform colonoscopy on a training phantom using the application with traditional precepting or traditional precepting alone. Magnetized polyps (size <5 mm) were placed in one of 5 pre-set location scenarios. Each trainee performed a total of 10 colonoscopies; completing each location scenario twice. During withdrawal, the trainee and the attending identified polyps. Outcome measures included number of polyps missed and participant satisfaction after each trial.

Results: 15 trainees (6 novice; 9 GI fellows) performed a total of 150 colonoscopies where 330 polyps in total were placed. Fellows missed fewer polyps using the tablet v. traditional precepting alone (4.2% v 12.5%; p=0.04). There was no significant difference in missed polyps for novices (12.5% v 18.8%; p=0.66). Overall, fellows missed fewer polyps when compared to novices regardless of precepting method (p=0.01). The attending and all trainees reported reduced stress with improved communication using the tablet.

Conclusions: Fellows missed fewer polyps using the tablet when compared to traditional endoscopy precepting. All trainees reported reduced stress, quicker identification of polyps, and improved educational satisfaction using the tablet. Our application has the potential to improve trainee plus attending team lesion detection and enhance the endoscopy training experience for both the trainee and attending preceptor.

Keywords: Colonoscopy; Training; Real-Time Annotation; Telestration; Telementoring

INTRODUCTION

Training GI fellows in endoscopy can be challenging for both the trainee and preceptor. Frustration can come from the inability to effectively communicate an area of interest or direction of view in the on-screen image. This may result in potentially missed lesions and erosion of a productive teacher-trainee relationship.

Developing proficiency in training is difficult to measure. Quality parameters set by the American Society for Gastrointestinal Endoscopy (ASGE) in clinical practice define competence as achieving cecal intubation in more than 90% of all cases and adenoma detection rates (ADR) of at least 25% for men and 15% for women aged 50 or older.[1,2] During training, these detection rates are usually obtained after 450 colonoscopies.[3] Polyp detection rate (PDR) has been shown to correlate with adenoma detection rate.[4] Tandem colonoscopy studies have shown that polyps less than 5mm are missed 26% of the time and improvement in the detection rate by 1% has been shown to decrease interval colorectal cancer by 3%.[3,5] Various methods to improve detection rates have been suggested with a focus on endoscopic training being hypothesized as a high-yield approach.[6] In one study evaluating simple educational interventions, ADRs increased significantly from 36% to 46%.[6]

More recent approaches for improving procedure-based education in surgery have been made using telementoring. Telementoring is the development of relationships between trainees and those with experience where the mentors are geographically removed from the trainee and communication is accomplished electronically. Telestration was developed to allow real-time freehand markups or annotations over images or video similar to use in sports or weather broadcasts since the early 1960's. The theory is that the annotations allow visual illustration in addition to verbal teaching--leaving less room for incorrect interpretation of the preceptor's instructions. Telestration can also add interactivity that results in increasing the quality of education leading to more efficient training.[7] Additionally, telestration has the ability to improve clinical outcomes through more accurate directions that help avoid clinical errors and reduce post-operative recovery time.[7]

Our team has developed a novel tablet based application (ScopeVUe) that allows for real-time mirroring of the colonoscopy exam while allowing the preceptor to telestrate directly on the viewing monitor (Figure 1). The utility of this application for improvement in trainee-team proficiency and team satisfaction in endoscopy remains unknown.

METHODS

Tablet Application:

ScopeVUe mirrors the on-screen endoscope image to an Android tablet and allows for real-time annotation directly on the endoscopic image. The annotations are then simultaneously displayed on the standard in-room endoscopy monitor. Preceptors can also "freeze-frame" an image and provide visual on-screen instruction. ScopeVUe can be utilized with any endoscopic platform that has a video output port.

Tablet Environment:

ScopeVUe was deployed on an Intel Core i7-2600 CPU @ 3.4 GHz host computer running Windows 7. This computer was used to acquire high fidelity composite video from the endoscopic video feed using a frame grabber (CronosPlus; Matrox Electronic Systems, Ltd.; Quebec, Canada) and MIL-Lite and OpenCV C++ application programming interfaces. The video was transmitted wirelessly to an Android tablet (Asus Transformer T700; ASUSTek Computer Inc.; Taipei, Taiwan) using TCP/IP communication protocols for reliable transmission via a Netgear RangeMax 150Mbps wireless router. Any annotations made by the preceptor on the tablet were integrated into the endoscopic video using the host computer. The endoscopy environment included a Karl Storz tower and endoscope (13803PKS, Karl Storz Gmbh & Co; Tuttlingen, Germany). Colonoscopy was performed using a colon phantom (Kyoto Kagaku, Case 2, M40 latex colon training model, Kyoto, Japan). A technical team member confirmed polyp visualization with a MacAlly 2.0 megapixel camera that was located inside the phantom.

Study Design:

Trainees (novices and GI fellows) performed colonoscopy on a colon phantom under the guidance of one attending preceptor (experience level: greater than 2000 colonoscopies) where sessile polyps were placed in one of five pre-set location scenarios (Figure 2). Trainees were randomly assigned to perform withdrawal colonoscopy using either the intervention (ScopeVUe) that included both visual and verbal precepting (Video 1) or traditional precepting with verbal precepting alone. Each team performed a total of 10 colonoscopies (5 tablet, 5 traditional) completing each polyp location scenario twice. Polyp identification on withdrawal was verbalized by the trainee and separately by light signal from the attending. A polyp miss (defined as completely unobserved or >1 s apart from attending visualization) was noted by a technical team staff member who viewed the location of polyps with a camera inside the phantom that was not visible to the trainee teams. The number of polyps missed and participant satisfaction were recorded for each trial.

Set-up included randomization of 5 color-coded polyp scenarios that included placement of 1 to 4 custom polyps. The number and distribution of polyps varied with each of the five scenarios (Supplementary Data Table A). The polyps were cast using silicone rubber (Smooth-On; Macungie, PA), and were constrained to be less than 5 mm in diameter. These polyps were placed endoscopically using forceps assisted by external compression of a color-coded tab corresponding to the randomized scenario. Adhesion was accomplished using small magnets both on the colon and within the polyps themselves. Magnets allowed the polyps to be placed in positions independent of gravity to better reflect clinical practice and to maintain a consistent location for each particular scenario among the trials. No polyps were located in the cecum or rectosigmoid colon. The number of folds between ring anchors was counted for each set-up to ensure consistency between scenarios. A research staffer advanced the endoscope to the cecum prior to each scenario. A cover was placed over the phantom to avoid visual inspection. Two Dell 22-inch HD monitors were placed side-by-side, one used for ScopeVUe and one used for traditional endoscopy only.

Study outcome and statistical analysis:

The main outcome measure was polyp miss rate. Secondary outcomes included withdrawal time, polyp miss rate for fellows and novices, polyp miss rate in specific regions of the colon, and participant satisfaction. A miss was defined as a polyp not being seen by the trainee and attending or if the trainee did not verbalize polyp identification within 1 second of attending visualization. This latter part of the definition, greater than 1 second, was designed to remove any clue a trainee may receive during standard endoscopy that signals them to slow down and find a polyp that would not have otherwise been found. Trainee analysis included the attending performance--thereby controlling bias by limiting precepting to one individual.

Polyp miss rate was calculated as the number of missed polyps divided by the total number of polyps. Power calculations for testing for difference in percentage of polyps missed within fellows (traditional precepting versus tablet) were based on the paired t-test, and calculations for comparisons of fellows to novices were based on the two-sample t-test. For comparing traditional precepting to tablet in fellows, prior data indicates that the standard deviation of the difference is about 6%. With 9 fellows, we have 90% power to detect a 7.4% difference in miss percentage. For comparing fellows to novices, prior data indicates that the standard deviation is about 7%. With 9 fellows and 6 novices, we have 90% power to detect a 13.0% difference between groups. All calculations assume a type I error rate of 0.05.

Withdrawal time was compared using a log rank test. The lower, median, and the upper quartile ranges were calculated for continuous variables. Pearson's product-moment correlation was used for the analysis of polyp miss rate and the number of colonoscopies performed. After completion of the trial, participant satisfaction was recorded by interview (How was your overall experience? What did you think of using the tablet for teaching as compared to traditional teaching? Do you have any concerns or suggestions?) and completion of a validated task load (TLX) assessment instrument (NASA Task Load Index v1.0, NASA Ames Research Center, Moffett Field, California, USA).[8]

The NASA TLX is a subjective workload assessment tool that is frequently used in human factors research—with over 300 publications to date.[9] It has been validated and successfully utilized in multiple fields including transportation, energy, construction, education, and healthcare.[10-17] The TLX is comprised of six subscales: demand (how much mental and perceptual activity was required), physical demand (how much physical activity was required), temporal demand (how hurried or rushed was the pace of the task), performance (how successful was the subject in accomplishing what they were asked to do), effort (how hard did the subject have to work to accomplish the level of performance), and frustration level (how insecure, discouraged, irritated, stressed, and annoyed was the subject).[8] All subscales range from 0 (very low) to 100 (very high), with the exception of Performance, where 0 is perfect and 100 is failure.

RESULTS

15 trainees, (6 novice--never touched an endoscope; 9 GI fellows--performed > 50 colonoscopies each), performed a total of 150 colonoscopies searching for a total of 330 placed polyps. There were 4 females among the fellows, and one among the novices. Fellows were older with a median age 30 compared to 24 among the novices (Table 1). Of the 9 GI fellows, 4 were in their first year of training (number of colonoscopies performed; median [Q25, Q75]: 115 [95, 125]) and 5 were in their second year of training (190 [172, 327]). The attending preceptor had performed more than 2000 colonoscopies with an ADR of 44% for average-risk screening colonoscopies.

The fellow teams missed fewer polyps using the tablet when compared to traditional precepting alone; 4.2% v. 12.5% (p=0.04) (Table 2). There was no significant difference in missed polyps between precepting methods for novices, 12.5% v. 18.8% (p=0.66), or for all teams combined, 4.2% v. 12.5% (p=0.2). Overall, fellow teams missed fewer polyps when compared to novice teams regardless of precepting method (p=0.01). There was no difference in polyp miss rate between methods when separating out the right colon (p=0.61), transverse colon (p=0.05) or left colon (p=1).

There was a significant negative association between the number of colonoscopies performed at the time of study enrollment and the team polyp miss rate when using the tablet if novices and fellows were included in the analysis (p=0.01); there was no evidence of an association when only fellows were included in the analysis (p=0.55) [Table 3].

Withdrawal times were longer using the tablet (Table 4). For all teams, the median withdrawal time using the tablet was 7.7 minutes compared to 6 minutes for traditional--a difference of 1.7 minutes (p=<0.01). The fellow teams took longer to withdraw the endoscope with an average of 7.8 minutes compared to the novice team of 5.7 minutes (p=0.01).

All trainees reported less stress, quicker identification of polyps, and a more positive educational experience when using the tablet (Supplementary Data Table B). Trainees also reported similar mental demand, physical demand, temporal demand, effort, and frustration level with improved sense of task performance (i.e. detecting polyps) when using the tablet as compared to traditional precepting (Table 5). The attending noted improved overall communication and reduced stress of precepting when using the tablet as compared to traditional precepting (Frustration: 15 v. 70 (0 is "very low," 100 is "very high"); Performance: 5 v. 25 (0 is "perfect," 100 is "failure"); with similar mental demand, physical demand, temporal demand and effort level).

DISCUSSION

To our knowledge, this study is the first of its kind to look at team proficiency during colonoscopy training utilizing a tablet compared to the traditional form of endoscopic precepting. The fellow team demonstrated a statistically significant improvement using the tablet when compared to the traditional precepting method with polyp miss rates dropping 3-fold, 12.5% to 4.2%, in this group. Eight of the nine fellow teams showed improved performance (89%).

The novice teams were originally included in the study to evaluate individuals at all levels of training and to assess if the tablet could help overcome the initial inability to manipulate the endoscope; however, when their results were evaluated individually or combined with the fellow teams, there was no evidence of difference in miss rates between precepting methods. It was felt that novice team results were limited given the novelty of all aspects of endoscopy--making it difficult to measure the specific impact of the tablet independently.

There was no difference in polyp miss rate when separating out the right, left or transverse colon. Differences in detection rates mostly in the right colon have historically been attributed to differences in polyp morphology along with challenging locations behind haustral folds or the inner curvature of flexures.[18,19] Given our study utilized a colon phantom model with standardized polyps and locations, the lack of difference in detection rates by region was expected.

While there was a significant negative association between the number of colonoscopies performed at the time of study enrollment and polyp miss rate for the tablet precepting method, when fellow teams and novice teams were included in the analysis, there was no significant association when the fellows alone were included in the analysis (novice teams removed). This finding was largely driven by the high polyp miss rate by the novice teams (18.8%). While the polyp miss rate between first and second year fellows were similar, if we examine the polyp miss rate for the fellow teams by the number of colonoscopies performed at time of enrollment, there is a trend toward lower polyp miss rate as the number of colonoscopies performed increased (Table 3). For the fellows who performed greater than 200 colonoscopies, the polyp miss rate for traditional and tablet precepting was 8.3% and 0% respectively. This improvement in polyp miss rate for even the more experienced fellows would suggest that the tablet may serve as a useful instrument throughout early endoscopic training.

All teams took longer to withdraw using the tablet. Longer withdrawal times have been known to contribute to improved rates of polyp detection.[6,7,18] In comparing fellow teams to novice teams specifically, our fellow teams took longer to withdraw, which along with their experience in endoscopy likely explains their improved performance. However, these factors were controlled when comparing the tablet to traditional precepting.

The attending preceptor was observed to have more endoscopic viewing time when using tablet (460 s [382, 514] v. 359 s [296, 437]). More viewing time can allow for more detailed technique instruction such as examining around folds and adequately cleaning the lens translating into improved performance including adenoma detection.[6,20] During traditional colonoscopy precepting, we observed an increase in transition time such as when the preceptor stood to point at the screen and increased distractions (i.e. phone, lab staff, background conversation) that kept the preceptor from viewing the screen or remaining completely engaged in the procedure at all times. This is similar to current real-world endoscopy precepting that occurs at training programs every day. Whether the difference between traditional precepting and tablet precepting, which we observed in our study, was due to the actual software presented in the application itself or whether the application/tablet simply served as a surrogate method to force a preceptor to be more engaged in teaching trainees, leading to increased attention/educational interaction by the teams, the end result of a positive educational experience with improvement in team lesion detection holds. Therefore, if the tablet method serves simply to increase a preceptor's level of engagement and attention during the precepted exam, when compared to traditional precepting, we may consider the tablet a successful tool.

All trainees preferred the use of a tablet for education and highlighting of areas of interest. They noted that the tablet allowed easier and more rapid identification of polyps with similar TLX scores. Novices appreciated the freeze-framing for more detailed discussion and direction of complex locations in the colon. More experienced fellows tended to dislike the freeze-framing, but agreed that the additional on-screen viewing time and the preceptors telestration arrows allowed for improved polyp identification and colon examination.

While our study included 15 teams from a single training center, we are currently planning a multi-center study and increasing enrollment of endoscopy preceptors. A skill assessment tool such as the assessment of competency in endoscopy–colon (ACE-C) will be utilized going forward to allow for additional objective measurements of improved training and learning curves.[21,22] As a phantom model was utilized in this study, with the advantage of controlled conditions and a perfect bowel preparation, the performance of the system in human clinical studies is unknown--although we anticipate that the same positive educational experience will hold constant regardless of the viewing condition/environment due to the robustness of the ScopeVue system.

In conclusion, the fellow teams missed fewer polyps when using the tablet as compared to traditional endoscopic precepting. All trainees reported reduced stress and quicker identification of polyps using the tablet. Educational satisfaction was also improved for both the trainees and attending with use of the tablet. In summary, our tablet application has the potential to improve trainee plus attending team lesion detection and enhance the endoscopy training experience for both the trainee and attending preceptor.

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TABLE LEGEND(S):

Table 1: Demographics for novice and fellow teams including sex, age and number of colonoscopies completed prior to the study

Team (total n)	**Female n (%)**	**Age Median [25%, 75%]**	**Colonoscopy Median [25%, 75%]**
Attending + Novices (n=6)	1 (17%)	24 [22, 24]	0 [0, 0]
Attending + Fellows (n=9)	4 (44%)	30 [29, 31]	172 [122, 190]
Combined (n=15)	5 (33%)	29 [24, 31]	108 [0, 172]

Table 2: Percentage of misses for novice and fellow teams by tablet vs. traditional precepting

Team	**Tablet Median [25%, 75%]**	**Traditional Median [25%, 75%]**	**Test Statistic p-value**
Attending + Novices (n=6)			
Total	18.8 [10.4, 20.8]	12.5 [9.4, 21.9]	p=0.66
Left colon	16.7 [10.4, 16.7]	16.7 [4.2, 22.9]	
Right colon	12.5 [12.5, 21.9]	6.2 [0, 12.5]	
Attending + Fellows (n=9)			
Total	4.2 [4.2, 4.2]	12.5 [4.2, 12.5]	p=0.04
Left colon	8.3 [0, 8.3]	8.3 [8.3, 8.3]	
Right colon	0 [0, 0]	12.5 [0, 12.5]	

Table 3: Percentage of polyp misses by number of colonoscopies performed by the trainee team member at the time of study enrollment for traditional and tablet precepting methods (Median [25%, 75%])

Precepting Method	**Number of Colonoscopies Performed**			
	0-50 (n=6)	51-100 (n=1)	101-200 (n=6)	>200 (n=2)
Traditional (p=0.14)				
Overall (n=15)	12.5 [9.4, 21.9]	12.5 [12.5, 12.5]	12.5 [6.3, 12.5]	8.3 [6.3, 10.4]
Fellow (n=9)	0 [0, 0]	12.5 [12.5, 12.5]	12.5 [6.3, 12.5]	8.3 [6.3, 10.4]
Novice (n=6)	12.5 [9.4, 21.9]	0 [0, 0]	0 [0, 0]	0 [0, 0]
Tablet (p=0.01)				
Overall (n=15)	18.8 [10.4, 20.8]	4.2 [4.2, 4.2]	4.2 [4.2, 10.4]	0 [0, 0]
Fellow (n=9)	0 [0, 0]	4.2 [4.2, 4.2]	4.2 [4.2, 10.4]	0 [0, 0]
Novice (n=6)	18.8 [10.4, 20.8]	0 [0, 0]	0 [0, 0]	0 [0, 0]

Table 4: Withdrawal time for tablet vs. traditional precepting by novice and fellow teams

Team	**Withdraw Time (s) Median [25%, 75%]**	**Tablet Median [25%, 75%]**	**Traditional Median [25%, 75%]**
Attending + Novices	344 [328, 370]	394 [364, 410]	296 [271, 314]
Attending + Fellows	469 [434, 514]	509 [495, 540]	432 [375, 457]
Combined	378 [344, 472]	460 [382, 514]	359 [296, 437]

Table 5: Unweighted Task Load Index (TLX) subscale rating for Tablet and Traditional precepting methods.

Subscale[&]	Unweighted rating, median [Q25, Q75]	
	Tablet	Traditional
Mental Demand	20 [10, 40]	15 [10, 25]
Physical Demand	15 [10, 35]	15 [10, 30]
Temporal Demand	20 [10, 35]	15 [10, 30]
Performance	15 [10, 30]	20 [10, 30]
Effort	30 [10, 65]	15 [10, 55]
Frustration	25 [10, 75]	25 [10, 45]

[&] All subscales range from 0 (very low) to 100 ("very high"); the exception is the subscale of "Performance," where 0 is "perfect" and 100 is "failure."

FIGURE LEGEND(S):

Figure 1: Real-time annotation (arrow) of a polyp on the tablet simultaneously displayed on endoscopy monitor

Figure 2: Colon training phantom model with tabbed color-coded magnetized scenarios

VIDEO LEGEND(S):

Video 1: Tablet utilization during withdrawal

SUPPLEMENTARY DATA:

Table A: Five color-coded location scenarios (A-E) that matched pre-set magnetized polyp locations in the ascending, transverse, and descending colon

Scenario	Ascending	Transverse	Descending
A	1	0	0
B	0	2	2
C	1	0	1
D	2	0	1
E	0	0	1

Table B: Representative participant interview comments

Comment	Quote
1	The tablet allowed easier and more rapid identification of polyps
2	I wish I had this on endoscopy now
3	Arrows helped the most
4	Instruct where to look in a complex site is much easier with visual cues, pausing screen
5	Don't like freezing, but I like the directions
6	Exposure on monitor more clear without tablet
7	I like the arrows
8	Great teaching tool
9	Really helped identify areas I wouldn't have seen
10	Better attention from attending
11	I didn't like loss of control (when freeze framed by attending)
12	Communication was easier
13	I understood what he was taking about, o'clock less helpful