Use of a Colonoscopy Simulator for Resident Teaching: Application of a Mastery Learning Model

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THESIS

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SUMMARY

A study of the application of mastery-based learning principles to computerized colonoscopy simulation was performed. Resident performance was assessed using a performance checklist. A group of expert endoscopists determined the appropriate mastery standard using a modified Angoff standard setting method.

Seventeen general surgery and gastroenterology residents with no prior endoscopic training participated in the study. Demographic information was collected as well as measures of previous endoscopic exposure, simulator exposure, and video game experience. Residents completed a pre-test on the simulator, and if they did not meet the mastery criterion, they proceeded to simulator training. The amount of time spent on deliberate practice on the simulator varied between learners, but all needed to meet the mastery criterion at a simulator post-test to proceed to live colonoscopy training.

Residents were more likely to meet the minimum passing score at the post-test. Overall scores improved from pre-test to post-test, and the number of egregious errors was significantly lower at the post-test. Only one resident failed the post-test, and this resident ultimately met the mastery criterion after additional simulator practice.
Residents expressed satisfaction with the use of the simulator as an adjunct to early colonoscopy skills training, and felt that the mastery criterion was reasonable and improved their confidence at performing colonoscopy.
I. Introduction

The use of simulation in residents’ colonoscopy training has become increasingly attractive in recent years due to concerns over patient safety (Bini et al., 2003), endoscopy unit efficiency (Sedlack and Kolars, 2004), and a desire for more learner-centered methods of instruction (Issenberg et al., 1999). There is evidence supporting the use of computerized colonoscopy simulators for residency training, in terms of discrimination of different levels of expertise (Felsher et al., 2005; Koch et al., 2008b); and skill transfer to live endoscopy (Park et al., 2007; Cohen et al., 2006). Nonetheless, questions remain as to the most effective ways to integrate colonoscopy simulator training into a residency curriculum.

The current study applies the conceptual framework of mastery-based learning to simulator-based colonoscopy skills training for surgery and gastroenterology residents. An expert panel used the Angoff standard setting method to identify an appropriate mastery standard for novice endoscopists to meet prior to performing live colonoscopy procedures. After deliberate practice on the colonoscopy simulator, residents were assessed against the mastery standard, and were required to complete further simulator training until the standard was met. This allowed us to determine whether colonoscopy simulator training allows residents to achieve a predefined level of mastery, and also how much simulator training time is required to achieve this level of mastery. This information is not available in the current colonoscopy simulation literature, and will help to inform the design of future colonoscopy training programs.
II. Background and Review of the Literature

A. Simulation in Colonoscopy Training: Rationale

Procedural skills in medicine have traditionally been taught in an apprenticeship manner. A learner performs a procedure under close supervision by an expert, who provides feedback and intervenes if necessary in the interest of patient safety. This “see one, do one, teach one” model is now being revised in many areas of procedural training, including colonoscopy, for several reasons.

First, the public is increasingly aware of medical errors (Kohn et al., 2000) and may be less accepting of undergoing an invasive procedure by a learner (Santen et al., 2004). For surgical procedures, patients are less likely to consent to surgery if the level of resident participation in the procedure is high (Porta et al., 2012). This is especially relevant in endoscopic procedures, where there can only be one operator at a time, so learners are effectively performing the procedure independently even when they are being supervised by an expert. Whether resident involvement in colonoscopy is actually associated with increased procedural risk is unclear. One study at a single academic institution did not show an increased rate of colonoscopic perforation when a resident was involved in the procedure (Misra et al., 2004). This contrasts with evidence that adverse event rates are two-fold higher for patients undergoing colonoscopy in July or August when residents begin their training programs (Bini et al., 2003). The odds of an adverse event increased with each milligram of sedation provided, so adverse events may have been due to inadequate experience providing sedation, or novice technique resulting in more patient discomfort (Bini et al., 2003). Patient satisfaction is also decreased when a resident is involved in performing colonoscopy, which is significant as it may decrease the likelihood that a patient will undergo a repeat endoscopy in the future (Bini et al., 2003; Schoen et al., 2000). The use of a colonoscopy simulator
provides a safe environment for learners to develop basic endoscopic skills prior to performing live endoscopy, may increase the public trust, and ideally would translate to patient safety outcomes, although this has not yet been demonstrated.

Secondly, time and cost implications of training residents in the endoscopy unit exist. Colonoscopies performed with resident involvement are 10-37% longer than those performed by an attending physician alone (McCashland et al., 2000). This translates to nine fewer colonoscopies being performed per day when a resident is performing colonoscopies (Sedlack and Kolars, 2004), and an estimated loss of institutional reimbursement to the institution of $500,000-$1,000,000 (USD) per year (McCashland et al., 2000). This is a financial disincentive to attending physicians, who will lose income by involving a learner in their practice. In a publicly-funded medical system, where wait times for procedures exist, this decreased endoscopy unit efficiency is even harder to justify. If residents can develop basic colonoscopy skills in a simulated setting, their procedure times may be faster, reducing some of this inefficiency.

Finally, traditional bedside procedural training takes place in a patient-centered learning environment. Patient comfort and safety, as well as procedural quality, must take first priority above the resident’s learning needs. This often means that the attending physician takes over the procedure when the resident is having difficulty, which deprives the trainee of the chance to learn. In addition, many expert endoscopists are at a stage of unconscious competence (Flower, 1999) which limits their abilities to verbalize the steps they are taking to complete a difficult portion of a procedure. By contrast, a simulated learning environment is learner-centered. The resident is able to make mistakes in a low-risk setting with no time pressures, complete standardized tasks with
opportunities for repetition and practice, and receive some degree of feedback from objective simulator metrics (Issenberg et al., 1999).

B. Colonoscopy Simulators

Currently, commercially available colonoscopy simulators include ex-vivo animal models, low-fidelity mechanical simulators, and high-fidelity computerized simulators. Ex-vivo animal models are mainly used for simulation of therapeutic procedures such as polypectomy and management of gastrointestinal bleeding (Hochberger and Maiss, 2006), although a bovine colon model for teaching basic colonoscopy skills has been described (Sedlack et al., 2007). Ex-vivo models are limited by the need for animal colons, which may limit the availability of the simulator for resident practice. When expert endoscopists compare mechanical simulators to computerized simulators, the mechanical models were found to be superior in terms of visual and tactile response to colonoscope advancement as well as management of colonoscope looping (Hill et al., 2012). However, these models present a relatively fixed scenario to the trainee, and do not provide the diversity of cases available with a computerized simulator. Mechanical and computerized simulators have not been compared in a training setting.

Two high-fidelity computerized colonoscopy simulators are currently commercially available. Both use a realistic colonoscope which is inserted into a simulated orifice. The computer interface provides a visual representation of the colon which responds to actions of the trainee such as air insufflation, suction, scope advancement, and scope looping. In addition to visual feedback, tactile force feedback is provided through the action of mechanical rollers in the simulator which mimic the resistance encountered during loop formation. Auditory feedback from the simulator includes the beeping of the patient heart rate monitors and expressions of discomfort from the simulator. After
reviewing the case scenario, the trainee is able to administer sedation to the patient, complete diagnostic and some therapeutic procedures, and receive feedback on a variety of performance markers. During the simulation, the learner can access an external view of the colonoscope path to determine the presence of loop formation, and its response to maneuvers such as loop reduction. The Symbionix GI Mentor visual representation is based on videotaped endoscopic procedures and a three-dimensional geometrical model and responds both locally and globally to actions of the trainee (Bar-Meir, 2006). This simulator also provides a hand-eye coordination module in which trainees must pop balloons inside the colon. The CAE Healthcare AccuTouch endoscopic simulator provides three-dimensional images based on CT scan reformatting views and also responds to trainee actions (Long and Kalloo, 2006). In an expert comparison of the two simulators, the GI Mentor was found to be less realistic than the AccuTouch, particularly in terms of haptic feedback (Hill et al., 2012).

C. Simulator Validation

In order for a simulation to be used as a teaching and assessment tool, validation evidence must be provided (Downing, 2003). The current concept of validity as it applies to assessment methods is one of validity as a unitary concept, with multiple types of validity evidence gathered to support the use of an assessment in a specific context (Messick, 1995; Ghaderi et al., 2015). Types of validity evidence include content validity (how well the content of the assessment reflects the content of the domain being assessed), response process (aspects of the assessment that may introduce construct irrelevant variance), internal structure including evidence of assessment reliability, relationship to other variables, and consequential validity (Downing, 2003, Ghaderi et al., 2015). Validity evidence supporting the use of computerized colonoscopy simulators has been established, including evidence of content validity, and relationship to other
variables. These other variables include simulator discrimination between endoscopists of varying levels of expertise, improved simulator performance after simulator training, and evidence of skills transfer to live endoscopy.

D. Content Validity

Content validity evidence for the colonoscopy simulator is provided through expert assessment of the realism of the simulation as compared to live endoscopy. The Simbionix simulator has been rated as somewhat realistic with expert ratings of 2.5/5.0 to 2.95/4.0 (Kim et al., 2010; Koch et al., 2008a). The lack of resistance encountered on scope advancement was the least realistic quality of the simulator (Kim et al., 2010), while the clinical situations and visual representation were rated favourably (Aabakken et al., 2000). Expert raters of the AccuTouch simulator rated the simulator as moderately realistic (5.5-8 on a 10-point scale) for domains including the visual graphics, force feedback, insufflation and suction, scope controls and loop management (Sedlack and Kolars, 2003). The Olympus TS-1 simulator may be slightly more realistic in terms of case difficulty, endoscope handling and force feedback, but this simulator is not yet commercially available (Koch et al., 2008b). In the only comparative study of simulator realism, the AccuTouch simulator was rated more realistic than the Simbionix simulator, particularly with respect to simulated anatomic structure, haptic feedback, response to air insufflation, and patient discomfort (Hill et al., 2012).

Despite the moderate realism of the simulators, expert assessment for both simulators indicates that the simulated procedures are significantly easier than live endoscopy, potentially making their use most appropriate for the novice learner (Sedlack and Kolars, 2003, Kim et al., 2010, Aabakken et al., 2000). In one study, raters with less clinical experience rated the usefulness of the simulator as higher than raters with more
procedural experience (Aabakken et al., 2000). Despite the gaps that exist in the realism of the simulators, experts consistently agreed that the use of computerized simulators should be considered in resident training, although not in credentialing (Kim et al., 2010; McConnell et al., 2012; Aabakken et al., 2000).

E. **Discrimination Between Levels of Expertise**

Simulator discrimination between performance of experts and novices provides construct validity evidence. For a simulator to teach and assess the construct of colonoscopic skills, more experienced endoscopists should outperform novices. The colonoscopy simulators have been shown to discriminate between experts and novices in a number of different studies. Learning curves on the Simbionix psychomotor skills module reached a plateau after two repetitions for experienced surgeons, five for residents, and seven for medical students (Eversbusch and Grantcharov, 2004). This has relevance due to the correlation between performance on the psychomotor skills module with performance on simulated colonoscopy for both experts and novices (Eversbusch and Grantcharov, 2004; Westman et al., 2006).

Comparison of studies is difficult due to their heterogeneity, as different endpoints and different definitions of “expert” are used in many reports. In a comparison of self-identified beginner and experienced endoscopists, significant differences were found between groups for screening efficiency, polypectomy rate, percent of colonic mucosa visualized, time to reach the cecum, and time with a clear view of the lumen (Felsher et al., 2005). Other studies have shown shorter procedure time (Koch et al., 2008b), shorter time to cecum (Ferlitsch et al., 2002), less time spent in red-out (McConnell et al., 2012), less pain (Koch et al., 2008b; McConnell et al., 2012), fewer adverse events (Ferlitsch et al., 2002), and less sedation used (McConnell et al., 2012), but increased
insertion force for experts compared to novices (Koch et al., 2008b). Several studies that used the performance markers which are automatically generated by the computer simulator have shown that many of these metrics do not differ between experts and novices, and the metrics that do consistently discriminate between them are mainly time-based, such as time to reach the cecum, time to various anatomic landmarks, time with a clear view of the lumen and total procedure time (McConnell et al., 2012; Kim et al., 2010; Sedlack and Kolars, 2003). Some of these endpoints discriminated between performance of experts and novices in some studies and not others, presumably due to the effects of small sample sizes in most studies. This issue indicates the importance of selecting appropriate performance markers when designing a simulator-based training program. Further supporting this need is evidence that the automated simulator metrics did not discriminate between experts and trainees (who had performed less than one hundred colonoscopies), but a Likert-based performance assessment tool was able to discriminate between the two groups (Sarker et al., 2010). Based on this evidence, relying solely on the computer-based performance metrics may not be adequate, and adding a subjective assessment of technical skills may improve simulator discrimination of performance.

The difficulty of the simulator case scenario may also impact simulator discrimination of skill level. Expert performance differs depending on the difficulty of the case scenario (Cantu et al., 2010). Similarly, a more difficult case scenario distinguished between novice and experienced endoscopists on multiple performance metrics, while an easier case only differed in the time taken to reach the cecum and screening efficiency (Fayez et al., 2010). This is another variable that differs between trials and makes study comparison difficult.
Although there is evidence that simulator performance can discriminate between experts and beginners, this has not been consistently shown with intermediate level endoscopists. One small study showed that experts (>100 colonoscopies) performed better than intermediate endoscopists (10-100 colonoscopies), who performed better than novices (<10 colonoscopies) as assessed by procedure time and percentage of mucosa visualized (Mahmood and Darzi, 2003). This finding is refuted by more recent studies. Expert endoscopists (>200 colonoscopies) performed better than residents (<50 colonoscopies) and students (no colonoscopies), on several performance metrics, but performance between residents and students was not significantly different (Grantcharov et al., 2005). In two other studies, novices with no prior endoscopic experience performed significantly worse on simulator metrics such as time to reach landmarks and time with clear mucosal views, but there was no difference between performance of experts (>1000 colonoscopies) and intermediate trainees (<200 or 200-1000 previous colonoscopies) (Haycock et al., 2009; Koch et al., 2008a). Based on this evidence, a recent systematic review concluded that the current computerized colonoscopy simulators should be limited to teaching basic endoscopic skills to novices only (Ansell et al., 2012).

F. Simulator Practice Improves Performance on the Simulator

For the simulator to have a role in residency training, endoscopic performance should improve after simulator training. An improvement in simulated colonoscopy performance after a simulator-based teaching intervention has been documented. Two hours of simulator practice per day for three weeks resulted in decreased adverse events, shorter insertion time and improved skills testing on the simulator for a group of novice endoscopists, and this improvement was not seen in controls with no simulator practice (Ferlitsch et al., 2002). A five-day intensive colonoscopy skills course, which included 25
simulated colonoscopies as well as an endoscopic curriculum, resulted in improved procedure time and screening efficiency on the simulator, and this improvement was maintained at nine months after the education intervention (Thomas-Gibson et al., 2007). Skills retention at four months was also documented in students who had no intervening simulator or live endoscopy practice after their initial simulator training (Snyder et al., 2010). In a longer intervention, residents practiced 10 simulated colonoscopies monthly for 2 years, with improvement of endoscopic efficiency documented over the course of the study, although live colonoscopy was also performed throughout training (Clark et al., 2005). Improvement in simulator metrics, including time to reach the cecum, screening efficiency, and total procedure time, was documented in a group of trainees with 10 hours of simulator practice (Cohen et al., 2006). In a randomized trial, however, a group of trainees randomized to 16 hours of simulation training outperformed trainees who had standard patient-based colonoscopy practice when assessed on the simulator, but were not significantly different when assessed on live colonoscopy (Haycock et al., 2010). This may raise concerns about skills transfer from simulated procedures to live colonoscopy. Similarly, in one of the first studies of colonoscopy simulator training, residents in the simulator trained group improved their simulator performance to match that of the experts with only two weeks of training (Ferlitsch et al., 2002). Trainees certainly do not achieve expert performance at live colonoscopy with only two weeks of training, so this rapid improvement on the simulator may not indicate similar skills improvement in the endoscopy suite. Evidence of skills transfer from the simulator to live colonoscopy is required for further validation of the colonoscopy simulator.

G. Skills Transfer to Live Colonoscopy

In order for simulator training to be useful, and for its costs to be justifiable, the skills learned during a simulated procedure must be transferable to live colonoscopy.
Gastroenterology fellows randomized to six hours of simulator training outperformed fellows who underwent standard patient-based colonoscopy training as measured by live colonoscopy metrics, including independent procedure completion, safe scope insertion, landmark identification, depth of scope insertion, mucosal visualization on withdrawal, and patient discomfort (Sedlack and Kolars, 2004). The superior performance in the simulator-trained group was maintained for the first 30 live colonoscopies, after which the two groups had similar performance (Sedlack and Kolars, 2004). Although this evidence supports the use of the colonoscopy simulator during early training, this was a small study, and evaluators were not blinded to residents’ randomization status. A randomized controlled trial of two to three hours of independent simulator practice compared to no training resulted in higher global ratings of live colonoscopy performance in the simulator trained group using a validated rating scale (Park et al., 2007).

In a small study based on mastery learning principles, residents were randomized to simulator training or a control group. The simulator group completed an average of 20 hours on the simulator to meet the predefined level of expert performance on the simulator. On subsequent blinded assessment at live colonoscopy, the simulator trained group had higher cecal intubation rates, faster procedure time, and less patient discomfort than residents who did not have simulator training (Ahlberg et al., 2005). Although outcomes were only assessed for the first 10 live colonoscopies performed, the authors extrapolated from historical data to estimate that simulator training could replace up to 50 live colonoscopies, thereby increasing the efficiency of training (Ahlberg et al., 2005).
In the largest randomized, controlled trial to date, gastroenterology fellows were randomized to 10 hours of colonoscopy simulator training or standard bedside training and performance on the next 200 live colonoscopies was assessed (Cohen et al., 2006). The simulator group had higher “objective competency scores” for the first 100 live colonoscopies, defined as reaching the cecum independently and identifying relevant pathology. Although this study provides evidence of simulator skill transfer to live endoscopy, the number of cases required to achieve 90% competency was the same in the simulator and control groups, again indicating that the benefit of colonoscopy simulation is mainly in the early stages of training (Cohen et al., 2006).

Contrary to these findings, authors of a study using the Olympus TS-1 colonoscopy simulator did not find a difference in live colonoscopy performance (assessed by Direct Observation of Procedural Skills) between a group who received 16 hours of simulator training and a group who received patient based training (Haycock et al., 2010). Based on the current literature, a Cochrane Collaboration systematic review determined that computer-based colonoscopy simulation is superior to no training, but there is no conclusive evidence that it is superior to traditional bedside procedural training (Walsh et al., 2012). Nonetheless, the colonoscopy simulators appear at least as effective as the standard apprenticeship model, with evidence of skills transfer to live endoscopy and reduction of the early phase of the learning curve for novice endoscopists. This evidence supports the use of simulated colonoscopy as part of an endoscopic curriculum for residents, and provides construct validity evidence for the use of the simulator as a potential assessment tool.

H. Applying Mastery Learning Principles to Colonoscopy Training
Most of the studies of colonoscopy simulator-based instruction used a predetermined length of practice time or number of repetitions as the education intervention. However, the number of times a skill is practiced does not necessarily correlate with competence. Learning curves of novice endoscopists demonstrate that individuals gain colonoscopy skills at different rates (Cohen et al., 2006), and even practicing endoscopists demonstrate variability in colonoscopy quality metrics despite similar experience levels (Dafnis et al., 2001). Based on this evidence, practice time spent on the simulator cannot be used as a surrogate marker for competent performance. Rather, competency standards should be determined, and learners should demonstrate that they have achieved these standards prior to performing live endoscopy.

Mastery learning is a type of competency-based education where strict performance standards are identified, and learners must meet these standards in order to progress (McGaghie et al., 2011). In this setting, learners may take different amounts of time to achieve the performance standard, but all learners must achieve the same outcomes by the end of the course of study. In the context of procedural skills learning, baseline factors, such as visuo-spatial abilities, may result in variable learning rates at colonoscopy (Westman et al., 2006; Luursema et al., 2010), and this needs to be taken into consideration in the development of a training program to ensure that trainees all meet the same standard before progressing to live colonoscopy.

Mastery learning principles have been successfully applied in other medical training contexts, including assessment of shoulder pain (Mann and Eland, 2005), advanced cardiac life support skills (Wayne et al., 2006), paracentesis (Cohen et al., 2013), lumbar puncture (Cohen et al., 2013), and laparoscopic hernia repair (Zendejas et al., 2012). Skills assessed on simulators improved after the mastery learning interventions, with
only a minority of learners requiring additional practice time to achieve the predetermined standard (Cohen et al., 2013; Wayne et al., 2006). The amount of practice time required to achieve the performance standard varied with the level of experience of the trainee (Zendejas et al., 2012), and learners who required additional practice time continued to perform below their peers (Wayne et al., 2006).

There is some evidence for skills transfer after a simulation-based mastery learning intervention. Residents who underwent this training required fewer attempts to start a central line (Barsuk et al., 2009b) than their untrained peers, and this skill was retained at 12 months after training (Barsuk et al., 2010). In contrast, there was no difference in performance of pediatric lumbar puncture or intravenous catheter insertion in a group of interns who completed a mastery learning curriculum compared to controls (Kessler et al., 2013), although a delay between training and patient based practice may have impacted the results.

Learners who undergo a mastery based instructional program have been shown to outperform learners who have undergone traditional experiential-based learning. Third year medical students trained in a mastery-based model were better able to interpret heart sounds than fourth year medical students who had already completed their clinical cardiology rotation (Butter et al., 2010). First year residents who completed a mastery-based lumbar puncture curriculum outperformed residents with up to three more years of clinical experience (Barsuk et al., 2012), and graduating nephrology fellows performed dialysis catheter insertion less well than incoming fellows who had completed a mastery-based learning simulator training program (Barsuk et al., 2009a). The number of procedures performed did not correlate with objective measurement of procedural skills
(Barsuk et al., 2012), again confirming that experience does not necessarily equate with skill.

One reason that simulator-based mastery learning may produce better outcomes than clinical experience is the opportunity for deliberate practice. Key features of deliberate practice are identification of a well-defined task, immediate performance feedback, and an opportunity to improve by performing the task repeatedly (Anders Ericsson, 2004). These features are achieved more readily in a simulator-based learning setting than in a patient care context. Deliberate practice correlates with performance in a variety of domains including sports, music, and art (Anders Ericsson, 2004; Krampe, 1996; Hyllegard, 2000; Helsen et al., 2000). Deliberate practice in medical education has been associated with performance on achievement tests, as well as clinical skills such as ECG interpretation and application of advanced cardiac life support algorithms (Moulaert et al., 2004; Hatala et al., 2003; Wayne et al., 2006).

Other elements of deliberate practice include motivated learners, an appropriate level of difficulty, the ability to monitor and correct errors, stringent measurement, and comparison to a mastery standard (McGaghie et al., 2011). These features fit well with a mastery learning model which requires explicit objectives, corrective feedback, well-organized self-instruction materials, and opportunities to demonstrate achievement of the objectives (Mann and Eland, 2005). The currently available colonoscopy simulators provide simulated cases that meet these criteria for self-instruction, difficulty level, objective assessment, and provision of feedback, but performance standards have not been identified for trainees.
The current study will apply the mastery learning model to colonoscopy training to determine whether deliberate practice on a colonoscopy simulator allows residents to achieve a predefined level of mastery, as assessed by the simulator. In order to answer this question, the level of mastery required for residents beginning their endoscopic training to perform procedures on patients must also be determined. The only other colonoscopy simulator study to apply a mastery learning model (Ahlberg et al., 2005) was a randomized controlled trial with only 6 residents in the simulator arm. The mastery criterion in that study was based on the actual simulator performance of expert endoscopists, which may not be an appropriate standard for residents at the beginning of their procedural training. The mastery criterion was also limited to metrics provided by the simulator such as time to reach the cecum, volume of air insufflation, and time in red-out. The current study addresses a gap in the literature by applying the mastery learning paradigm to a larger group of residents, using the Angoff standard setting method to determine an appropriate mastery standard for novice endoscopists, and integrating markers of procedure quality beyond those provided by the simulator metrics.
III. Methods

A. Study Participants

First year gastroenterology subspecialty residents and third year general surgery residents at the University of Alberta, from July 2008 to July 2010, were invited to participate in the study. Gastroenterology residents were recruited in July at the onset of their subspecialty residency program, prior to beginning formal endoscopic training. General surgery residents were recruited at the onset of their Endoscopy rotation (which is a two month rotation in the third year of the residency program). These groups were selected to reflect novice endoscopists with no significant prior endoscopic exposure. Informed, voluntary consent was obtained, in accordance with the University of Alberta Health Research Ethics Board, and the University of Illinois, Chicago Institutional Review Board.

B. Endoscopic Simulation

The CAE Healthcare AccuTouch endoscopic simulator (CAE Healthcare, Montreal, Quebec, Canada) was used for all simulated endoscopy testing and for learners’ deliberate practice sessions. This is a computerized endoscopic simulator, with force feedback, based on a haptic mechanism to replicate the tactile sensation of live endoscopy, and visual feedback via a computer interface which presents an endoscopic view of the colon, including simulated colonic pathology. Realism of the simulator is also supported by the use of a colonoscope similar to those used for live endoscopy, as well as continuous vital signs monitoring, and verbal feedback from the simulated patient during episodes of discomfort.

C. Mastery Standard Setting
A previously validated colonoscopy checklist by Sedlack et al was used as the basis for the pre- and post-test checklist (Sedlack et al., 2007). Additional items were added to this checklist to reflect quality assurance parameters (Lieberman et al., 2007) including withdrawal time (Barclay et al., 2006), mucosal visualization, safety parameters (perforation, oversedation, recognition of pathology), and patient comfort (air insufflation, response to patient discomfort). (Appendix A)

Eight expert endoscopists (>1000 colonoscopies performed) were selected for the standard setting exercise. All were board certified gastroenterologists at an academic institution with previous experience teaching colonoscopy to novice learners. A modified yes-no Angoff method (Ricker, 2006) was used to assess each checklist item and determine the overall mastery criterion score. Only one standard setting judge had previous experience with the Angoff method.

Judges performed the three test modules on the colonoscopy simulator prior to the standard setting session to gain familiarity with the realism and degree of difficulty of the simulator modules. A written description of the mastery learning protocol and its purpose, as well as a summary of the Angoff method, was distributed to judges prior to the standard setting meeting. Judges discussed as a group their perceptions of how well a novice endoscopist would perform on the checklist tasks. Through this discussion, a consensus description of the borderline candidate was established. No normative data was provided to judges prior to the standard setting exercise.

An iterative approach to standard setting was taken. Each judge rated the checklist items independently, making a “yes/no” judgment for each checklist item. The group average for each checklist item was discussed after the first round. Each judge repeated
their ratings in a second round, and the mean scores for each checklist task were then summed to determine the mastery criterion cut score for the simulator test. The cut score as determined by this method was 8.6/14.

A non-compensatory scoring system was used, requiring the learner to meet the cut score for each of the three modules on the pre/post-test. The standard setting judges also agreed that an “egregious error”, consisting of a serious complication (oversedation or perforation) during a simulated colonoscopy, would constitute an automatic fail, regardless of the checklist score.

D. **Study Protocol**

Participants completed a baseline questionnaire to collect their demographic information and prior endoscopic experience. They then completed a pre-test comprised of three simulated colonoscopies of varying levels of difficulty on the AccuTouch simulator. The same three simulated colonoscopy modules were used for all pre-tests and post-tests, and were chosen to reflect a spectrum of procedure difficulty levels. The first was a relatively easy colonoscopy which did not require loop reduction, the second was moderately difficult, and the third module represented a redundant sigmoid colon which required loop reduction for procedure completion. If the learner did not meet the mastery criterion standard on all three simulated colonoscopies (non-compensatory scoring), they proceeded to simulator training.

The simulator training consisted of self-directed deliberate practice on the AccuTouch endoscopic simulator. Practice on diagnostic sigmoidoscopy, diagnostic colonoscopy, and colonoscopy with polypectomy modules provided diverse cases for simulated endoscopy.
A single rater was used to assess the learner at pre-test and post-test. The checklist (Appendix A) included both objective markers of colonoscopy performance (advancement to various anatomic landmarks, time to reach the cecum, withdrawal time, retroflexion, percent of mucosa visualized, perforation, oversedation) which were provided by the simulator, and subjective measures of colonoscopy performance (recognition of pathology, loop reduction, limitation of air insufflation, and appropriate response to patient discomfort) as assessed by the rater.

This gastroenterologist-rater gave feedback to the learner after the pre-test, but only simulator feedback was provided during the deliberate practice sessions. Practice time was recorded by login times to the endoscopic simulator. The learners did not participate in live colonoscopy procedures during the simulator training period.

When the learner felt confident in their mastery of the simulated colonoscopy procedure, they completed the simulator post-test. This consisted of the same three simulated colonoscopy modules, and used the same procedural skills checklist. If the learner met the checklist cut score on all three simulated colonoscopies, they were deemed to have met the mastery criterion and were able to proceed to live colonoscopy training. If they did not meet the checklist cut score, they completed further simulator training until they were able to meet the mastery criterion.

A post-intervention questionnaire was completed by each participant. This was used to assess their satisfaction with the simulated colonoscopy training, and their impressions of the mastery learning process.

E. Statistical Analysis
Descriptive statistics were used to analyze the learners’ demographics, practice time, and responses to the post-intervention questionnaire. A paired t-test was used to compare the pre-and post-test performance both on the checklist, and comparing the rates of egregious errors at pre- and post-test. Statistics were calculated using SPSS software (IBM SPSS Statistics for Windows, Version 19.0, Armonk, NY: IBM Corp.).
IV. Results

A. Study Participants

All residents consented to participate in the study. A total of 17 residents were included in the study; 4 were surgery residents, and 13 were gastroenterology residents. Demographic information is presented in Table 1. The majority of the residents had completed 20 or fewer colonoscopies or gastroscopies. All of the residents had some endoscopic exposure prior to this study despite having no formal endoscopic training. A minority of residents had prior exposure to the colonoscopy simulator, but for all of these participants, five or fewer simulated procedures were performed. Despite some prior endoscopic exposure, none of the residents described themselves as being comfortable with performing colonoscopy.
# TABLE I

DEMOGRAPHIC CHARACTERISTICS OF STUDY PARTICIPANTS (n=17)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age: mean (SD)</td>
<td>29.8 (2.61)</td>
</tr>
<tr>
<td>Gender: no. (%)</td>
<td>10 (59)</td>
</tr>
<tr>
<td>Training program: no. (%)</td>
<td></td>
</tr>
<tr>
<td>Gastroenterology</td>
<td>13 (76.5)</td>
</tr>
<tr>
<td>General Surgery</td>
<td>4 (23.5)</td>
</tr>
<tr>
<td>Previous colonoscopies performed: no. (%)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>3 (17.6)</td>
</tr>
<tr>
<td>1-20</td>
<td>10 (58.8)</td>
</tr>
<tr>
<td>21-50</td>
<td>1 (5.9)</td>
</tr>
<tr>
<td>51-100</td>
<td>3 (17.6)</td>
</tr>
<tr>
<td>&gt;100</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Previous gastroscopies performed: no. (%)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0 (0)</td>
</tr>
<tr>
<td>1-20</td>
<td>11 (64.7)</td>
</tr>
<tr>
<td>21-50</td>
<td>3 (17.6)</td>
</tr>
<tr>
<td>51-100</td>
<td>2 (11.8)</td>
</tr>
<tr>
<td>&gt;100</td>
<td>1 (5.9)</td>
</tr>
<tr>
<td>Previous colonoscopy simulator use: no (%)</td>
<td>4 (23.5)</td>
</tr>
<tr>
<td>Previous simulated colonoscopies performed: no. (%)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>13 (76.5)</td>
</tr>
<tr>
<td>1-5</td>
<td>4 (23.5)</td>
</tr>
<tr>
<td>6-10</td>
<td>0 (0)</td>
</tr>
<tr>
<td>11-25</td>
<td>0 (0)</td>
</tr>
<tr>
<td>&gt;25</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Self-perceived comfort level with colonoscopy: mean (SD) range of 1-5 (not confident to very confident)</td>
<td>2.12 (1.05)</td>
</tr>
<tr>
<td>Frequency of video game playing: mean (SD) range of 1-5 (never to daily)</td>
<td>2.59 (1.12)</td>
</tr>
</tbody>
</table>

## B. Colonoscopy Simulator Performance

The mean pre-test score for all residents was 9.0/14 (SD 2.19). Four residents met the minimum passing score at the pre-test with a mean score of 11.79/14 (SD 0.49), while thirteen residents failed the pre-test with a mean score of 8.15/14 (SD 1.71). Thirteen residents made an egregious error (oversedation or perforation) in at least one simulated
case at the pre-test. By definition, none of the residents who passed the pre-test made an egregious error. Of the thirteen residents who failed the pre-test, eight residents made one egregious error, four residents made two egregious errors, and one resident made three egregious errors.

The average simulator practice time was 220 minutes, with a range of 117-383 minutes.

The proportion of residents meeting the minimum passing score improved significantly from pre-test to post-test, as did the rate of egregious errors. (Figure 1) One resident failed the post-test and caused a colonoscopy perforation at the post-test. This resident had additional simulator practice time totaling 12.7 minutes and subsequently met the minimum passing score with no egregious errors.

Figure 1: Proportion of residents meeting the MPS and making egregious errors pre-test to post-test

* = p<0.05
The mean overall score on all three simulator modules improved significantly from pre-test to post-test (Table II). Most individual checklist items also showed significant improvement from pre-test to post-test. Items which did not improve between pre-test and post-test were advancement to rectosigmoid colon, advancement to sigmoid-descending colon junction, limiting air insufflation, withdrawal time, and recognition of pathology.

Table II

OVERALL SCORE AND INDIVIDUAL CHECKLIST ITEM PERFORMANCE

<table>
<thead>
<tr>
<th>Item</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall test score (max=14)</td>
<td>9.00</td>
<td>12.59</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Advanced to recto-sigmoid (%)</td>
<td>100</td>
<td>100</td>
<td>NS</td>
</tr>
<tr>
<td>Advanced to sigmoid-descending (%)</td>
<td>96</td>
<td>100</td>
<td>0.33</td>
</tr>
<tr>
<td>Advanced to splenic flexure (%)</td>
<td>82</td>
<td>100</td>
<td>0.008</td>
</tr>
<tr>
<td>Advanced to hepatic flexure (%)</td>
<td>74</td>
<td>100</td>
<td>0.001</td>
</tr>
<tr>
<td>Advanced to cecum (%)</td>
<td>66</td>
<td>98</td>
<td>0.001</td>
</tr>
<tr>
<td>Advanced to terminal ileum (%)</td>
<td>37</td>
<td>80</td>
<td>0.001</td>
</tr>
<tr>
<td>Time to cecum &lt; 15 min (%)</td>
<td>64</td>
<td>88</td>
<td>0.014</td>
</tr>
<tr>
<td>Limits air insufflation (%)</td>
<td>84</td>
<td>88</td>
<td>0.55</td>
</tr>
<tr>
<td>Reduces loop formation (%)</td>
<td>35</td>
<td>90</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Withdrawal &gt; 6 min (%)</td>
<td>58</td>
<td>63</td>
<td>0.669</td>
</tr>
<tr>
<td>Retroflexion in rectum (%)</td>
<td>35</td>
<td>92</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&gt;90% mucosa visualized (%)</td>
<td>62</td>
<td>92</td>
<td>0.003</td>
</tr>
<tr>
<td>Recognizes relevant pathology (%)</td>
<td>74</td>
<td>94</td>
<td>0.20</td>
</tr>
<tr>
<td>Avoids perforation (%)</td>
<td>76</td>
<td>100</td>
<td>0.001</td>
</tr>
<tr>
<td>Responds to patient discomfort (%)</td>
<td>41</td>
<td>63</td>
<td>0.036</td>
</tr>
<tr>
<td>Avoids oversedation (%)</td>
<td>78</td>
<td>98</td>
<td>0.004</td>
</tr>
</tbody>
</table>

C. Learner Satisfaction

A post-intervention questionnaire was completed by 9/17 participants. All survey items were rated on a 5 point Likert scale from 1= strongly disagree to 5= strongly agree.
The utility of the colonoscopy simulator as a modality for early endoscopic training was rated positively by the majority of residents. Residents felt that the simulator was realistic compared to live colonoscopy, but was not as difficult as live colonoscopy. Residents found the mastery learning standard to be reasonable, and did not think that residents who required extra practice time to meet the minimum passing score would be seen in a negative light.

**Table III**

**LEARNER SATISFACTION**

<table>
<thead>
<tr>
<th>Survey item</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using the colonoscopy simulator was a good use of my time</td>
<td>4.33</td>
<td>1.00</td>
</tr>
<tr>
<td>Using the colonoscopy simulator improved my technical skills</td>
<td>4.22</td>
<td>0.83</td>
</tr>
<tr>
<td>Using the colonoscopy simulator improved my confidence in performing live colonoscopy</td>
<td>4.33</td>
<td>0.71</td>
</tr>
<tr>
<td>The simulator was realistic compared to live colonoscopy</td>
<td>3.67</td>
<td>1.00</td>
</tr>
<tr>
<td>The simulator was difficult compared to live colonoscopy</td>
<td>2.33</td>
<td>1.12</td>
</tr>
<tr>
<td>The mastery criterion I needed to meet was reasonable</td>
<td>4.33</td>
<td>0.71</td>
</tr>
<tr>
<td>The need for additional practice if the mastery criterion was not met was reasonable</td>
<td>3.71</td>
<td>0.76</td>
</tr>
<tr>
<td>The mastery learning concept improved my confidence at performing colonoscopy</td>
<td>4.11</td>
<td>0.78</td>
</tr>
<tr>
<td>Learners who needed additional practice time may be seen in a negative light</td>
<td>3.11</td>
<td>1.05</td>
</tr>
</tbody>
</table>
V. Discussion

This study shows an increase in colonoscopy skills after computer-based simulation in a mastery based learning setting. Only two prior studies have described the application of mastery based learning to colonoscopy training. One study used a psychomotor task on the Simbionix simulator rather than a colonoscopy module (van Sickle et al., 2011). In this study, the passing standard was defined as the mean scores achieved by expert endoscopists performing the psychomotor task. An average of 13 trials of the psychomotor task was required for learners to meet this standard, which was estimated to take three to four hours of practice time (van Sickle et al., 2011). After simulation training, residents reduced the time required to reach the cecum, time spent without clear mucosal views, and overall global performance score (van Sickle et al., 2011). The present study uses simulated colonoscopy cases rather than an abstract psychomotor task, with cases of varying difficulty levels. Clinical variation and varied difficulty levels have been identified as key elements of well-designed simulation-based education (Cook et al., 2013), which may support the design of the current study. In addition, using expert performance as the minimum passing score for novice endoscopists may not be appropriate.

The other study using a mastery based learning paradigm for teaching colonoscopy skills used expert performance on a simulated colonoscopy module as the minimum passing score (Ahlberg et al., 2005). Expert performance was defined solely by simulator feedback metrics including time to reach the cecum, use of virtual attending function, percent of time with no patient discomfort, volume of air insufflated, and percent of time in red-out. Trainees averaged 20 hours of simulator practice time to reach this expert standard (Ahlberg et al., 2005). The simulator group subsequently demonstrated shorter procedure time, less patient discomfort, and increased independent procedure
completion in their first ten live colonoscopies compared to a control group (Ahlberg et al., 2005).

This literature, combined with the current study, supports the use of a mastery-based learning simulator curriculum for colonoscopy skills teaching. The variable amounts of practice time required in the two previous studies, compared to 220 minutes in the present study, may reflect differences in the chosen minimum performance standard. The two prior studies implementing mastery-based learning in a colonoscopy setting used expert performance on the simulator as a performance standard (van Sickle et al., 2011; Ahlberg et al., 2005). Previous attempts to determine an expert benchmark on the colonoscopy simulator showed significant variability in simulator performance metrics amongst experts (Phitayakorn et al., 2009). All metrics were based on those provided automatically as simulator feedback. The percent of mucosa examined and time with a clear view of the mucosa were the most consistent metrics (Phitayakorn et al., 2009). In another study, not using a mastery-based learning protocol, no residents were able to meet expert performance standard on the colonoscopy simulator after three simulator-based colonoscopy practice sessions totaling 10 simulated colonoscopies (Kruglikova et al., 2010a). This indicates that using expert performance standard as a performance standard for novices may not be appropriate.

Computer-based colonoscopy simulator performance standards derived from experts have been shown to be different from those of partially trained endoscopists or novices (Sedlack and Kolars, 2002). As with all standard setting, identification of a performance standard involves expert judgment, taking into consideration the level of learner, and the consequences of the examination. The strengths of the current study’s performance standard include the Angoff process and inclusion of quality assurance markers, and
subjective measures of procedural technique and interpretation of simulator images, rather than relying solely on automated simulator metrics. In fact, in previous studies of the computerized colonoscopy simulators, many simulator-based metrics did not distinguish between different levels of endoscopic skill (McConnell et al., 2012; Kim et al., 2010), while scoring rubrics that focused on overall skill as judged by an expert observer discriminated more consistently between levels of experience (Sarker et al., 2010).

Although overall performance improved with simulator training in our study, this was not true for all individual checklist items. Advancement to the rectosigmoid colon and sigmoid-descending colon junction did not differ between the pre-test and the post-test, as most learners were able to advance to the descending colon on the pre-test. Limiting air insufflation and recognizing relevant pathology were also performed well on the pre-test and improvement did not reach statistical significance after simulator training. Interestingly, the improvement in withdrawal time did not reach statistical significance from pre-test to post-test, and residents on average did not achieve the quality marker of six minute withdrawal time (Barclay et al., 2006) even at the post-test. This is consistent with assessment of practicing endoscopists where withdrawal time on the simulator was greater than six minutes in only 33-40% of simulated cases (Cantu et al., 2010). This may indicate either a limitation of the simulator in this regard (a colon that is too short or simplistic to realistically spend six minutes on withdrawal) or an existing quality improvement gap.

Advancement to landmarks more proximal to the descending colon, insertion time, ability to retroflex in the rectum, loop reduction, mucosal visualization, response to patient discomfort, oversedation, and perforation all improved significantly from pre-test to post-
Previous studies focused on simulator performance metrics have consistently found the time-based metrics to be the best discriminators of performance between novice and experts (McConnell et al., 2012; Kim et al., 2010), although sedation and time spent with clear mucosal views also discriminates between different levels of experience (McConnell et al., 2012), which is consistent with findings in the current study. The high rates of complications (oversedation and perforation) seen in our study have not been reported previously, and may relate to the instructions to the learner to attempt to reach the cecum in each case. This differs from live endoscopy, where the attending physician would take over the case when the learner begins to have difficulty.

A. Limitations

Limitations to the current study were the small sample size. This precluded subgroup analysis, using inferential statistics, which would have been useful to compare performance between gastroenterology and surgery residents, or to determine whether the amount of previous endoscopic experience or video game playing predicted performance on the colonoscopy simulator. Another limitation is the high proportion of learners who had some experience with live endoscopy or with the colonoscopy simulator. Previous studies have varied in their definitions of novice endoscopist, but in most cases this is interpreted as no prior endoscopic experience. However, the current study was not intended to draw comparisons between endoscopists of varying experience levels, and the limited endoscopic experience seen in our learners is likely reflective of the average group of learners beginning gastroenterology fellowship or surgical endoscopic training.

In this study, pre-test and post-test assessments of simulator performance were performed by a single rater. A previous study of mastery-based laparoscopic skills also
used a only a single rater (Korndorffer et al., 2005), and the use of a single rater could potentially provide more consistent ratings than a larger group of raters who range in stringency. There is some evidence that raters with the most rating experience provide clinical assessments that are more reliable than those of less experienced raters (Ferguson et al., 2012). The rater in this study is responsible for evaluating the colonoscopy simulator performance for surgical residents at this institution, so would be considered an experienced rater. Nonetheless, the assessments of resident performance could have been strengthened with the use of multiple raters and evidence of high inter-rater reliability.

A final limitation is the use of feedback in combination with the colonoscopy simulator. In this study, feedback was limited to that provided by the simulator itself. This included use of the “virtual attending” feature, use of the external view feature to determine the location of the colonoscope tip and any loops present, and calculated metrics such as insertion and withdrawal time and percent of the mucosa visualized. The most appropriate use of feedback in the setting of colonoscopy simulation is still not clear. Irrespective of the level of experience of the learner, when no feedback was given there was no improvement in simulator performance in one study (Mahmood and Darzi, 2004). This included blinding any feedback from the simulator itself. In a subsequent study, no difference in performance was detected between groups of students who received proctored feedback or feedback from the colonoscopy simulator alone (Snyder et al., 2010). Conversely, feedback from a supervisor during and after colonoscopy simulation has resulted in improved performance compared to a control group, including a significant reduction in the rate of simulated colonoscopy perforation (Kruglikova et al., 2010b). When concurrent and terminal feedback were compared in two groups of learners performing simulated colonoscopy, there was no difference in their post-test
performance but improved skills transfer in the group who received terminal feedback (Walsh et al., 2009). Despite the evidence supporting feedback as an adjunct to simulator training, the two largest randomized controlled trials to show a benefit to the colonoscopy simulator did not use any feedback as part of their training sessions (Cohen et al, 2006; Park et al., 2007).

B. **Future Directions**

The optimal use of colonoscopy simulation in resident teaching remains to be fully determined. The bulk of the evidence demonstrates that simulation is most useful at the very early part of the learning curve, to potentially improve early procedural skills on live endoscopy (Cohen et al., 2006). This study is the first to demonstrate the applicability of the mastery based learning model to colonoscopy instruction, with improved skills performance, as well as resident satisfaction with the simulation as well as with the mastery learning model. This is consistent with previous evidence that residents value the simulator experience and report an increased confidence in their colonoscopy skills with increasing amounts of simulator practice (Lightdale et al., 2010).

Technology-enhanced simulation in medical education has been shown to improve learner knowledge and skills with more modest effects on patient outcomes (Cook et al., 2011). Independent predictors of improved outcomes of technology-enhanced simulation programs include use of a mastery learning paradigm, high fidelity simulation, and provision of feedback (Ilgen et al., 2013; Cook et al., 2013). This is directly applicable to the utility of computerized colonoscopy simulation. Future studies will need to directly compare different modes of simulator training, such as use of the mastery learning paradigm versus simulator practice with no mastery performance standard to determine the most effective use of this instructional strategy.
In order to maximize the utility of colonoscopy simulator training, it should be integrated into the curriculum as a whole, and should provide informative feedback (Kneebone, 2005; McGaghie et al., 2011). Future implementation of colonoscopy simulation at our institution will address these needs by increasing the availability of expert feedback, integrating colonoscopy simulator training with other teaching modalities, and providing opportunities to reinforce learning with simulator practice throughout the novice phase of the learning curve.

In addition to curricular integration, implementation of a successful simulator-based curriculum also requires faculty commitment, and support in terms of both manpower and funding dollars (McGaghie et al., 2011). These facets of implementation are another area for future research. Studies of learner and faculty perceptions of colonoscopy simulation are required to address misconceptions and increase support and integration of this technology. Informal feedback elicited during this study demonstrated some reluctance on the part of the residents to participate in simulation rather than live endoscopy as the simulation was perceived as a step down from live procedures. Residents also tended to blame deficits in their performance on the simulator rather than on gaps in their own technique. This was reported in a previous study when an expert caused a colonoscopy perforation in a simulated case and commented, “I suspect software malfunction, not my poor technique” (McConnell et al., 2012). A qualitative study of such faculty and student attitudes would be an important step to identifying and removing barriers to simulator curriculum implementation.

Finally, computer-based colonoscopy simulation is an expensive instructional method, especially if attending physicians are required to be present to provide feedback. Cost-
effectiveness data supporting the use of colonoscopy simulation has not yet been reported. Identifying potential cost-savings in terms of time saved in the endoscopy suite after simulator training would help to build support for simulator implementation from both attending physicians and administration.

C. Conclusions

An acceptable mastery performance standard was determined and successfully applied to colonoscopy simulation. Residents who participated in simulator training showed improved procedural skills after an average of 220 minutes of deliberate practice on the colonoscopy simulator. Both the simulation and the mastery learning paradigm were accepted by the residents. Future studies should compare elements of simulator training to determine the most effective methods to deliver this resource. In addition, qualitative studies focused on the attitudes of current medical culture towards simulation are needed in order to address barriers to implementation.
Appendix A: Colonoscopy Performance Checklist

Scope Advancement
1. Advances colonoscope to recto-sigmoid junction /0.5
2. Advances colonoscope to sigmoid-descending junction /0.5
3. Advances colonoscope to splenic flexure /0.5
4. Advances colonoscope to hepatic flexure /0.5
5. Advances colonoscope to cecum /1.0
6. Advances colonoscope to terminal ileum /1.0
7. Time to cecum less than 15 minutes /1.0
8. Limits air insufflation /1.0
9. Reduces loop formation /1.0

Scope Withdrawal
10. Withdrawal time greater than 6 minutes /1.0
11. Retroflexion accomplished in rectum /1.0
12. Greater than 90% of mucosa visualized /1.0
13. Recognizes relevant pathology /1.0

Patient Safety
14. Avoids perforation /1.0
15. Responds appropriately to patient discomfort /1.0
16. Avoids oversedation /1.0

Total /14

Insertion time: ___________ minutes
Procedure time: ___________ minutes
CITED LITERATURE


VITA

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ABSTRACTS:

WellnessRx: Development of an interprofessional educational initiative for nutrition and physical activity. Canadian Conference on Medical Education, Quebec City, Canada, April 22, 2013.


Peerani F, Dicken B, **Bistritz L**. Effectiveness of an educational intervention targeting medical students’ nutrition knowledge and skills. Canadian Digestive Disease Week, Montreal, Canada, February 25, 2012.


PUBLICATIONS:


http://www.sciencedirect.com/science/article/pii/S0149718914001499#


