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Fabrication of An Inexpensive but Effective Colonoscopic Simulator

Mark W. Jones, DO, Matthew J. Deere, DO, Justin R. Harris, DO, Anthony J. Chen, DO, Werner H. Henning, DO

ABSTRACT

Because of increasing requirements for simulator training before actual clinical endoscopies, the demand for realistic, inexpensive endoscopic simulators is increasing. We describe the steps involved in the design and fabrication of an effective and realistic mechanical colonoscopic simulator.

Key Words: Colonoscopy, Education, Endoscopy, Internship and residency.

INTRODUCTION

General surgery programs accredited through the Accreditation Council for Graduate Medical Education (ACGME) require simulated endoscopic training before performing colonoscopies on live patients. Currently, the ACGME recommends that surgical residents perform a minimum of 50 colonoscopies and 35 esophagogastroduodenoscopies. In 2018, the American Board of Surgery will require that graduating residents complete a flexible endoscopy curriculum, Fundamentals in Endoscopic Surgery (FES), which includes endoscopic simulator training before performing endoscopies in the clinical setting.[1]

There are several categories of endoscopic simulators including mechanical, live animal models, composite explanted animal organ models, and computer simulation models. Mechanical simulators are among the earliest and historically least realistic; they usually consisted of a rubber mannequin and an endoscope. Live animal models are far more realistic; however, cost and ethical concerns make this model prohibitive to use. Composite and explanted animal organ simulators are cumbersome and expensive, as they are fabricated from frozen plastic torsos combined with explanted porcine organs. Computer-based virtual reality simulators that provide good tactile feedback and realistic visuals are becoming more widely available; however, the initial cost, future repairs, and maintenance expenses can be prohibitive.[2–5]

The most crucial factors in becoming a proficient endoscopist are familiarization and repetition. It has been demonstrated that more hours spent on a simulator equate to better performance on competency evaluations.[6] To be effective, simulators must be easy to use, readily available, and provide an experience that allows the participant to practice and hone the skills needed to become a proficient endoscopist. Mechanical models offer a cost-effective practice model to fulfill these needs.

We chose to design a mechanical model because it could be cost efficient, yet effective, in training junior residents. When designing a mechanical model, specific anatomic characteristics should be considered, including the characteristic "box" shape of the colon with angles at the splenic and hepatic flexures, the "S" shape of the sigmoid colon, the thinner walled saccular appearance of the cecum, the diameter of the colon (2–5 cm), and the length of various colonic segments. Our model considers these factors and improves upon previous models by including advanced features that add realism and closely mimic details encountered in live colonoscopies.

MATERIALS

We chose the materials for fabrication of our colonoscopic simulator to closely mimic conditions during an actual colonoscopy. We also wanted a design that would allow the shape of the device to change in order to mimic various colon configurations (extreme corners and redundancies). Two-inch foam insulation was cut into a base ~120 × 80 cm, then holes were drilled in various locations to hold 7/8-inch diameter dowels cut to ~15-cm lengths. These dowels were used to support and stabilize the actual simulator tubing and could easily be moved to change the colon configuration. When designing the layout of the simulator, specific lengths from the anal verge were measured as follows: anus, 0–4 cm; rectum, 4–16

Department of Surgery, McLaren Greater Lansing, Lansing, Michigan, USA (all authors).

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Address correspondence to: Mark W. Jones, DO, Department of Surgery, McLaren Greater Lansing, 2720 S. Washington Ave. Suite 300, Lansing, MI 48910, USA. Telephone: 517-487-8255, Fax: 517-487-2059, E-mail: mjones9006@aol.com

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cm; rectosigmoid, 15–17 cm; sigmoid, 17–57 cm; descending, 57–82 cm; transverse, 82–132 cm; ascending, 132–147 cm; and the cecum, 150 cm.[7]

Two layers were used to simulate the colon: an outer and an inner layer. The outer section of 3-inch flexible drainage tube was cut to a length of 150 cm to mimic the actual colon. The external tubing was secured to the dowels with rubber bands (**Figure 1**). To make the experience more realistic, an inner layer was made from a long surgical sonographic probe cover measuring 14 cm inner diameter × 244 cm long. The top of a 1-L drink bottle was cut to simulate the anus. The inner layer was then placed through the outer layer and secured with rubber bands over the drink bottle. A small cut was made in the inner tubing at the mouth of the bottle to simulate the sphincter. This opening closely simulated the anus and maintained insufflated air in the inner sheath during endoscopy. The end of the probe cover was tied shut to simulate the cecum.

Simulated polyps of various shapes and sizes were created from foam padding and secured to the inner surface of the inner sheath with contact cement (**Figure 2**). Several loose rubber bands were placed at various locations along the length of the inner sheath, very closely mimicking the muscle contractions of the colon (**Figure 3**). Lubricating gel and a small amount of water were added to the inner sheath to reproduce the moist inner layer of the bowel accurately and necessitate appropriate insufflation. A standard colonoscope was used in conjunction with the simulator (**Figure 4**).

Figure 1. Partially constructed simulator showing materials used.

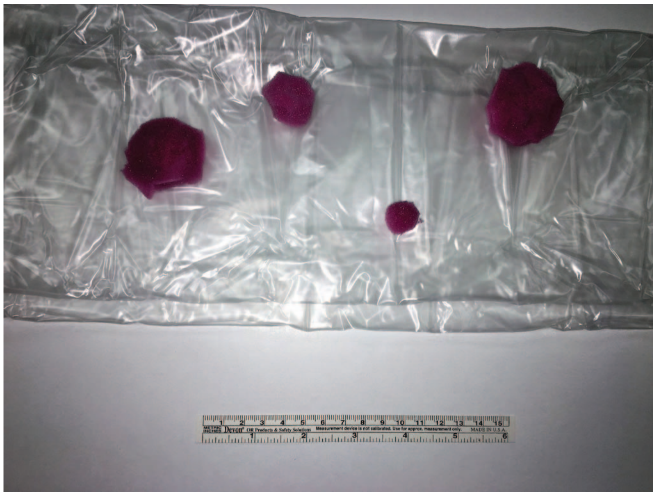

Figure 2. Replications of foam polyps (pedunculated and sessile) secured to the inner lumen of the inner sheath.

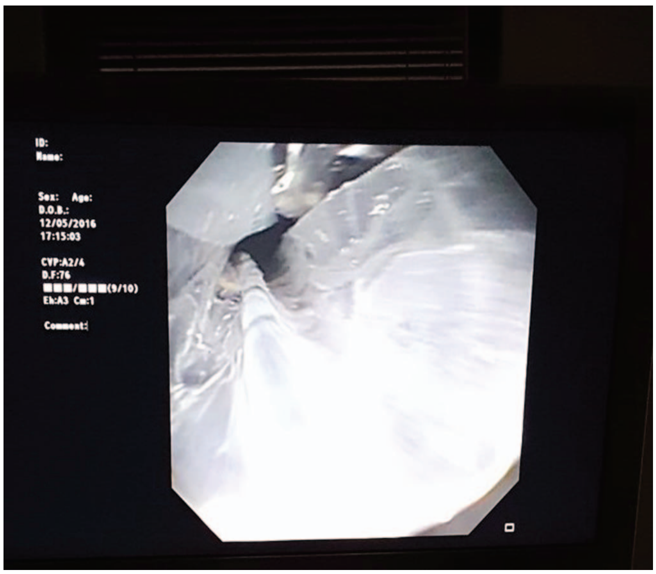

Figure 3. Endoscopic view during simulator practice closely replicating colonic mucosa of actual colonoscopy.

The best method of evaluating any simulator would be a direct comparison to actual live colonoscopies. To validate our model, we asked experienced endoscopists to complete a training session on our simulator. They were then asked to complete a survey comparing our simulator to live colonoscopies (**Figure 5**). The questions in the survey were based on the FES evaluation for endoscopic proficiency.[8] The responses were based on a Likert scale of 1 (strongly disagree) to 5 (strongly agree). In this way, the simulator's utility to complete the FES training was easily assessed.

DISCUSSION

There are various categories and designs for colonoscopic simulators. In fact, a very similar design was discovered during our literature review.[9] We feel that the modifications of our simulator design to fabricated foam polyps and use of a rubber band haustra made a significant difference in providing a more realistic learning experience compared with that obtained with other currently available mechanical simulators.

Thirteen proficient endoscopists completed the training session with our simulator and the survey. All endoscopists were in agreement that our device closely replicates the skills needed for live colonoscopy with an average response of 4.1 (range, 3–5). It was also agreed by all participants that our simulator would meet the training requirements set forth by the FES (**Table 1**).

Most endoscopic training curriculum involves measuring the time it takes to reach the cecum and withdraw the endoscope.[10–12] While timing is important, we feel that meeting endoscopic goals is most important for patient safety. Residents are evaluated by successfully reaching the simulated cecum and by locating and removing all polyps placed for the drill. Skills using biopsy forceps and

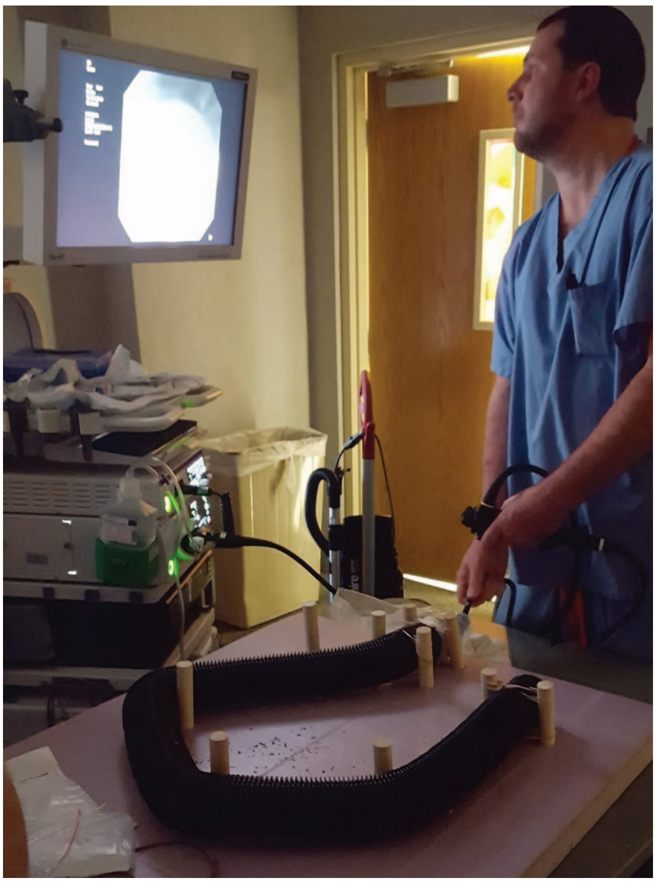

Figure 4. Demonstration of simulator in use.

Please respond to the following questions based on the following scale.

Strongly Disagree – Disagree – Neutral – Agree – Strongly Agree

(1) (2) (3) (4) (5)

1. This simulator closely replicates the skills necessary for live colonoscopy.

   (1) - (2) - (3) - (4) - (5)

2. This simulator would be effective to teach residents/fellows scope navigation.

   (1) - (2) - (3) - (4) - (5)

3. This simulator would be effective to teach residents/fellows basic maneuvers such as insufflation, suction and retroflection.

   (1) - (2) - (3) - (4) - (5)

4. This simulator would be effective to teach residents/fellows to keep a clear endoscopic field.

   (1) - (2) - (3) - (4) - (5)

5. This simulator would be effective to teach residents/fellows instrumentation. (i.e. biopsy and snare polypectomy.

   (1) - (2) - (3) - (4) - (5)

6. This simulator could be used to effectively evaluate residents/fellows for efficiency and quality of examination during colonoscopy.

   (1) - (2) - (3) - (4) - (5)

Figure 5. Colonoscopy simulator survey.

Table 1.
Survey Results

Survey Question	Response	Range
1. This simulator closely replicates the skills necessary for live colonoscopy.	4.1	3–5
2. This simulator would be effective to teach residents/fellows scope navigation.	4.5	4–5
3. This simulator would be effective to teach residents/fellows basic maneuvers such as insufflation, suction, and retroflection.	4.5	4–5
4. This simulator would be effective to teach residents/fellows to keep a clear endoscopic field.	4.2	3–5
5. This simulator would be effective to teach residents/fellows instrumentation. (i.e. biopsy and snare polypectomy.	4.3	3–5
6. This simulator could be used to effectively evaluate residents/fellows for efficiency and quality of examination during colonoscopy.	4.1	2–5

endoscopic snares are also evaluated and honed, as is overall handling of the colonoscope. Proper polypectomy and insufflation techniques must be used to avoid puncturing the inner sheath.

CONCLUSION

Repetition and familiarization are the hallmarks of becoming a proficient endoscopist.[10] With the implementation of the FES curriculum for general surgery residents instituted by the American Board of Surgery, the need for inexpensive colonoscopic simulators is apparent. The currently available mechanical simulators cost more than $2,500, whereas virtual reality simulators range from $20,000 to $100,000.[13–15] The simulator described above is simple and inexpensive to fabricate, costing ~$100 and requiring 30 minutes of setup time. Experienced endoscopists agree that its unique modifications and design afford residents a platform to perfect and test their skills while closely duplicating the nuances encountered in live colonoscopies.

References:

1. Pearl J, Fellinger E, Dunkin B, et al. Guidelines for privileging and credentialing physicians in gastrointestinal endoscopy. *Surg Endosc*. 2016;30:3184–3190.

2. Desilets DJ, Banerjee S, Barth BA, et al. Endoscopic simulators. *Gastrointest Endosc*. 2011;73:861–867.

3. Harpham-Lockyer L, Laskaratos FM, Berlingieri P, Epstein O. Role of virtual reality simulation in endoscopy training. *World J Gastrointest Endosc*. 2015;7:1287–1294.

4. Kim S, Spencer G, Makar GA, et al. Lack of a discriminatory function for endoscopy skills on a computer-based simulator. *Surg Endosc*. 2010;24:3008–3015.

5. Koch AD, Buzink SN, Heemskerk J, et al. Expert and construct validity of the Simbionix GI Mentor II endoscopy simulator for colonoscopy. *Surg Endosc*. 2008;22:158–162.

6. Eversbusch A, Grantcharov TP. Learning curves and impact of psychomotor training on performance in simulated colonoscopy: a randomized trial using a virtual reality endoscopy trainer. *Surg Endosc* 2004;18:1514–1518.

7. National Cancer Institute Surveillance, Epidemiology and End Results (SEER). Colonoscopy Measurements (cm) from Anal Verge. Available at https://training.seer.cancer.gov/colorectal/anatomy/figure/figure1.html. Accessed December 22, 2016.

8. American Board of Surgery, Flexible Endoscopy Curriculum for General Surgery Residents. Available at http://www.absurgery.org/xfer/abs-fec.pdf. Accessed February 1, 2017.

9. King N, Kunac A, Johnsen E, Gallina G, Merchant AM. Design and validation of a cost-effective physical endoscopic simulator for fundamentals of endoscopic surgery training. *Surg Endosc*. 2016;30:4871–4879.

10. Buzink SN, Koch AD, Heemskerk J, et al. Acquiring basic endoscopy skills by training on the GI Mentor II. *Surg Endosc*. 2007;21:1996–2003.

11. Vyasa P, Willis RE, Dunkin BJ, Gardner AK. Are general surgery residents accurate assessors of their own flexible endoscopy skills? *J Surg Educ*. 2017:74;23–29.

12. McIntosh KS, Gregor JC, Khanna NV. Computer-based virtual reality colonoscopy simulation improves patient-based colonoscopy performance. *Can J Gastroenterol Hepatol*. 2014;28:203–206.

13. 3-D med, Learning Through Simulation. Colonoscope Training Model. Available at https://www.3-dmed.com/product/colonoscope-training-model. Accessed February 1, 2017.

14. Anatomy Warehouse.com. Koken Colonoscopy Simulator Type 2. Available at https://www.anatomywarehouse.com/koken-colonoscopy-simulator-type-ii-a-105297. Accessed February 13, 2017.

15. Bittner JG, Marks JM, Dunkin BJ, Richards WO, Onders RP, Mellinger JD. Resident training in flexible gastrointestinal endoscopy: a review of current issues and options. *J Surg Educ*. 2007;64:366–409.