



# How to make cost-effective polyp simulators for high-fidelity simulation-based training in postpolypectomy bleeding management and EMR

Ally Y. Zhao, OSSD,<sup>1</sup> Nikko Gimpaya, BSc, MEd,<sup>1</sup> Mary Raina Angeli Fujiyoshi, MD, MSc, FJGES,<sup>1</sup> Yusuke Fujiyoshi, MD,<sup>1</sup> Rishad Khan, MD,<sup>2,3</sup> James Lisondra,<sup>4</sup> Catharine M. Walsh, MD, MEd, PhD, FAAP, FRCPC,<sup>5</sup> Samir C. Grover, MD, MEd, FRCPC, FASGE<sup>6,7</sup>

## BACKGROUND

Simulation-based training promotes the acquisition of skills related to performing endoscopic procedures in a low-risk environment.<sup>1-3</sup> In addition, simulation can be used to increase exposure to advanced endoscopic procedures, including EMR and bleeding management, that are oftentimes completed ad hoc and are associated with a steep learning curve.<sup>4-6</sup> Currently, simulation-based training programs for advanced procedures predominantly use animal models and/or virtual reality simulators.<sup>7</sup> Both modalities are expensive and may be limited in the number of endoscopic techniques that can be practiced, and animal models require special equipment.<sup>6,8,9</sup>

In this article, we demonstrate 3 novel and cost-effective simulated polyps designed for training in the management of postpolypectomy bleeding and conventional and underwater EMR (Video 1, available at [www.videogie.org](http://www.videogie.org)). The simulated polyps were developed using materials procured from local and online stores in Toronto, Ontario, Canada, in 2022. Some materials used were readily available at St. Michael's Hospital in Toronto.

## METHODOLOGY

The 3 simulated polyps are derived from the same base mixture of gelatin, cornstarch, salt, vinegar, glycerin, red food dye, and orange food dye (Fig. 1, Video 1, Appendix 1, available online at [www.videogie.org](http://www.videogie.org)).

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Division of Gastroenterology, St. Michael's Hospital, Toronto, Ontario, Canada (1), Division of Gastroenterology, St. Michael's Hospital, Toronto, Ontario, Canada (2), Temerty Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada (3), Division of Gastroenterology, St. Michael's Hospital, Toronto, Ontario, Canada (4), Division of Gastroenterology, Hepatology, and Nutrition and the Research and Learning Institutes, Hospital for Sick Children, Department of Paediatrics and the Wilson Centre, Temerty Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada (5), Division of Gastroenterology, St. Michael's Hospital, Toronto, Ontario, Canada (6), Temerty Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada (7).

To create the postpolypectomy bleeding simulator, a pedunculated polyp is formed using low-cost ingredients and a 3-dimensionally printed mold (Figs. 2 and 3, Video 1, Appendix 1, available online at [www.videogie.org](http://www.videogie.org)). An 18-gauge angiocath is then inserted in a fashion similar to that of the Welsh Institute for Minimal Access Therapy colonoscopy suitcase bleeding polyp model.<sup>10</sup> A syringe filled with simulated blood is attached to the catheter and is pumped out when resected.

The simulated polyps for conventional EMR training are made of 3 parts: a simulated mucosa, a plug to secure the simulator to the phantom, and the lesion. The simulator body is created by folding a flattened base mixture to encircle a sponge and fibrous material to ensure mucosal lifting (Figs. 4 and 5, Video 1, Appendix 1, available online at [www.videogie.org](http://www.videogie.org)).

Polyp simulators for underwater EMR are also created from a simulated mucosa, a thicker plug to secure the simulator to the phantom, and the lesion. To ensure buoyancy of the underwater EMR polyps, add baking soda to the base mixture (Figs. 6 and 7, Video 1, Appendix 1, available online at [www.videogie.org](http://www.videogie.org)).

Opinions from experts and gastroenterology fellows were used during the developmental stage to ensure visual realism and fidelity when using endoscopic instruments. Simulators were mounted on the descending colon of a commercially available colonic phantom (Koken Colonoscopy Simulator II; Koken Co, Ltd, Tokyo, Japan). We performed simulated colonoscopies using a standard video colonoscope (CF-HQ190L/I; Olympus Canada, Richmond, Ontario, Canada) and recorded videos using a high-definition recording device (MediCap USB 300; MediCap-ture Inc, Plymouth Meeting, Penn, USA).

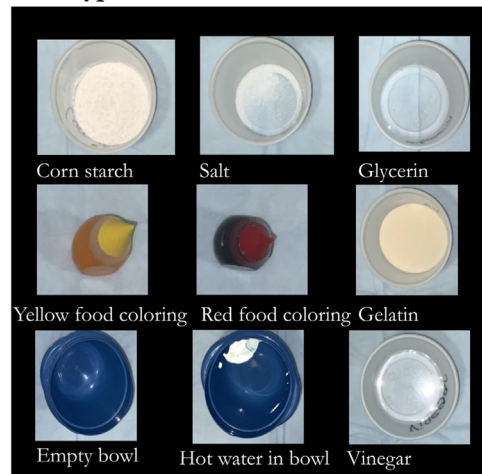
## RESULTS

Trials of all 3 simulators were used in the 2022 and 2023 endoscopic simulation courses in Toronto. The bleeding polypectomy model was demonstrated in the 34th International Course on Therapeutic Endoscopy, held in Toronto.

On average, it takes 25 minutes (including refrigeration) to make 5 of the bleeding polypectomy simulators and 1 of

### Base Mixture For All Three Polyp Simulators

Materials And Cost Per Batch Base Mixture (USD)	
Corn starch (2 tsp)	\$0.49/100 g
Salt (1/8 tsp)	\$0.65/1 kg
Glycerin (1/2 tsp)	\$2.05/59 mL
Red food coloring (1 drop)	\$0.76/7.1 mL
Orange food coloring (1 drop)	\$0.76/7.1 mL
Gelatin (2 tsp)	\$4.09/100 g
Vinegar (3 tsp)	\$0.95/1 L
Small, plastic, tupperware bowls	\$2.67/pack of 3
Hot water to fill 1/3 of one bowl	Readily available in institution



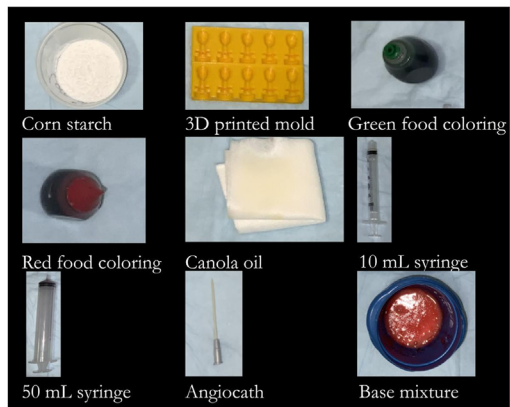
#### Instructions:

- 1) Fill one bowl with boiling water until 1/3 full.
- 2) Mix dry ingredients together into bowl.
- 3) Place bowl with dry ingredients above bowl containing hot water.
- 4) Combine wet ingredients into the bowl along with food coloring. Mix well until semi-viscous consistency (add more vinegar if necessary).

**Figure 1.** Cost and instructions for manufacturing the base mixture used in all 3 simulators. Prices were derived in Toronto, Ontario, Canada, in 2022 and converted to U.S. dollars. Some materials could be accessed for free from the home institution.

### Post-Polypectomy Bleed Simulator

Materials And Cost Per 5 Post-Polypectomy Bleeding Simulators (USD)	
Corn starch (1/2 tsp)	\$0.49/100 g
3D-printed mold in 0.3 resolution	\$0.076/1 g filament
Food coloring green (1 drop)	\$0.76/7.1 mL
Food coloring red (9-10 drops)	\$0.76/7.1 mL
Canola Oil	\$1.91/500 mL
10 mL syringe	Readily available at institution
50 mL syringe	Readily available at institution
Angiocath between 16-20 G in size	Readily available at institution
Base mixture	Refer to Figure 1



#### Instructions:

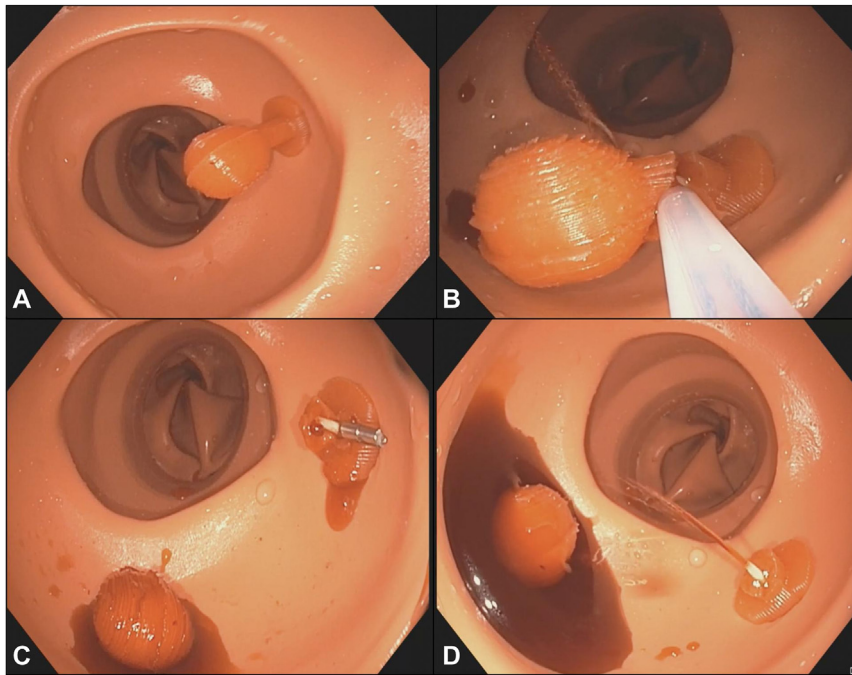
##### Making the simulated pedunculated polyps:

- 1) 3D print the STL files of the polyp mold in 0.3mm resolution with PLA plastic filament. The link to the STL file can be found in the description under Figure 2.
- 2) Apply oil to surface of 3D-printed mold. Hold the two pieces of mold together with tape.
- 3) Create a batch of base mixture (refer to Figure 1), and inject into mold using the 10 mL syringe. Tap the mold against a hard surface to prevent air bubbles.
- 4) Refrigerate for 15 minutes. Carefully separate the mold pieces and remove polyp simulators.

##### Making the simulated blood:

- 1) Combine cornstarch, green food coloring (1-2 drops) and red food coloring (7-9 drops) into cup with water. Adjust food coloring and cornstarch until desired color is reached.
- 2) Draw simulated blood into a 50 mL syringe.
- 3) Insert angiocath into base of polyp, extending the catheter until halfway through stalk.
- 4) Connect catheter to syringe, 'squirting' the simulated blood once the peduncle has been cut.

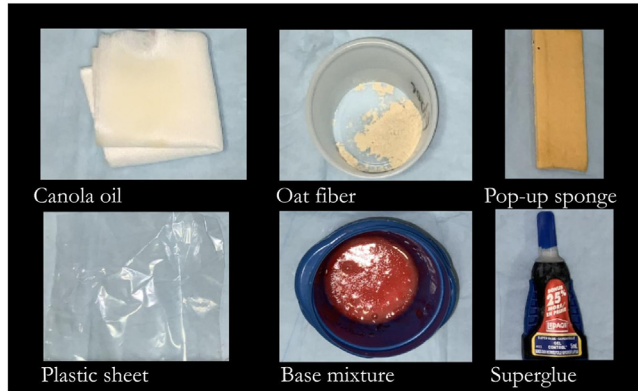
**Figure 2.** Prices and step-by-step manufacturing instructions for the postpolypectomy bleeding simulator. A stereolithography file for the 3-dimensionally printed mold is available at: <https://github.com/Zhaoa23/Simulated-Polypectomy-Mold>. Prices were derived in Toronto, Ontario, Canada, in 2022 and converted to U.S. dollars. Some materials could be accessed for free from the home institution.



**Figure 3.** Visual demonstration of the postpolypectomy bleeding simulator. The images show the simulator: **A**, prepolyectomy; **B**, the bleeding concurrent with resection; **C**, postpolypectomy hemorrhage; and **D**, after treatment with hemostatic clipping.

### Conventional Endoscopic Mucosal Resection Simulator

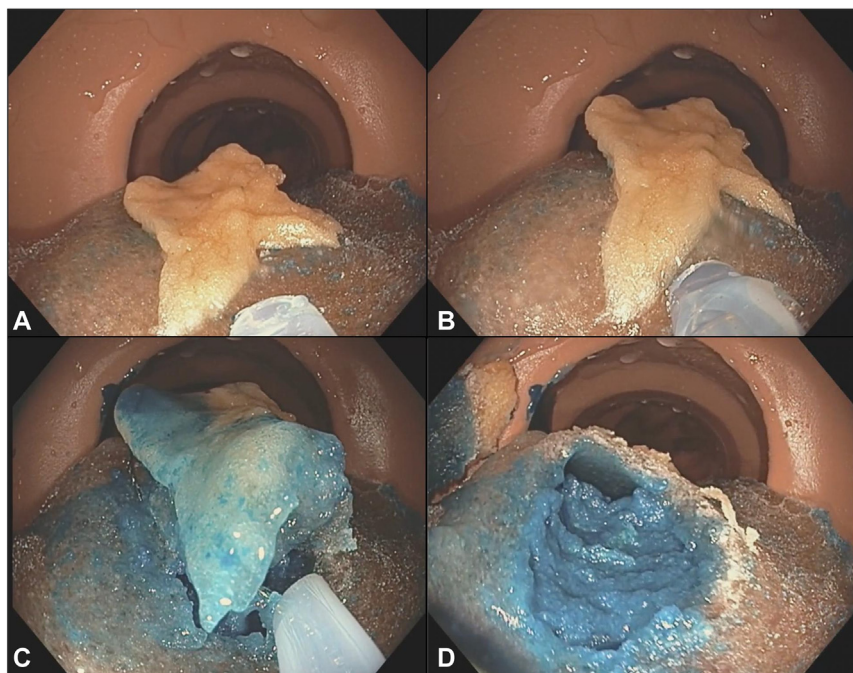
Materials And Cost Per Conventional EMR Simulator (USD)	
Canola Oil	\$1.91/500 mL
Oat fiber (¼ tsp or less)	\$0.57/100 g
Pop-up sponge	\$1.85/sponge
Plastic sheet	Readily available at institution
Base mixture	Refer to Figure 1
Superglue	\$9.16/5 g



#### Instructions:

- 1) Apply oil to plastic sheet. Scoop base mixture into a thin, approximately 6 cm in diameter circle onto one side of the plastic sheet to form mucosa. Scoop a smaller amount onto the other side of the plastic sheet and fold sheet into cylindrical shape to form a plug for phantom attachment. Secure with an object, such as a roll of tape. Wait 15 minutes to dry.
- 2) Cut pop-up sponge into a 3x1.5x0.3 cm shape.
- 3) Apply oat fiber to middle of simulated mucosa, place sponge in the center. Apply superglue along the sides of the mucosa. Fold in half and apply pressure to the sides to seal tightly.
- 4) Superglue plug to one side of simulated mucosa.
- 5) Utilize a plastic utensil to insert a dollop of remaining polyp mixture to form a lesion on the side opposite to the plug. If desired, use a drop of food coloring for the lesion to be distinct in color.

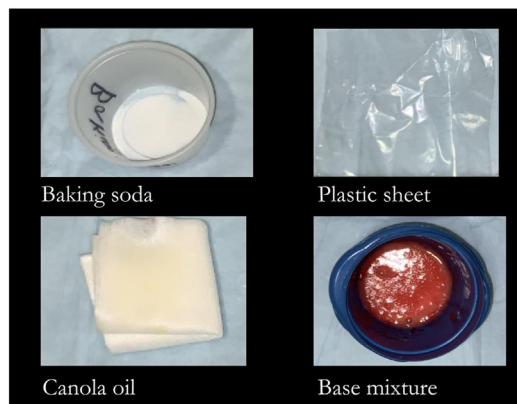
**Figure 4.** Cost and instructions for manufacturing the conventional EMR simulator. Although oat fiber was used in this simulator, any fine, fibrous material could be used. Prices were derived in Toronto, Ontario, Canada, in 2022 and converted to U.S. dollars. Some materials could be accessed for free from the home institution.



**Figure 5.** Visual demonstration of the capabilities of the conventional EMR simulator. The images show the simulator: **A**, before injection; **B**, after injection; **C**, during resection; and **D**, the remnant tissue after resection.

**Underwater Endoscopic Mucosal Resection Instruction Table**

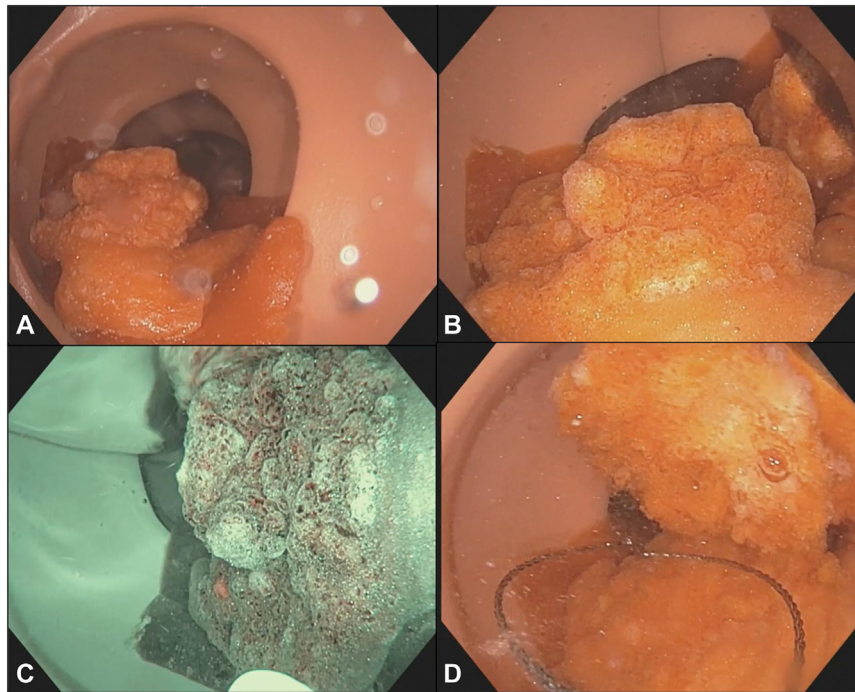
Materials And Cost Per Underwater EMR Simulator (USD)	
Baking soda (¼ tsp)	\$0.47/100 g
Plastic sheet	Readily available at institution
Canola oil	\$1.91/500 mL
Superglue	\$9.16/5 g
Base mixture	Refer to Figure 1



**Instructions:**

- 1) Apply oil to plastic sheet. Scoop base mixture into a thin circle approximately 4 cm in diameter onto one side of the plastic sheet to form mucosa.
- 2) Scoop a smaller amount onto the other side of the plastic sheet, and fold sheet into cylindrical shape to form plug for phantom attachment. Secure with an object, such as a roll of tape. Wait 15 minutes to dry.
- 3) Superglue the plug to the simulated mucosa. Secure until dried.
- 4) Mix ¼ tsp baking soda into remaining base mixture. Adjust color with red or yellow food coloring until desired color is reached. Stir to combine ingredients until foam-like consistency, do not overstir.
- 5) Use a utensil to place a dollop of base mixture from previous step onto the center of simulated mucosa opposite to the plug. Wait until completely dried before use.

**Figure 6.** Cost and instructions for manufacturing the underwater EMR simulator. Prices were derived in Toronto, Ontario, Canada, in 2022 and converted to U.S. dollars. Some materials could be accessed for free from the home institution.



**Figure 7.** Visual demonstration of the capabilities of the underwater EMR simulator. The images show the simulator: **A**, before immersion; **B**, after immersion; **C**, under narrow-band imaging; and **D**, the visual realism of the simulator postpolypectomy.

the EMR simulators. Scalability of the simulators is increased through having the materials used being commonplace, the 3-dimensionally printed molds being open access (Fig. 2), and simulators being stored for months through refrigeration. Simulation course personnel, who had no additional training aside from a short instructional guide (Appendix 1, available online at [www.videoie.org](http://www.videoie.org)), manufactured and set up the simulators.

## DISCUSSION

The simulators detailed in this article show potential for usage in advanced polypectomy training programs. This submission demonstrates a how-to guide for the manufacturing of these simulators, and there is a need to determine the face, construct, and content validity of the simulators. Additionally, the conventional EMR simulator could be designed to ensure the absence of leakage during injection, and to increase the realism of the mucosa.

## DISCLOSURE

Dr Khan has received research grants from AbbVie (2018) and Ferring Pharmaceuticals (2019) and research funding from Pendopharm (2019). Dr Grover has received research grants and personal fees from AbbVie and Ferring Pharmaceuticals, personal fees from Takeda, and education grants from Janssen, and has equity in Volo Health-

care. The other authors did not disclose any financial relationships.

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## APPENDIX 1. DETAILED INSTRUCTIONS FOR CREATING THE 3 POLYP SIMULATORS

### Base mixture:

- The same base mixture is used to create all 3 polypectomy simulators.
- To create the simulator, fill a larger bowl until it is 1/3 filled with hot tap water.
- Mix 2 tsp corn starch, 2 tsp gelatin, and 1/8 tsp table salt into another bowl.
- Place this bowl with dry ingredients directly on top of the larger bowl with hot water to hold off solidification.
- Add 3 tsp vinegar to create a homogenous solution.
- Add 1/2 tsp glycerin to the mixture as it is a plasticizer and creates flexibility.
- Add 1 drop of red and 1 drop of yellow food coloring to create a desired color similar to that of the phantom.
- Stir the mixture until homogenous.
- Adjust amount of vinegar if necessary to achieve a semi-viscous consistency.

### Postpolypectomy Bleeding Simulator:

- Print the stereolithography file of the polyp mold in 0.3 mm resolution with any 3D printer that utilizes polylactic acid (PLA) filament. The mold is found at: <https://github.com/Zhaoa23/Simulated-Polypectomy-Mold>.
- Dampen a cotton pad with oil, and use it to lubricate the 3D-printed mold.
- Use plastic tape to secure the 2 halves of the mold in such manner that the polyp indentations and flanges align.
- Follow instructions to create the base mixture.
- Use a 10-mL syringe to inject the polyp mixture into the mold opening, until it is filled. Tap the mold against a hard surface, and wiggle the 2 halves side-by-side to prevent air bubbles.
- Refrigerate for 15 minutes in a standard refrigerator (between 35-38 degrees Fahrenheit).
- Carefully remove the polyp from the mold, and separate any webbing that may have formed.
- Insert and 14-gauge Angiocath catheter with needle removed into the base of the polyp and extend the catheter until halfway through the stalk.
- To create simulated blood, fill a cup with 50 mL of water. Add cornstarch (1 tsp), green food coloring (1-2 drops), and red food coloring (7-9 drops).
- Draw the simulated blood into a 50 mL syringe.
- The polyp is attached to the phantom through the larger flange being on the outer surface, and the smaller flange resting on the phantom lumen.
- Attach the syringe once the polyp has been inserted into the phantom, and attach any electrocautery wires that come with the colon phantom if desired.

- Once the polyp is resected, push on the syringe in a pulsatile manner until endoscopic clips are applied.

### Conventional EMR simulator:

- Use a plastic sheet that is smooth and 20 cm in length and 6 cm in width.
- Create the base mixture.
- Dampen a cotton pad with oil, and use it to lubricate the plastic sheet.
- Use a spoon-to-scoop base mixture into an approximately 2 mm thick and 6 cm in diameter circle onto one side of the plastic sheet. This will form the mucosal surface.
- Scoop polyp mixture onto the other side of the plastic sheet. Fold the sheet into a cylindrical shape that is 1 cm in diameter, and 2 cm in length. Allow the cylinder to dry in this shape. This will form a plug for attachment to the phantom.
  - o Once the mixture is almost dried and very viscous, it can be shaped further to serve as a correctly sized plug for the hole in the phantom.
- Wait 15 minutes for the simulators to dry. During this time, keep the base mixture on hot water to prevent solidification.
- Cut a pop-up sponge into a 3 x 1.5 x 0.3 cm shape.
- Remove the simulated mucosa from the plastic sheet. Place the cut sponge in the center.
- Apply oat fiber (1/4 tsp) onto the middle of the flat mucosa.
- Apply a line of superglue along the sides of mucosa. Fold in half and apply pressure to the sides to seal tightly.
- Apply a small dollop of base mixture to form the lesion on one side of the simulated mucosa.
- Remove the plug from the plastic sheet.
- Use superglue to glue the plug to the side of the simulated mucosa opposite the lesion.
- To insert the conventional EMR simulator into a phantom, place the entire simulator into the lumen of the simulator at first. Manipulate the plug and drag it outside the hole for polyp attachment. Ensure the plug rests outside the phantom, and the mucosa and lesion are lumen side. Attach electrocautery wires.

### Underwater EMR simulator:

- Use a plastic sheet that is smooth and 20 cm in length and 6 cm in width.
- Create the base mixture.
- Dampen a cotton pad with oil, and use it to lubricate the plastic sheet.
- Use a spoon-to-scoop base mixture into a circle that is 2 mm thick and 4 cm in diameter onto one side of the plastic sheet. This will form the mucosal surface.
- Scoop polyp mixture onto the other side of the plastic sheet. Fold the sheet into a cylindrical shape that is 1 cm in diameter, and 2 cm in length. Allow the cylinder to dry in this shape. This will form a plug for attachment to the phantom.

- o Once the mixture is almost dried and very viscous, it can be shaped further to serve as a correctly sized plug for the hole in the phantom.
- Wait 15 minutes for the simulators to dry. During this time, keep the base mixture on hot water to prevent solidification.
- Remove the simulated mucosa from the plastic sheet.
- Place  $\frac{1}{4}$  tsp of baking soda into the remaining base mixture and stir until a fluffy consistency is reached.
  - o Adjust the color if necessary (add more red or yellow food coloring).
  - o Do not over stir, as the fluffy consistency will be lost.
- Apply a small dollop of the new base mixture onto the center of the simulated mucosa. Wait 5 minutes to dry.
- Remove the plug from the plastic sheet.
- Use superglue to glue the plug to the side of the simulated mucosa opposite the lesion.
- To insert the underwater EMR simulator into a phantom, place the entire simulator into the lumen of the simulator at first. Manipulate the plug and drag it outside the hole for polyp attachment. Ensure the plug rests outside the phantom, and the mucosa and lesion are lumen side. Attach electrocautery wires

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