Technique Articles

A High-Fidelity Percutaneous Model Used to Demonstrate ECMO Cannulation

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Abstract: Medical simulation provides a realistic environment for practitioners to experience a planned clinical event in a controlled educational setting. We established a simulation model composed of synthetic ballistic gelatin that provided an inexpensive high-fidelity model for our extracorporeal membrane oxygenation (ECMO) team members to develop, master, and maintain clinical skills necessary for percutaneous cervical or femoral cannulation. The simulation component includes a cervical torso or femoral percutaneous synthetic gelatin model that is attached to either a static fluid model or to the high-fidelity perfusion simulator. Either model can be accessed with ultrasound guidance, cannulated with appropriately sized cannula, and connected to an in situ ECMO circuit. This article explains how the model is made and connected to the simulator with the purpose of re-creating this high-fidelity experience at any institution. Keywords: ECMO (extracorporeal membrane oxygenation), education, simulation, high-fidelity simulation, percutaneous, cannula, cervical, torso, femoral, clear ballistic gelatin, Cali perfusion simulator system. J Extra Corpor Technol. 2021;53:208–13

Medical simulation bridges didactic learning with real-life clinical experiences using a planned set of events that reproduce clinical experiences in a safe learning environment. Our primary goal is improving quality and patient safety by replicating clinical practices that may be high risk with a low volume occurrence. Extracorporeal membrane oxygenation (ECMO) is normally an emergent, unplanned event involving clinicians with varying levels of experience, thus necessitating ongoing education to support varying cannulation approaches and emergent hemodynamic lifesaving strategies. Simulation education is a well-documented tool for critical care education (1). Venovenous (VV) ECMO cannulation has proven to be challenging in the pediatric population, so we created a model to promote these techniques. Percutaneous femoral cannulation for venous arterial (VA) ECMO cannulation is equally challenging. Developing models that support any percutaneous approach supports our effort to promote education and improve quality.

DESCRIPTION

We created vascular access ballistic gelatin models to practice a standardized approach to ECMO cannulation using the Avalon Elite (Getinge, Göteborg, Sweden) bi-caval dual lumen and Bio-Medicus NextGen cannulae (Medtronic, Minneapolis, MN). Models constructed of ballistic gelatin affixed with vessels were created to mimic...
vessels used for VV and VA ECMO access (2–5). The vascular models were positioned on classroom tables or on any commercially available standard simulation mannequin (Figure 1). Physicians practiced cannulation with ultrasound guidance and support from their colleagues. These high-fidelity models were a focal point for active demonstration using ultrasound, needle placement, guide wire advancement, vessel dilatation, and catheter placement.

Key elements used with our training include custom synthetic gelatin models connected to static fluid (intravenous bags at set heights) or the Caliﬁa perfusion simulator (Biomed Simulation, Inc., San Diego, CA). Cannulation adjuncts allow for cannula placement to be used with ultrasound guidance. The synthetic mold is the primary focal point that initiates the demonstration.

The synthetic gelatin model mimics cervical or femoral vascular access for VA or VV ECMO (Figure 2). Synthetic mineral oil–formulated gelatin products are skin-safe, latex free, odor free, insoluble in water, and require a simple process of mixing with Silc Pig Flesh Tone Silicone Pigment (Smooth-On, Inc., Macungie, PA) coloring product at a temperature just above 198°F. Blood vessels can be positioned in the mold just under the surface. The firmness of the polymer product mimic human tissue. Synthetic ballistic gelatin (Clear Ballistics, Greenville, SC) was correlated to swine muscle tone, which is comparable to human muscle tone. We used basic 10% ballistic gelatin preparation by Clear Ballistics to form the applicable anatomic region of the body. Medical grade ballistic gelatin products are available and contain varying degrees of hardness above or below the basic 10% or 20% formulas at a higher cost. Feedback from our surgeons validated use of the 10% formula for our simulation experiences.

Ballistic gelatin was poured into commercially available mannequin forms used to model clothing (Figure 3). All were available on various Amazon sites (Amazon, Seattle, WA). The mannequins were front formed with a hollow back. The molds have ½-inch holes affixed for tubing placement. Tubing is secured in the mold with short tubing segments that offer stability (Figure 4). This holds the...
vessel in place to improve the “push-ability” of the needle, wire, dilator, and cannula.

We use one 10% Ballistic Gelatin FBI Blocks (16 inch length by 6 inch width by 6 inch height) purchased from Clear Ballistics. The 9.8 quarts of synthetic gelatin is heated to a temperature above 198°F in two 8-quart crock pots. This normally takes 8 hours to liquify in a standard crock pot and 8 hours to cool or solidify in the respective mold. The cervical and torso models each hold 9.8 quarts of gelatin. The femoral mold holds 5 quarts or half the amount of the standard FBI block (Figure 5).

We have used standard commercially available Penrose drains (Charles Bingham Penrose) because of the flexible silicone material that we believed mimicked the blood vessels. While using the Penrose vessels we experienced too much flexibility and difficulty cannulating. When the dilators and cannula were positioned, negative feedback from physicians was received due to the tubing being thin and pliable. To help us identify the ideal tubing, we used different tubing sizes and durometers with the same base gelatin model molds. Tubing with larger wall thickness and increased durometer withstood repeated cannulation experiences. Identifying the ideal durometer and wall thickness helped improve the model.

High-temperature 1/16-inch wall thickness 3/8-inch internal diameter silicone opaque rubber tubing with a durometer of 35A (McMaster-Carr Supply Company, Chicago, IL) was used for our original models because it was thought tubing with a low durometer would be ideal. The quality of the ultrasound image and poor ability for repeated cannulations led us to trial higher durometer tubing. High-strength 1/16-inch wall thickness 3/8-inch internal diameter Tygon Versilic SPX-50 silicone tubing with a durometer of 50A (United States Plastic Corporation, Lima, OH) was used for our current molds. Tubing

Figure 3. Pigmented synthetic gelatin model that mimics a cervical, torso, or femoral field for extracorporeal membrane oxygenation (ECMO) cannulation. All of these items were made by the primary author.

Figure 4. Short tubing segments are used to stabilize the vessels in the gelatin for added strength when the dilator and cannula are placed. This promotes stability limiting flexibility or movement when the vessel is augmented with the cannula adjuncts and the cannula placement.
that mimics arterial and venous blood vessels was respectively positioned <1 cm below the surface in the respective anatomical cannulation area (6). Positioning the silicone tubing in the mold to sustain the minimal depth is dependent on the position and size of the holes drilled into the mold. The carotid artery was placed medial and anterior to the jugular vein. We used the same tubing in all the models to mimic the artery and vein.

Thirteen physicians all with varying levels of experience using the Avalon Elite bi-caval dual lumen cannula practiced insertion on each model. One model was made with the 35A durometer tubing while a second model was made using 50A durometer tubing. The ultrasound image, assessment using the needle, dilators, and the cannula, favored the 50A durometer tubing. The results of this limited survey helped our team identify the gelatin and tubing ideal for future molds. Anatomical arrangement of the model and the corresponding cannulation techniques were referenced using a variety of anatomical citations (6) and physician input. The diameter of the respective blood vessel is related to cannula selection and the corresponding dilators. The depth of the vessel affixed in the gelatin varied from 5 to 10 mm, but specific cannulation techniques were institutional and directed by the physician authors.

**Low-Fidelity Simulation**

Any of the percutaneous models can be used in concert with a stand-alone intravenous set and bags attached to Buretrol IV Solution Sets with 150-mL Clearlink Burette (Baxter Healthcare-DMG, Deerfield, IL) to monitor blood loss. Separate intravenous sets attached to the artery and vein, with bright red and dark blue food coloring, enhance the realism. Changing the height of each intravenous bag establishes a static mean vessel pressure. This can be measured using a standard pressure transducer with modest height adjustments (Figure 6).
High-Fidelity Simulation

Any of the percutaneous models, using applicable straight connectors, can be attached to the Califa Perfusion Simulator System for VA ECMO simulation. This simulator mimics all the hemodynamics experienced with ECMO therapies. This includes simulating pulsatile arterial pressures, blood loss monitoring, and venous pressure. Used in concert with the percutaneous cannulation experience this supports continued reproductions for other allied health professionals well after cannulation, initiation, and stabilization (Figure 7).

Pre-Hospital Setting Simulation

We have used the gelatin mold for several ECMO cardiopulmonary resuscitation demonstrations that involved emergency medical service providers in the pre-hospital setting. This realistic model for femoral cannulation supports education for what we believe will be a reality in the pre-hospital setting (1, 5). Our most recent simulation included a femoral model affixed with tulle mesh material tied to the simulation mannequin (Figure 8). This offers an area to cannulate and support other advanced life support skills such as cardiopulmonary resuscitation, intravenous and intraosseous, intubation, ventilations, and defibrillation. Combining simulation experiences using any commercially available high-fidelity manikin heightens the realism because learners can practice a variety of advanced life support critical skills. We believe the future for these models is combining this model with any hospital-based high-fidelity simulator manikin (1, 5).

DISCUSSION

Using simulation as a tool to extend the clinical experience of ECMO cannulation and initiation proved to be an effective educational strategy. Setting up this clinical

Figure 7. The Califa perfusion simulator can be attached to the gel model tubing offering a high-fidelity experience. Setting the Califa reservoir at a height near or equal with the venous limb mirrors central venous pressure. The arterial limb of the model can simulate pulsatile arterial flow. Cannulation times and blood loss can be recorded.

Figure 8. Pigmented synthetic femoral gel model used with any standard simulation mannequin.
opportunity, in a controlled setting, adds to the overall understanding, whereas exposure to these simulated events solidifies clinical routines, establishes proficiency, and improves care. Skill-based performance is a cognitive habit best learned by experience and practicum. Simulation works to develop this automatic clinical routine (7).

Physicians have a reproducible model to demonstrate needle and guidewire positioning with ultrasound cannulation placement. With their feedback, we were able to review two different types of tubing and distinguish the best model. We used the torso model to in-service and provide competency assessments for our surgeons and various allied health providers. It also helped to identify which tubing durometer mimics the sensation and skin turgor as compared to human cannulations.

Many hospitals are experiencing a shortage of nurses and surgical technicians. The need to educate and assure competency for new staff requires either a high volume of ECMO patients or simulated experiences. These simulation models improve the experience level of new team members. Circulating nurses and the surgical technicians learn the prepping, general set up, physician cannulation routine, and ECMO circuit line placement. Critical care nurses in any of our intensive care units have an opportunity to practice vital hemodynamic variations, advanced life support requisites, and other clinical duties related to stabilizing the patient before, during and after ECMO initiation. This can also be an opportunity for physicians in the critical care environment to support the team approach to care. These multidiscipline simulations also provide an opportunity to educate administrators about our clinical experiences and exemplify what is used and needed for departments while garnering support for new products, capital, or personnel.

The future for this type of simulation is infinite and includes areas such as simulating a code with active chest compressions and concurrent ECMO cannulation. This controlled environment could also be an educational opportunity when speaking to family regarding care and therapies for loved ones receiving ECMO support.

CONCLUSION

To address the ongoing need for education at our hospital we developed various models that mimic clinical experiences our team would likely encounter. This is an opportunity for our teams to work together and better understand a clinical experience in a controlled setting. These simulated events solidify clinical routines, control medical errors, and improve care. Skill-based performance is a cognitive habit best learned by experience. Simulation works to develop this automatic clinical routine through “learning while doing” (7).

REFERENCES