Innovative and Inexpensive Designs for Wound Packing Task Trainers

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Conflict of Interest Statement
The authors of this manuscript declare no conflicts of interest. Innovations were designed at the STRATUS Center for Medical Simulation when author BFQ was employed there.

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Brief Description
With the number of mass casualty incidents increasing worldwide (Zhao et al., 2019), the role of bystander intervention is becoming increasingly important to ensure positive patient outcomes (Hoyme & Atkins 2016). Prehospital tourniquet use, direct pressure, and wound packing are proven to be safe and effective measures for treating uncontrolled hemorrhage (Parry, 2021). Between the years 2003 and 2015, over 382,376 trauma cases relating to penetrating injuries by stab or gunshot wounds were reported to the National Trauma Data Bank (Zeineddin et. al, 2021). With these alarming statistics, it is imperative bystanders, medical personnel, and first responders are prepared to care for such injuries. In our project, we designed and built an innovative, cost-effective task trainer to teach users how to efficiently and effectively care for traumatic wounds. The cost-effective materials used to create this model aim to provide equitable access to clinical training, as commercial simulators may not be readily available in under-resourced areas. The model allows learners to practice treating various injuries including gunshot wounds, stab wounds, and lacerations.

Introduction
In recent years, failure to manage severe traumatic injuries has been a leading cause of preventable death amongst surgical and trauma patients in the prehospital setting (Smith et al. 2018). Educational interventions are needed to minimize the occurrence of deaths and to improve patient care delivery. Medical simulation training has been shown to increase participant understanding of clinical knowledge and management for difficult medical conditions (Zhang et. al, 2015, Lauffenburger et. al 2022, Vattanavanit et. al, 2017). Notable educational programs like Stop The Bleed (STB) by The American College of Surgeons are designed to teach students the basics of wound packing and hemorrhage control (Gowen et al. 2020; Lei et al. 2019).

Since traumatic injuries can occur unexpectedly, knowing how to stop bleeding before significant blood loss occurs is an essential life-saving skill in times of crisis (Latuska et al. 2019; Sidwell et al. 2018; Zwislewski et al., 2019). However, access to this training may be limited by financial and economical constraints, particularly in lower resource settings (Martinerie et al. 2018; Nitin et al. 2022). The highest quality commercial wound packing task trainers cost approximately $700 (USD). However, these trainers represent only one specific injury, making it more challenging and costly to train learners in managing multiple injuries.

Another limitation of commercial simulators is the requirement of a second operator to initiate active bleeding. However, in resource-limited areas, a second operator may not be available, underscoring the need for a trainer that can actively bleed without additional personnel. To help address this issue, we propose methods to design realistic and inexpensive wound packing task trainers using ballistics gel and repurposed materials. We hope to expand the access of high-fidelity STB training at a lower cost without sacrificing educational or technical quality (Pringle et. al, 2015). The following methods will provide instruction on creating task trainers with injuries representing a deep laceration, a gunshot wound (GSW), and a stab wound.

Objective

Simulated task trainers are efficient training modalities that help clinicians practice clinical skills in a low-risk, psychologically safe environment. Our purpose for creating these models is to provide an affordable and efficient wound packing task trainer to teach lay responders and health care workers the proper application of combat and bandage gauze when handling different types of traumatic injuries.

Materials

Three wound packing task trainers were created using repurposed materials to serve as an affordable adjunct to expensive commercial wound packing trainers sold in the medical simulation market (Table 1). Ballistics gel was chosen as the medium for the model due to its likeness to human biological tissue (Caldwell & Mooney 2019; Filipchuk & Gurov 2015), creating a higher fidelity experience for the learner. A GladWare Salad & Soup Storage Lunch Box was used as the mold. Models created represent a deep laceration, a singular GSW, and a penetrating trauma injury from a pocketknife.

(Continued on next page)

Table 1

Total Cost of Materials

Model Components	Quantity for 3 simulators	Cost per unit (in USD)
10% Ballistics Gel FBI Block	1	$89.98
Silicone Pigment (Color Paint)	1	$6.88
Rubber Latex Surgical Tubing 5/16"IDx1/2"OD (8x12mm)	1	$13.90
Chefmaster Super Red Liqua-Gel Food Coloring	1	$6.49
Pocketknife	1	$9.90
Electric Slow Cooker	1	$46.49
1 Liter Simulated IV Fluid Bag	3	$3.88
Baxter IV Administration Sets	3	$7.68
Cardinal Health Salem Sump Nasogastric Tube	3	$ 2.78
GladWare Soup & Salad Food Storage Lunch Box (64 oz)	3	$3.49
Total Cost for Three Simulators		**$223.53**
Total Cost for One Simulator		**$74.51**

Note. Items are typically bought in bulk and individual units are used to create the model. Prices are reflective of USD as of August 2024 and may be subject to change over time. The total cost for three simulators was calculated by multiplying each component's price by the quantity and summing the prices. The total cost for one simulator was calculated by dividing the total cost for the three simulators by three.

Preparing the Ballistics Gel

For detailed instructions, please refer to the full protocol (see Appendix A). For all three task trainers, we made one incision on the lateral side of the mold, a 64-ounce Gladware soup and salad storage lunch box. The incisions were large enough to fit the rubber latex tubing through and create a tight seal, preventing ballistics gel from leaking. The mold is suspended above the table to allow any excess ballistics gel to drain without sticking to the surface.

Then, we cut the ballistics gel into smaller pieces to allow even melting in an electric slow cooker. Silicone pigment was mixed into the melted ballistics gel to simulate skin tone. The melted gel was then poured into the lunch box in differing methods depending on the trainer, described below. Briefly, for the deep laceration and stab wound task trainers, we filled the mold in one pour, creating the injury after the ballistics gel set. For the GSW model, additional latex tubing was placed in the mold prior to pouring the ballistics gel, allowing the gel to set around it and form a circumferential entry point. The hot ballistics gel should take no more than forty-five minutes to completely solidify at room temperature. Following the same steps used to create the wound packing models, the ballistics gel can be remelted and repurposed to produce new simulators featuring different injuries than those in the original trainer.

Preparing Simulated Blood

The intravenous (IV) fluids and the latex tubing from the models were bound together using a lumen cut from a Cardinal Health Salem Sump nasogastric tube to prevent leaking. Red food coloring was injected into IV fluids in varying amounts to simulate the colors of arterial and venous blood. For lighter arterial blood, 10 cubic centimeters (cc) of food coloring was added to a saline bag, while 25cc was used for the darker venous blood. Before use, IV fluids must be opened, hung above the trainer, and connected to an administration set to enable effective blood flow and simulate active bleeding.

The models actively bleed using the methods described and can be easily operated by a single learner. Simulated wounds can be packed and stabilized efficiently with cotton roll gauze, combat gauze, or other adjuncts necessary for bleeding control, depending on the simulation setting and situational need. When the bleeding is successfully controlled, the IV tubing must be locked to prevent the continuous flow of fluid for all task trainers. The standard setup used for all three models and completed wound packaging trainer is shown below (Figure 1).

Figure 1

A *Standard Setup* **B** *Completed Wound Packaging Trainers*

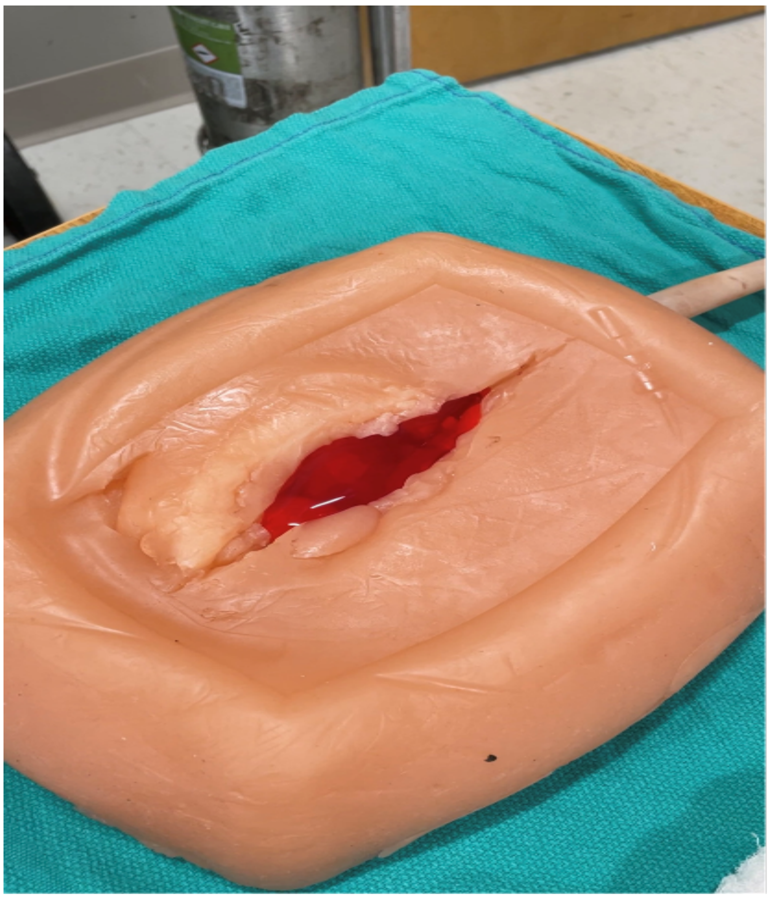
Note. Panel A: Standard setup allows for single person use of task trainers. Sample items provided for the learner includes gauze rolls, purple nitrile gloves, an IV pole to hang simulated blood, towel, and adjustable table. Panel B: Preliminary models were created using plastic containers of different sizes; however, the final models described in these instructions are uniform in size across all three trainers.

Deep Laceration Model Design

For the deep laceration task trainers, we prepared the mold, latex tubing and ballistics gel as described above. Melted ballistics gel was poured into the container and filled to the top of the lunch box mold in one pour. The cooled ballistics gel was removed from the mold and flipped upside-down. A large laceration was made by cutting down the center of the ballistics gel with a pocketknife, partially exposing the latex tubing underneath. To create the laceration, external pressure was applied to the interior of the newly created gash to create space for wound packing. Simultaneously, the ballistics gel near the opening of the wound was pulled inwards to create a high-fidelity deep laceration (Figure 2). The IV tubing to simulate bleeding was attached as described above.

Figure 2

Deep Laceration Wound Model



Gunshot Wound Model Design

For the gunshot wound task trainers, we prepared the mold, latex tubing and ballistics gel as described above. In addition to the previously described lateral incisions, an incision was made on the bottom side of the mold to accommodate the latex tubing. Melted ballistics gel was poured three-quarters of the way to the top of the mold and left to completely solidify. Once the ballistics gel set, the tubing on the bottom side was removed completely and reinserted partially near the top of the opening to create depth for the simulated GSW. A final layer of ballistics gel was poured to fill the mold to the top (Figure 3). This final layer must cover the latex tubing to prevent angulations in the model's shape and to minimize risk of tubing breaking from the bottom side. In future designs, a lunch box with multiple lateral and bottom incisions can be made and the above process can be repeated to create multiple actively bleeding GSWs on the same model. The IV tubing to simulate bleeding was attached as described above.

Figure 3

A *Bleeding Gunshot Wound Model* **B** *Packed Gunshot Wound Model*

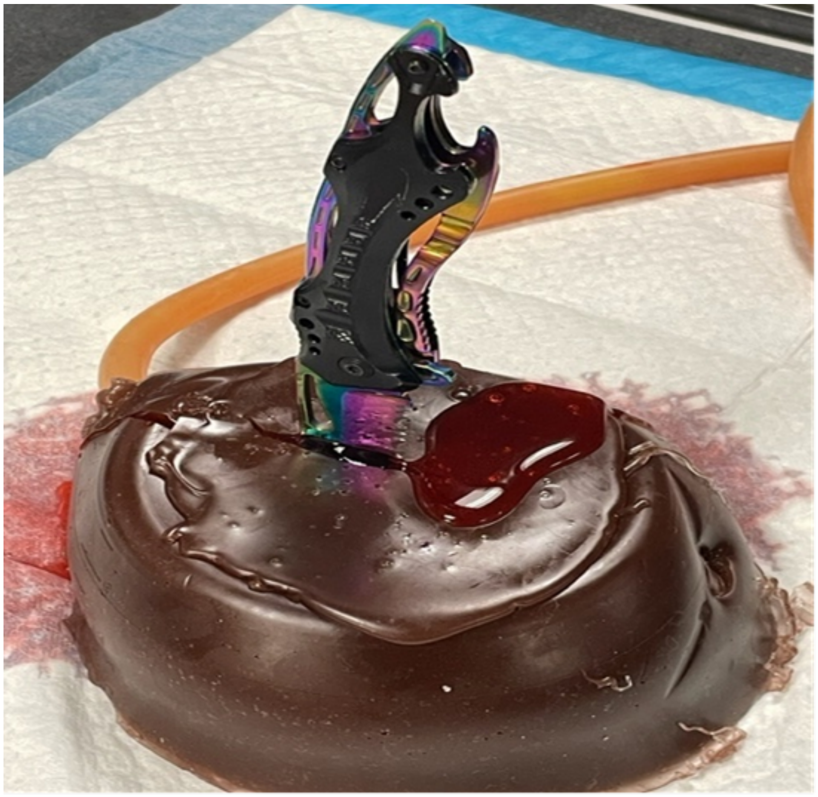
Note. Panel A: Depth of the wound is approximately 2.5 inches deep. Blood exits exclusively from the entry wound of this model. Exit wound and simulated bullets were not included in the design of this model. Panel B: This image shows the gunshot wound model packed with cotton roll gauze.

Stab Wound Model Design

For the stab wound task trainers, we prepared the mold, latex tubing and ballistics gel as described above. Melted ballistics gel was poured into the container and filled to the top of the lunch box mold in one pour. Once the ballistics gel set, a small incision was made on the top of the model until the latex tubing underneath was visible. The model was then pierced with a pocketknife to create slits in the latex tubing for blood to leak out of. The pocketknife was then carefully inserted through the tubing and into a deeper section of the ballistic gel to prevent accidental dislodging (Figure 5). The IV tubing to simulate bleeding was attached as described above. Practical uses for this model can include the application of cotton roll gauze for impalement, wound stabilization, and hemorrhage control. Although a stab wound with a pocketknife was used to exemplify the penetrating trauma, the knife can be substituted with other objects common in penetrating injuries like scissors and rebar rods.

Figure 5

Stab Wound Model



Note. It is important to use care when handling and using this task trainer to avoid unintentional injury from the penetrating objects.

Discussion

Stopping a major bleed is a lifesaving intervention that requires a realistic and affordable trainer, both of which these trainers could deliver. When packing a wound from a traumatic injury, applying adequate pressure is crucial. Each of the three wound packing models was designed to replicate realistic injuries, featuring a bleeding function that creates a sense of urgency and allows learners to see when proper wound-packing technique has successfully stopped the bleeding. The total cost for all three simulators was $223.53 USD with no anticipated maintenance costs.

The models successfully demonstrate appropriate bleeding and can be constructed with only one operator. These models can be used to create a hybrid simulation with a live actor or low fidelity model, providing a higher fidelity learning experience in managing active bleeding wounds. Additionally, the durability of the ballistics gel increases the likelihood of the task trainer's longevity. However, this model does require access to electricity to use the slow cooker, and in areas of conflict or poverty, electricity may be a costly resource. The simplicity of the design and general construction allows for each creator to adapt the functionality and appearance to meet specific learning objectives. Currently, the model is designed for rapid trauma response to stop the bleed, but it has the potential to expand its reach to different specialties. For example, the deep laceration model could be modified for dermatologists to practice deep tissue suture repair using mesh and distinct layers of tissue. The GSW model could also include the bullet itself that would be removed by a surgeon in a simulated surgical scenario. Lastly, the penetrating trauma model could include different potential contaminants of which nursing could practice cleaning and dressing the wound.

Limitations of Simulators

There are several limitations present in these simulators. First, due to the lack of structural integrity, these bleeding models are not effective for training the psychomotor skills of tourniquet application. Tourniquet application is a trauma care skill that functions to inhibit blood flow to a wounded limb and is essential for stopping massive hemorrhages. This skill, in addition to wound packing, has been shown to lower patient complication rates when applied correctly in clinical settings (Inaba et. al, 2015, Passos et. al, 2014). Due to the lack of firm surfaces within the model, compressing the latex tubing is limited, resulting in no change in blood flow when a tourniquet is applied. To practice this skill, we suggest using a secondary trainer for tourniquet application like a simulated limb or foam roll.

Second, because latex tubing and IV fluid are used to create the bleeding mechanism in these simulators, blood pools into the injury site at a fixed speed, effectively simulating a venous bleed. However, there is no way to simulate an arterial bleed which spurts blood from the injury site rhythmically. This may be resolved by adding a pumping mechanism in future designs. Additionally, we recognize that latex can be a potential allergen to some users and understand the risk of including it in our model design. Prior to use, users should be made aware of the latex tubing and given latex-free exam gloves for practice. Furthermore, the latex tubing can be substituted with latex-free tubing.

Lastly, using dyed IV fluid to simulate human blood may slightly compromise the fidelity. Human blood, unlike the IV fluid, is generally more viscous and may even contain thrombi. To remedy this, commercial simulated blood products may provide learners a more realistic experience with our simulators, albeit more expensive.

Conclusion

Using inexpensive and repurposed materials, we successfully constructed three wound packing task trainers for approximately $74.51 USD per trainer. The models can be used to teach the basics of wound packing without sacrificing the fidelity that comes with more costly trainers. We anticipate using these new models to provide a high-quality learning experience in our interdisciplinary training center. Those who could greatly benefit from learning basic STB skills with these trainers include medical providers in emergency medicine and surgical fields, as well as public safety personnel such as security officers, police, and firefighters. Lastly, we hope to provide an affordable and customizable alternative to expensive wound packing simulators and to make STB training more accessible to lower resource areas.

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Appendix A

Step by Step Instructions for Model Making

https://docs.google.com/document/d/1g1uH2Q8oV2Al2tNA0EBZ3mXq-aPAFiIREkuwC-PVox4/edit?tab=t.0