Low Cost Surgical Simulation Models

by

Matthew Geib

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by

Matthew Geib

Greenville, NC

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Approved by:

Dr. Shawn Moore

Department of Surgical Education

Abstract:

What if a surgeon's first attempt was on you? Surgical residency lives up to every stereotype of being an extreme challenge, even for the brightest of doctors. Fresh out of medical school, their medical education is still far from over and they must grapple with the challenge of tests turning from paper and pencil to scalpel and skin. Residents will see hundreds of different surgeries, needing to assist and understand all of them in detail. Drinking information from the proverbial fire hydrant is nothing new, but now real patients are involved, and each mistake is costly. It is one thing to learn when making a mistake only results in a poor grade, but in this case, each mistake the residents make could be life threatening to their patients. With stakes this high, it begs the question of how can we improve the training of surgical residents while still keeping costs affordable for medical schools. The Brody School of Medicine has allowed us the opportunity to implement our low cost surgical simulation models into the surgical curriculum, allowing us to give residents training that correlates with what they are learning and seeing.

Background:

Surgical simulation technology can vary drastically depending on cost and most energy has been focused on making extremely high-quality models that are realistic as possible. These models typically cost anywhere between $30,000 and $100,000.[2] This simulation technology is manufactured by large companies and sent in single use packages. For schools with very high budgets this is okay as it requires only ordering the technology and letting residents use it, but for schools with lower budgets it is far too expensive to be used in training.

It is important to note that this category of simulation does not include robotic surgery training systems, which are significantly more expensive, ranging from several hundred thousand to millions of dollars. Although institutions like the Brody School of Medicine are equipped with such robotic trainers, they do not address the broader need for cost-effective, repeatable practice models suitable for foundational surgical skill development. Our research is centered around using low cost or recycled materials to create high quality and reusable surgical simulations for residents to get as much practice as they want. It is intended for these simulations to be highly customizable and still accurate.

Dr. Shawn Moore has been working with surgical residents at Brody School of Medicine for years to make low cost yet high-quality simulations for them to practice on. Through his experience he has researched a lot through trial and error on what materials and methods work best for practice with different surgeries and his simulations have come a long way. Our research will build upon his foundation of knowledge and take what was once an informal project to a full-scale methodology and curriculum for residents in future years. Improving simulations with a focus on modulating the models so that the cost will go down and the effort to construct models will also decrease. By improving and recording simulation technology, the education of surgical residents for years to come will be improved and take less effort for the people in charge of constructing the low fidelity models. This is all to answer the question of if a curriculum for surgical residents at Brody School of Medicine can be achieved at a sustainable workload and cost while maintaining quality of surgical simulations.

Methodology:

To complete this project, we will rely mostly on data from previous years of surgical simulations. We will look at what models worked best, giving the most realistic simulation of actual techniques and surgery. This will be quantified by survey data from prior surgical residents who have used low fidelity surgical simulations from Dr. Moore. These residents have seen both the simulations and actual surgeries so it will be a direct comparison to see how the simulations line up with what happens in the actual operating room. In addition to data from previous years we will dive into a literature review of current low fidelity surgical simulation models in the field. We are not the first group to make models from low cost recycled materials, to see what other groups have done will help to improve our own models. A third resource that we will use is information from the mid-level fidelity surgical simulation models. By ordering and examining how very advanced models are made we will be able to better understand how to simulate different parts of the body with lower cost materials. The goal is not to recreate models to this level but instead to learn from them. We will see how their materials hold up under different conditions and attempt to emulate them in a lower cost form. A combination of these three sources of information will help us to build our simulations and ultimately the curriculum for the surgical residents at Brody.

Aneurysm Model

Background:

` The most recent model that the research team constructed was an aneurysm model. An aneurysm is the bulging or ballooning of a blood vessel due to the weakening of the vessel wall. This weakening can be congenital or acquired over time due to trauma to the arm, infections, hypertension, hyperlipidemia, or repeated iatrogenic injuries such as IV placements, catheterizations, or port placements.

Our model focuses on an aneurysm in the arm, which represents a fusiform aneurysm which is just a uniform bulge involving all 3 layers of the vessel. It is important to note that this is not the only type of aneurysm as it can also be described as saccular or a pseudo aneurysm. A saccular aneurysm also involves all 3 layers of the vessel but is localized to one part of the wall rather than uniformly distributed about the circumference of the vessel. A pseudo aneurysm does not involve all 3 layers of the vessel, and occurs when blood leaks out of the vessel through a hole or tear but is still contained by the surrounding tissue.[1]

Aneurysms in the arm are clinically significant because of the potential risks that they come with. Aneurysms can lead to thrombosis and embolization, compression of nerves, and of course rupture which can cause damage to limb function. Surgical treatment is typically recommended. This surgery involves excision of the aneurysmal section followed by vascular reconstruction. The reconstruction can be done through direct end-to-end anastomosis or placement of a graft with the overall goal of restoring proper blood flow.

Materials and Methods:

- Ecoflex 00-10 Silicone A and B
- Colored Dye
- Plastic Arm
- Commercial enzyme treated bovine arteries
- Meat Tenderizer (Active ingredient Bromelain)
- Trypsin
- Fake Blood Mixture
- Spongy Silicone

The process of creating the model began by taking commercially enzyme treated bovine arteries and converting them to vein. The vein was then treated with a mixture of water, meat tenderizer (Bromelain), and trypsin and soaked for hours allowing the collagen matrix to be peeled off of the vein. This step was to simulate the vessel fragility of an aneurysm. Once treated, a catheter was inserted into the vessel segment and inflated to slowly deform the vessel. Once sufficiently deformed, the vessel was placed in a cartridge and engorged with a fake blood mixture. The vessel was mirrored by a vessel with no deformity and the cartridge was covered in different layers of colored silicone that simulated different layers of skin fat and muscle. The cartridge was then inserted into a plastic arm model and was covered with more silicone to simulate the top layers of the arm. The different steps of the model construction are shown below.

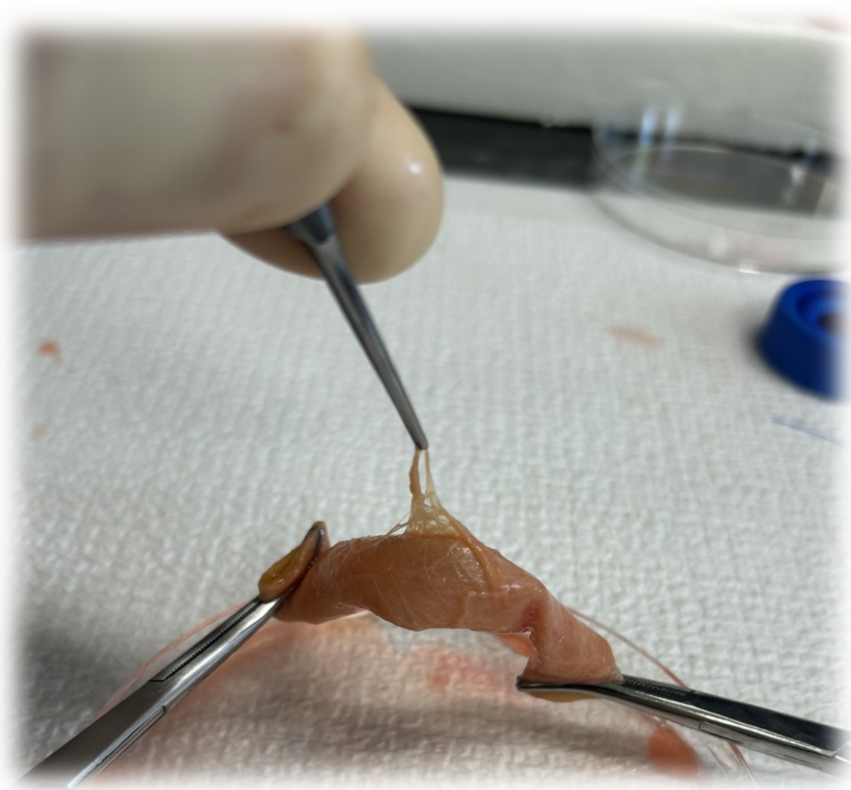

Figure 1 – Collagen matrix being pulled off of tenderized vessel.

Figure 2 – Catheter being inflated inside of weakened vessel.

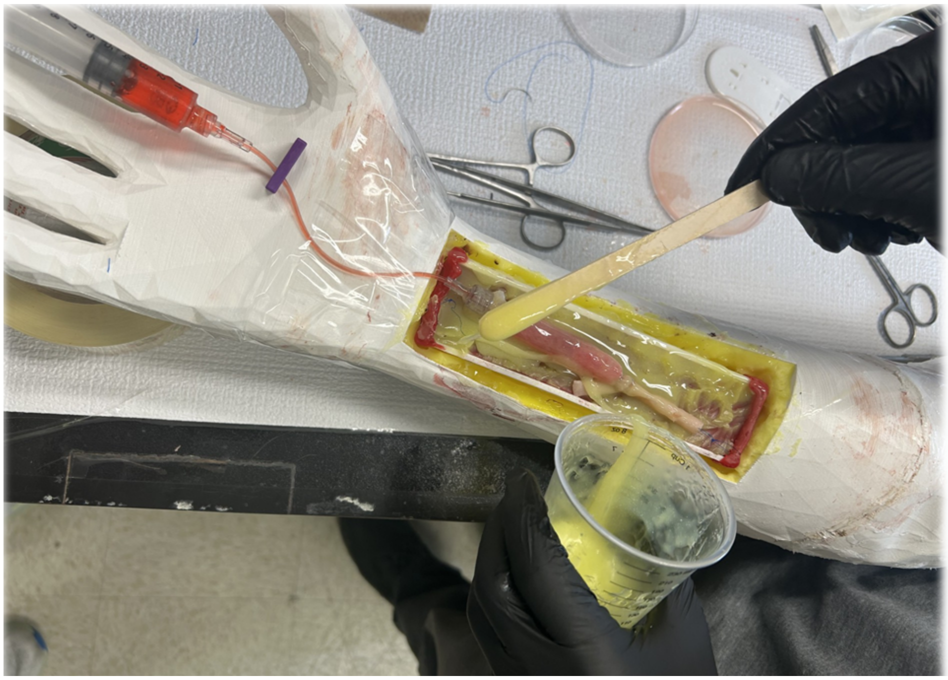

Figure 3 – Cartridge with engorged vessel being covered by layers of silicone.

Results and Discussion:

In a study of 16 residents, most found the aneurysm model highly effective, accurate, and user-friendly. While there were some suggested improvements in consistency, the overall response was overwhelmingly positive. Vascular and transplant surgeons support the simulator, noting its realistic vessel dissection, ease of suturing, and fluid testing for the accuracy of anastomosis.

Future studies should attempt to address how to construct different types of aneurysms. This study only made a model for the general fusiform aneurysm but there are many other types.

This could potentially be accomplished by using selective weakening methods and different shaped catheters.

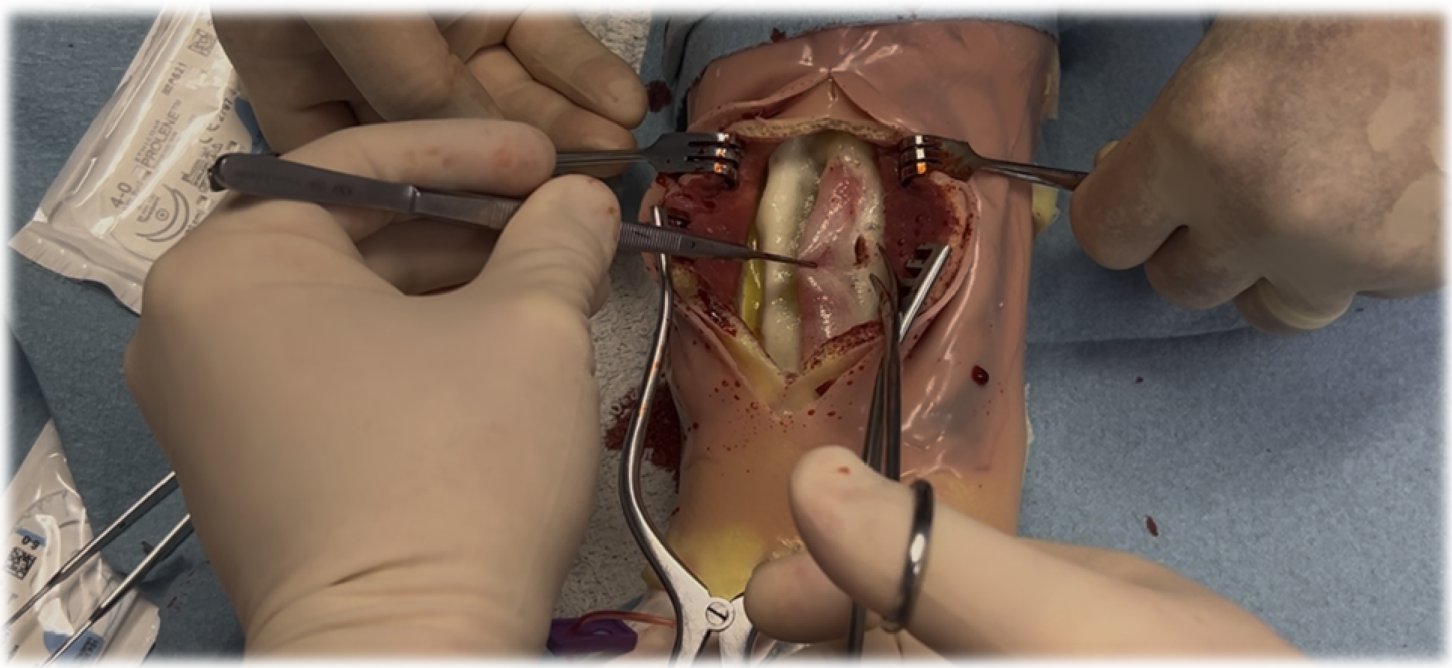

Figure 4 – Final model being operated on by residents.

Closure:

As an aspiring Trauma Surgeon, I hope to have access to adequate practice resources during my own residency. As the saying goes, practice makes perfect, and we cannot expect surgical residents only to learn by observation. With surgery being such a tactile field, it is of utmost importance for these skills to be trained just as much as information about the surgery is drilled into the curriculum. It is one thing to know all the different ways surgery can go wrong but it is another to have confidence in your physical abilities and be able to do something about it when something does go wrong. Our research will train the next generation of surgeons and improve patient outcomes for years to come.

Works Cited

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2) Silverman, E.; Tucker, S. A.; Imsdahl, S.; Charles, J. A.; Stellato, M. A.; Wagner, M. D.; Brown, K. M. Conducting Elite Performance Training. *Surgical Clinics of North America* **2015**, *95* (4), 839–854. https://doi.org/10.1016/j.suc.2015.04.011.