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Brief Report

Comprehensive Regional Anesthesia Workshops With Anatomic Ballistic Gel Phantom Task Trainers: A Cost-Effective Approach to Boosting Resident Competence

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Introduction

Peripheral nerve blocks (PNBs) are a vital skill for anesthesiologists, enabling anesthetic and analgesic options beyond general anesthesia and opioids. However, acquiring regional anesthesiology skills presents a challenge for novice residents due to the need to interpret 2D ultrasound images to guide real-time needle placement. The Dreyfus and Dreyfus model of skill acquisition and deliberate practice theory emphasizes the importance of structured repetitive practice and expert feedback to enhance residents' proficiency and confidence.[1] Gel phantom models are effective tools for repetitive practice in a low-stakes simulated setting, helping residents develop the necessary hand-eye coordination before providing patient care.[2-4] Nevertheless, gel phantoms have been limited by a lack of realistic sonoanatomy and number of needle passes they can withstand before requiring replacement.[5] Once a needle traverses a gel phantom, it leaves an air track that compromises the ability to perform subsequent ultrasound examinations. Ballistics gel is a gelatin substance designed to mimic the density of human tissue and was originally created to test the anticipated penetration of ammunition in human tissues. Unlike traditional gel trainers, ballistics gel comes in small cubes and can be rewarmed to remove needle tracks, allowing for multiple uses.

We developed two reusable ballistic gel phantom models for frequently performed PNBs (interscalene [ISB] and adductor canal [ACB]) and incorporated them into a comprehensive workshop for novice anesthesia residents. This study aimed to assess the effectiveness of these novel anatomic ballistic gel task trainers by evaluating their impact on the knowledge and confidence of novice anesthesia residents in performing ISB and ACB nerve blocks.

Materials and Methods

We conducted a single group preimplementation/postimplementation cohort study of novice anesthesia residents using novel gel phantom task trainers to teach technical performance relative to pertinent anatomy of the ISB and ACB. The study protocol was approved by the Mayo Clinic Education Research Committee (ID# 24-033, 5/28/2024) and exempted by the Mayo Clinic Institutional Review Board (ID# 24-003628, 6/5/2024).

Participants

We invited incoming first-year clinical anesthesiology (postgraduate year 2 [PGY-2]) residents training at Mayo Clinic Rochester to participate in an ungraded formative workshop during their introductory anesthesia month.

Materials

We developed 2 novel gel phantoms with embedded structures representing pertinent anatomy for the ISB and ACB (Appendices 1 and 2). For the ISB trainer, the initial cost was $69.12 with each subsequent trainer costing $15.60. For the ACB trainer, the initial cost was $147.99 with each subsequent trainer costing $11.46. We provide itemized cost data in the Supplemental Online Material (Appendices 1 and 2).

Educational Context

We conducted a 3-hour workshop in a simulation center with 3 1-hour segments: a lecture, ultrasound scanning on standardized patients, and gel phantom needling with ultrasound on our novel task trainers (see Supplemental Online Material, Appendices 1 and 2). We designed a standardized teaching script based on Peyton's 4-step approach to learning.[5] Based on standard practice for our institution, we taught both in-plane and out-of-plane approaches for the ISB and an in-plane approach for ACB. We used B. Braun echogenic 50-mm needles for ISB and 100-mm needles for ACB.

Study Instruments

We administered a survey before and after the workshop and again at 1 month and 4 months after the workshop along with assessing interval clinical exposure to nerve bocks. Residents' prior clinical experience and resident confidence with each nerve block were self-reported using a 5-point Likert scale. We developed a 12-item multiple-choice sonoanatomy

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identification quiz consisting of 6 items each for ISB and ACB, pilot tested with 3 board-certified anesthesiologists and revised the quiz to standardize the laterality of the sonoanatomy images.

Statistical Analysis

We analyzed prior and interval clinical experience using descriptive statistics. We calculated 95% confidence intervals using a 1-sample t test. We analyzed change in knowledge and change in confidence across each of the 4 time points (pretest, posttest, and 1- and 4-month follow-up) using paired Wilcoxon signed rank tests to compare each of the time points to the pretest in pairwise fashion using BlueSky Statistical Software (BlueSky Statistics, LLC; Chicago, IL), version 10.3.4. For all analyses, we performed 2-tailed tests and considered $p < .05$ to be statistically significant.

Results

A total of 18 PGY-2 anesthesia residents participated in our workshop. Fourteen (78%) residents completed the 1-month follow-up survey, and 9 residents (50%) completed the 4-month follow-up survey. Prior and interval clinical experience with ISB and ACB is presented in Table 1. Knowledge scores improved significantly from preworkshop to postworkshop ($p < .001$) and remained significantly improved at 1 month ($p = .018$) and 4 months ($p = .025$). Initially, most residents reported no confidence in their ability to perform an ISB or ACB. However, confidence improved significantly postworkshop for both nerve blocks (Figure 1, $p < .001$) and remained significantly improved at 1 month ($p = .005$ ISB; $p = .008$ ACB) though there was no statistically significant difference from the pretest at 4 months ($p = .053$ ISB, $p = .265$ ACB).

Discussion

In this study, we found that the workshop using novel ballistic gel phantom task trainers significantly improved anesthesia residents' knowledge and confidence in performing ISB and ACB. Knowledge was retained at 1-month and 4-month follow-ups. Confidence improved immediately but was not sustained beyond the short term. Our costs were significantly lower than commercially available trainers. Our findings align with previous studies highlighting the benefits of simulation-based education and the use of phantom models in medical training.[4-6] Ballistic gel models offer a cost-effective, nonperishable, and durable medium that provides more realistic sonoanatomy compared with other established gel models or traditional chest breast needling mediums.[7-9] Whereas the chicken breast model is easy to obtain and low cost, its perishability and risk for bacterial overgrowth limit its use. Additionally, other gel phantom models do not reflect anatomically relevant structures but rather present a generic target for trainees to aim at.[9] This poses a challenge as planning one's needle trajectory and angle is critical for success and is dependent on relevant anatomy. Our gel phantoms add the necessary fidelity to account for depth and needle angulation required when performing either the interscalene or adductor canal nerve blocks. Rosenberg et al[10] utilized commercially produced anatomically correct phantom trainers but noted their limitations of 10 passes and expense though exact pricing was not published nor publicly available.

Our updated model not only offers a cost-effective and reusable solution with anatomically accurate targets, but they can also be easily maintained with a heat gun to remove air bubbles and needle tracks, ensuring reusability. The initial investment for our task trainers was approximately \$70 (ISB) to \$150 (ACB) to produce the molds, whereas each subsequent phantom costs \$15. This is in stark contrast to commercially available trainers, which cost more than \$850 per phantom and are not reusable.[11] In these commercial phantoms, once a needle path is created by a learner, the entrained air from needling renders that part of the phantom unusable for further ultrasound-guided practice.

There are several limitations to our study. First, the sample size (n = 18) was relatively small and consisted of a single academic institution, and this may limit the generalizability of our findings to other settings. Additionally, we lost many residents at the 4-month follow-up, which likely prevented us from reaching statistical significance on their 4-month confidence scores. Other studies have found similar associations between lack of clinical exposure and reduction in confidence among novice learners. For instance, Dehmer et al[12] and Barr and Graffeo[13] observed that limited procedural exposure can lead to decreased confidence among junior learners. In our study, the learners had very limited to no procedural exposure to nerve blocks in the clinical setting over this time frame, and this likely contributed to the observed reduction in confidence. Furthermore, because this workshop included several teaching components (lecture, scanning on standardized patients, and gel phantom needling), it is challenging to determine which specific intervention contributed most to confidence and knowledge retention over time. However, the addition of the novel gel phantom task trainers was the only change in curriculum compared with previous years. Unfortunately, we do not have historical data for comparison. This absence of historical data limits our ability to draw more robust conclusions about the specific impact of the gel phantom model.

Our findings show that incorporating ballistic gel phantom task trainers into anesthesia residency workshops enhanced residents' confidence and knowledge with peripheral nerve blocks. This cost-effective approach improved knowledge acquisition and procedural confidence for junior residents, supplementing traditional educational methods to bridge theoretical knowledge and practical skills. Our findings suggest that residents may benefit from booster training after 4 months. Future research should focus on multicenter studies exploring long-term retention and objective measurements of skills acquired using enhanced ballistic gel models, such as speed and quality of block performance. Investigating optimal timing of booster sessions, varying complexity across training stages, and isolating workshop components to determine the specific impact of the gel phantom model compared with other didactic components could provide further insights. Additionally, exploring the optimal timing for incorporating these models into training programs, such as before a regional rotation versus early in residency, could maximize their effectiveness.

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Acknowledgments

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Abstract

Background: Acquiring regional anesthesiology skills presents a unique challenge for novice residents as ultrasound hand-eye coordination is learned through manual dexterity practice while simultaneously interpreting critical sonoanatomy. We developed low-cost ballistic gel phantom models as task trainers for interscalene and adductor canal nerve blocks to train novice anesthesia residents.

Methods: We conducted a single group preimplementation/postimplementation cohort study with first-year clinical anesthesiology (postgraduate year 2) residents at the Mayo Clinic, Rochester. Residents attended a workshop that included lectures, ultrasound scanning, and gel phantom needling practice using 2 anatomic ballistic gel trainers. The initial costs for the interscalene and adductor canal trainers were \$69.12 and \$147.99, respectively, with each subsequent trainer costing \$15.60 and \$11.46. Surveys assessed knowledge and confidence before, immediately after, and at 1 and 4 months postworkshop and were analyzed using paired Wilcoxon signed rank tests.

Results: Eighteen residents participated, showing significant improvements in confidence ($p < .001$) and knowledge immediately following the workshop ($p < .003$). Average knowledge scores were sustained at 1 month (9 points [6,11]; $p = .018$) and at 4 months (8 points [7,10]; $p < .025$) despite minimal clinical exposure. Confidence remained significantly higher than preworkshop at 1 month ($p = .005$ interscalene block; $p = .008$ adductor canal block) though not sustained at 4 months ($p = .053$ interscalene block, $p = .265$ adductor canal block).

Conclusions: Comprehensive workshops incorporating anatomic ballistic gel trainers significantly enhance residents' confidence and knowledge in performing nerve blocks. This cost-effective approach supplements traditional training methods, bridging the gap between theoretical knowledge and practical skills.

Keywords: Task trainer, gel phantom, simulation-based education, graduate medical education, regional anesthesia, peripheral nerve block.

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Figure

Figure 1. *Progression over time of anesthesia residents' confidence in their ability to perform nerve blocks. Anesthesia residents' mean self-reported confidence on a 1- to 5-point Likert scale for the (A) interscalene nerve block and (B) adductor canal nerve block. One-sample t tests were used to calculate 95% confidence intervals. Pairwise comparisons were performed using Wilcoxon signed rank tests to compare each timepoint to the pretest.*

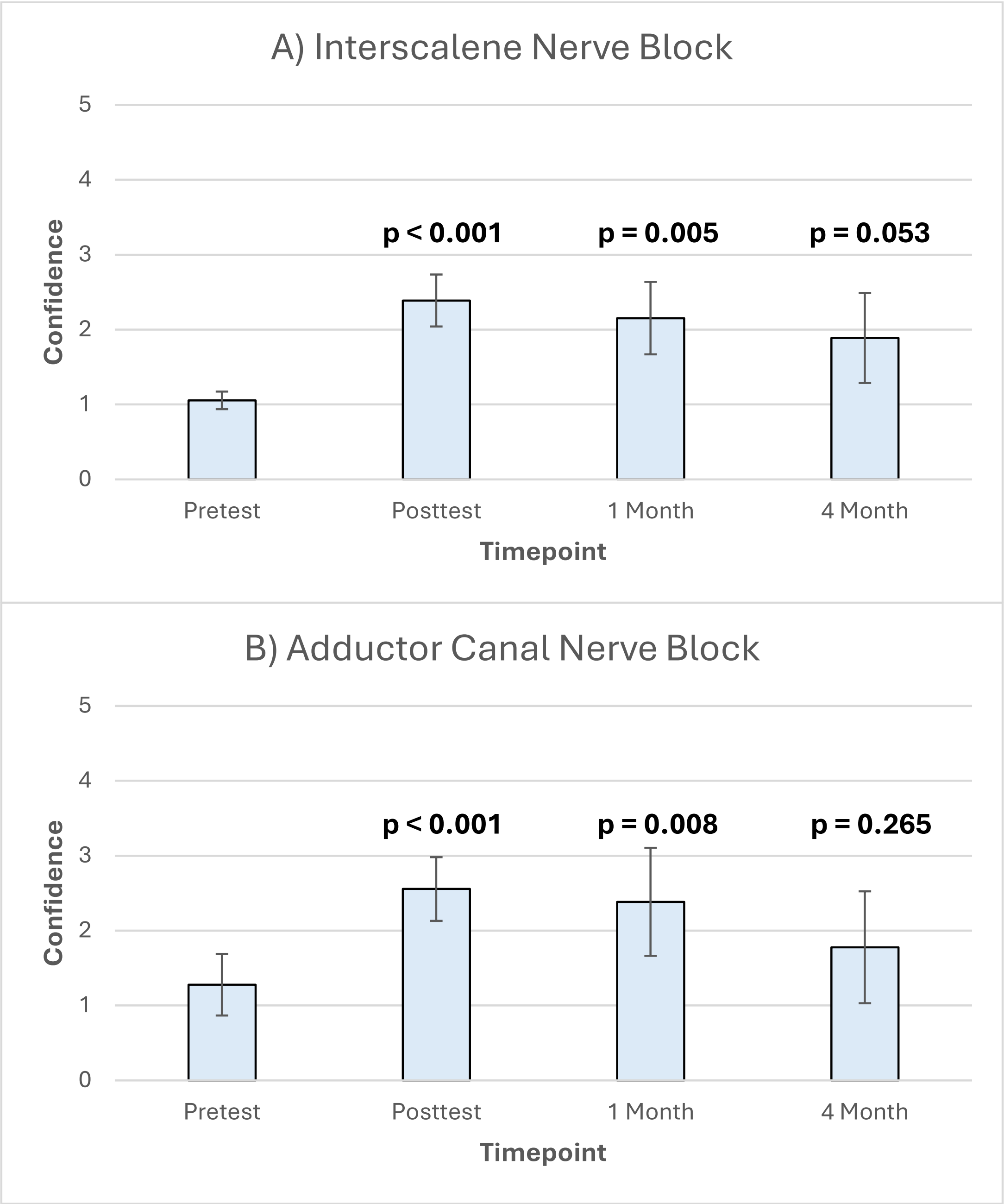

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Table

Table 1. *Knowledge Scores and Clinical Experience for Anesthesia Residents*

Timepoint	N	Quiz Score (Maximum = 12) Median (IQR)	*P*-Value	Prior/Interval Clinical Experience (n %)	
				Interscalene Block	Adductor Canal Block
Pretest	18	5 (4, 7)	-	2 (11%)	2 (11%)
Posttest	18	12 (10, 12)	<.001[a]	-	-
1-month follow-up	14	9 (6, 11)	.018[a]	1 (7%)	4 (29%)
4-month follow-up	9	8 (7, 10)	.025[a]	2 (22%)	3 (33%)

Abbreviation: IQR, interquartile range.

[a] Wilcoxon signed rank test *p*-value compared with pretest. Clinical exposure represents the number and percentage of residents reporting any clinical exposure to the nerve block (yes/no) preworkshop, and at 1-month and 4-month intervals.

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Supplemental Online Material

Appendix 1. *Interscalene Block Trainer Cost Breakdown and Silicone Gel Phantom Trainer Assembly Process*

Interscalene Nerve Block Task Trainer

Interscalene Block Trainer Cost Breakdown

Material	Retail Size	Retail Cost	Units Needed	Cost	Comments
Upfront Cost					
Convection Oven	10.8"D x 14.5"W x 8.8"H	$59.99	1 oven	$59.99	Black and Decker 4 slice toaster oven. Used for melting the ballistics gel.
Silicone bake pan	12"	$3.50	1 pan	$3.50	None
Aluminum rod 1/2"	36"	$4.11	12"	$1.37	Place through holes made in silicone bake pan.
Aluminum rod 3/8"	36"	$3.58	12"	$1.20	Place through holes made in silicone bake pan.
Steel rod 1/8"	48"	$4.08	3 x 12"	$3.06	Place through holes made in silicone bake pan.
TOTAL INITIAL COST: $69.12					
Per Task Trainer Costs					
Humimic Clear Ballistic 10% gel	16" x 6" x 6"	$128.00	~67.5 cubic inches	~$15.00	Deconstruct into small 1" pieces, place in silicone bake pan, then melt in convection oven at 220F.
Slic pig pigment by Smooth On	1 tray	$9.95	1 pinch	~$0.10	Flesh skin tone
Silicone stoppers	-	$0.10	5 stoppers	$0.50	Contain the ultrasound liquid (simulated blood)
TOTAL COST $15.60 per task trainer					

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Supplemental Online Material *continued*

Interscalene Block Silicone Gel Phantom Trainer Assembly Process

Our interscalene block molds were created using a 12'' silicone bake pan and 12'' rods with varying diameters to represent nerves, vessels and veins (Image A and B).


Image A

Image B

Ballistics gel is then torn into small pieces and added to the model (Image C). Pigment can optionally be added to the ballistics gel to simulate flesh color. It is then heated and melted at 220F in the convection oven until the gel has completely liquified and all air bubbles have been removed. The oven is then shut off and the ballistics gel is allowed to cool completely.

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Supplemental Online Material *continued*

Image C

The ballistic gel is removed from the bake pan and the metal rods are removed from the mold (Image D and E). Ultrasound fluid is added to each of the 5 blood vessels/nerves, and silicone stoppers are used to contain the ultrasound fluid.

Image D

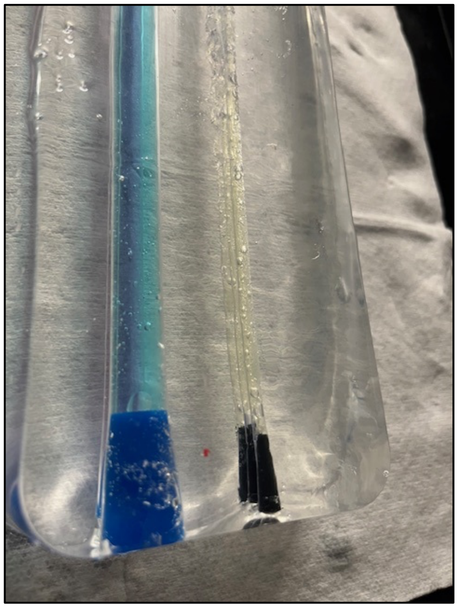

Image E

Final ballistics gel phantom trainer (left = with pigment, right = without pigment, Image F)

Image F

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Supplemental Online Material *continued*

Ultrasound imaging of our gel phantom includes a vascular structure to mimic the carotid artery in addition to circular structures to mimic the C5 and C6 nerve roots; note C6 is bifurcated (Image G, unlabeled and Image H, labeled).

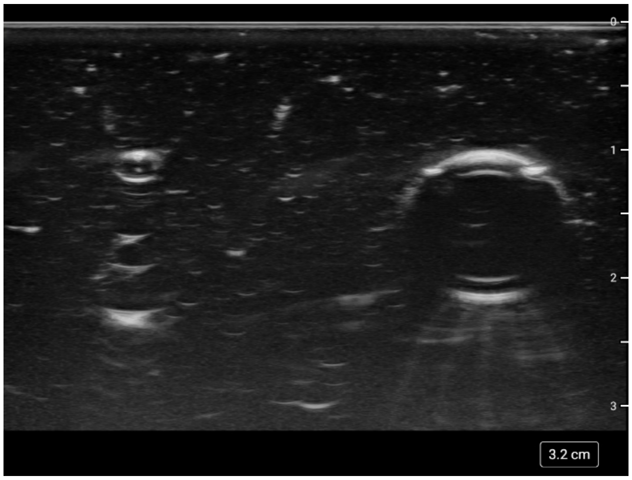

Image G: Unlabeled interscalene ultrasound sonoanatomy image with embedded anatomic structures

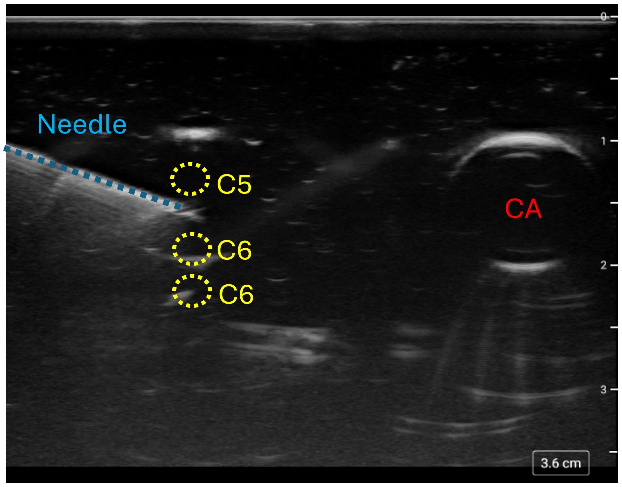

Image H: Labeled anatomic structures and in-plane needle path; CA = carotid artery

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Supplemental Online Material *continued*

Appendix 2. *Adductor Canal Block Trainer Cost Breakdown and Silicone Gel Phantom Trainer Assembly Process*

Supplemental Digital Content 2: Adductor Canal Nerve Block Trainer

Adductor Canal Block Trainer Cost Breakdown

Material	Retail size	Retail Cost	Units Needed	Cost Per Trainer	Comments
Upfront Cost					
Convection Oven	10.8”D x 14.5”W x 8.8”H	$59.99	1 oven	$59.99	Black and Decker 4 slice toaster oven. Used for melting the ballistics gel.
Mold Star Silicone	2 Gallon (becomes 1 Gallon after mixing)	$223.00	0.25 gallons	$55.75	Silicone poured to cast 3D printed model
3D printed model	1000ml white resin	$149.00	213 mL	$31.74	Used to make 2-part mold for ballistics gel
Aluminum rod 3/8"	36” length	$3.58	5”	$0.51	Place through holes made in silicone mold.
TOTAL INITIAL COST $147.99					
Per Task Trainer Costs					
Clear Ballistic 10% gel, 16 x 6 x 6	16” x 6” x 6” block	$128.00	?	~$11.00	Deconstruct into small 1" pieces, place in silicone mold, then melt in convection oven at 220F.
Power mesh	1 square yard	$2.14	4” x 4”	$0.16	Used to simulate fascia
Slic pig pigment by Smooth On	1 tray	$9.95	1 pinch	~$0.10	Flesh skin tone
Silicone stoppers	-	$0.10	2 stoppers	$0.20	Contain ultrasound liquid (simulated blood)
TOTAL COST $11.46/ADDITONAL TRAINER					

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Supplemental Online Material *continued*

Adductor Canal Block Silicone Gel Phantom Trainer Assembly Process

Our adductor canal molds were created using a 3D printer a Formlabs resin printer (Image A) with white resin. To create the molds to be anatomically representative, we created a separate triangular insert (Image B) that would fit on top of our primary phantom (Image C) to allow us to interlay mesh.

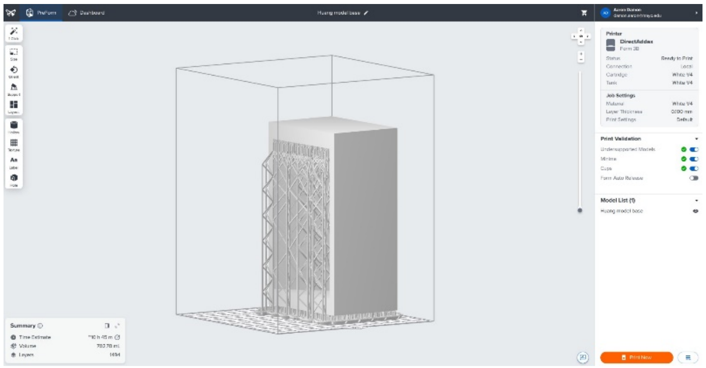

Image A: Formlabs Resin Printer Interface Design

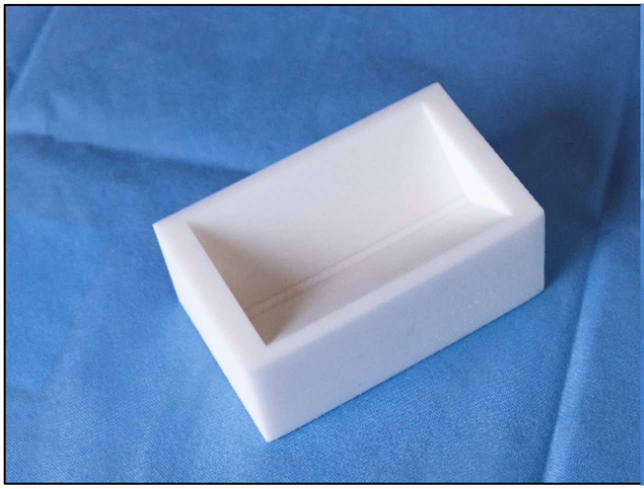

Image B: Triangular insert

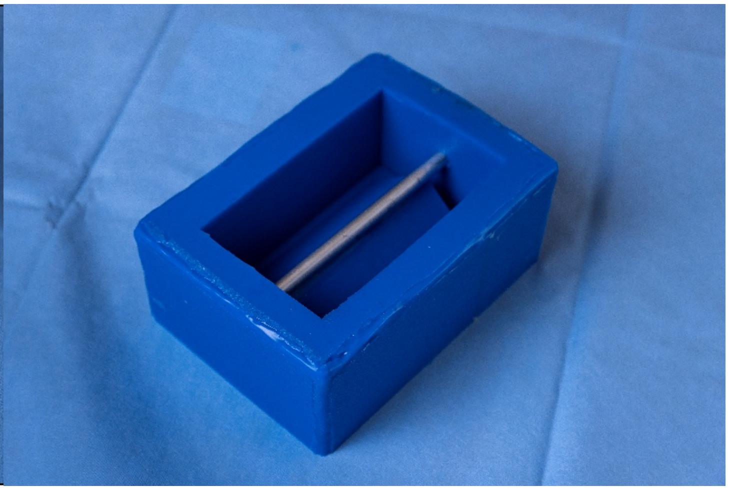

Image C: Primary phantom cast

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Supplemental Online Material *continued*

The molds were then utilized to pour, contain, and cast the ballistics gel. A 5" rod with a diameter of 3/8" is utilized to simulate the vessel and create a cavity for simulated blood.

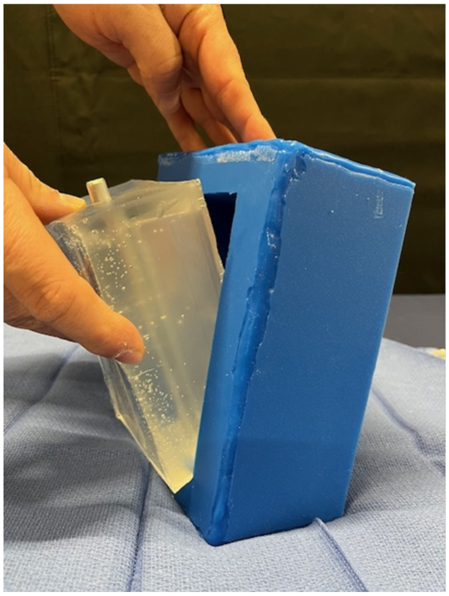

Image D: Removal of gel phantom from mold

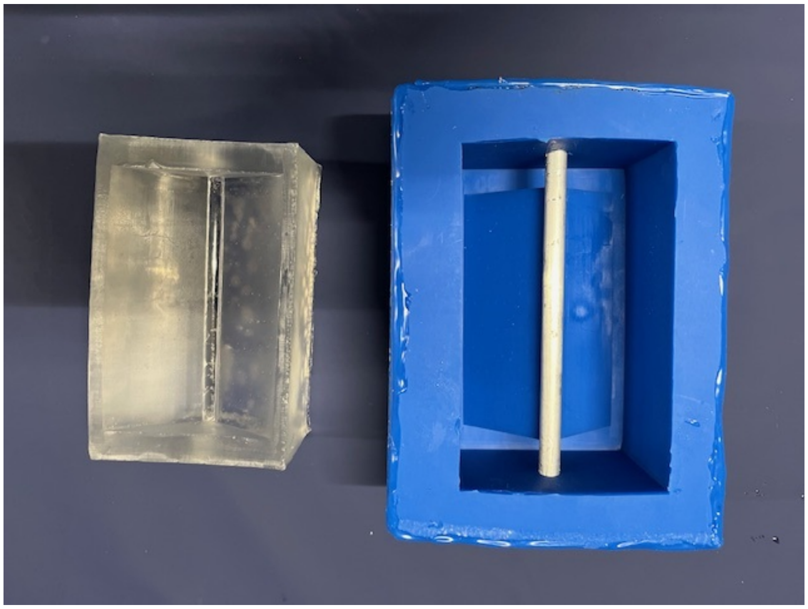

Image E: Gel phantom on left and mold on right.

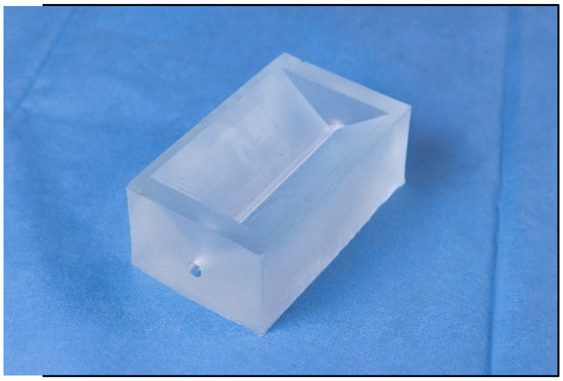

Image F: Triangular mold

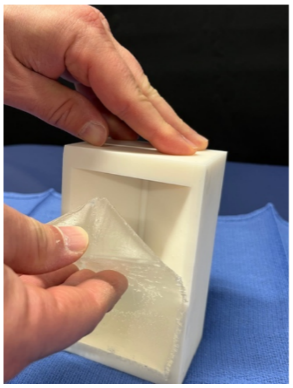

Image G: Removal of triangular phantom

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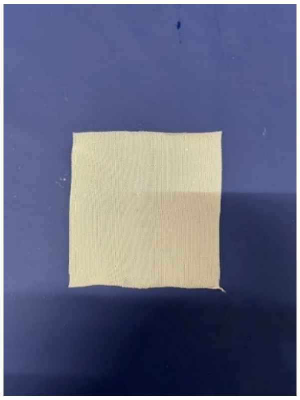
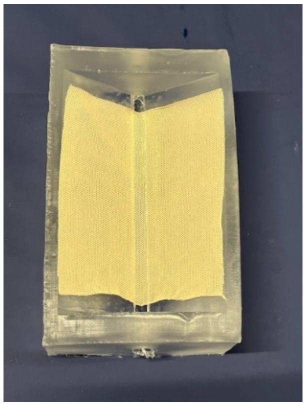
Supplemental Online Material *continued*

A power mesh is cut into a 4" X 4" square to simulate facial planes. The mesh is laid into the model and the top triangular ballistics gel piece is placed over the mesh and heated to seal (Images H-K).


H.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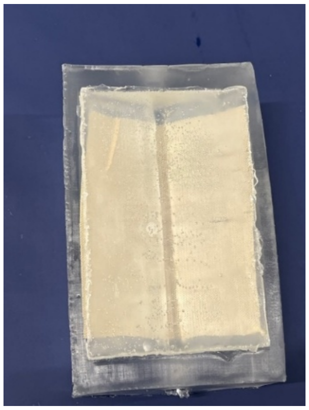
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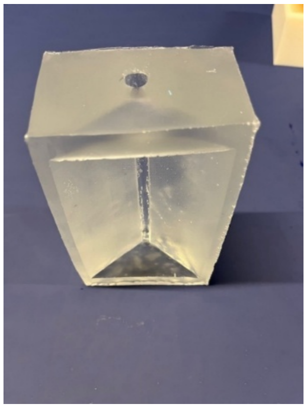
K.

Pigment may be optionally incorporated into the ballistics gel to achieve a flesh-colored appearance (Image L). The ballistics gel is then heated at 220F until it completely liquifies and all air bubbles have been removed. The oven is then shut off and the ballistics gel is allowed to cool completely.


Image L: Flesh-colored pigment added

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Supplemental Online Material *continued*

Materials and final product are shown below (Image K).

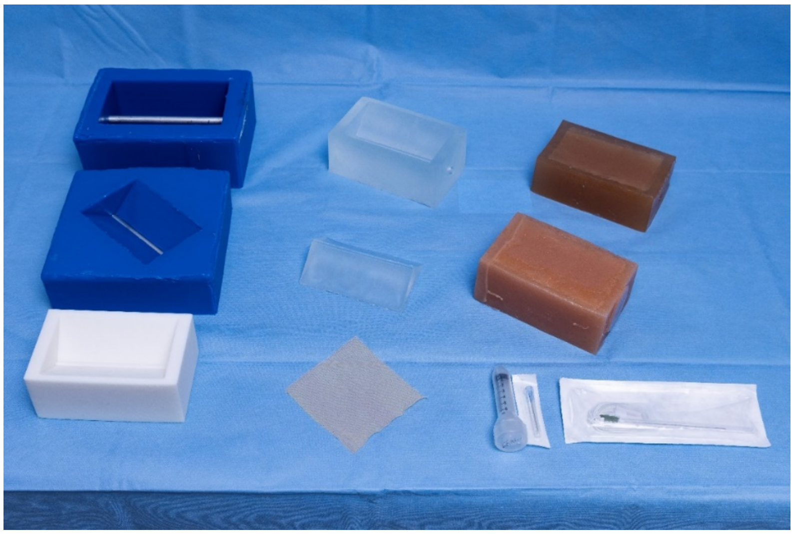

Image K: Materials and final product.

Ultrasound imaging of our gel phantom includes a vascular structure to mimic the superficial femoral artery. The triangular plan represents the sartorius muscle (top of triangle), the vastus medialis muscle (anatomically lateral) and adductor longus muscle (anatomically medial); Image M (unlabeled) and N (labeled and with needle).

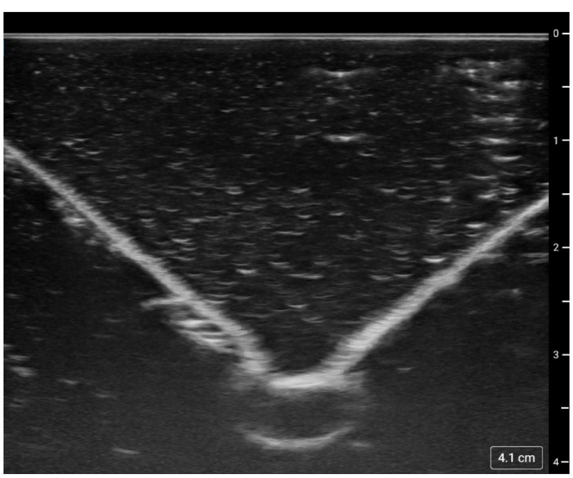

Image M: Unlabeled adductor canal ultrasound sononatomy image with embedded anatomic structures.

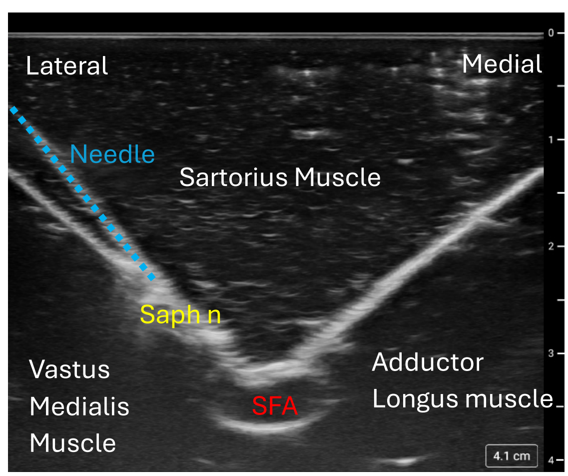

Image N: Labeled anatomic structures and in-plane needle path; SFA = superficial Femoral artery; Saph n = saphenous nerve