**Custom 3D printed ultrasound-compatible vascular access model: training residents for safe real-world vascular access**

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## I. Specific educational aims

1. Develop a novel and inexpensive 3D printed ultrasound-compatible vascular access model utilizing patient anatomy derived from computed tomography scans.
2. Develop a vascular access simulation experience for trainees across multiple disciplines.
3. Assess trainee competence of ultrasound guided vascular access with the custom model.

## II. Project rationale

Ultrasound (US) guidance is commonly used for vascular access and has been shown to reduce the risk of complications and to improve access time versus palpation-guided access (1, 2); however, vascular access can lead to complications in even experienced hands. A recent study demonstrated that attending physicians with an average of thirteen years of experience properly used US for central venous access only 40% of the time with 14% of physicians inadvertently puncturing the carotid artery or requiring more than two needle passes to successfully access the targeted vein. Furthermore, these experienced physicians were significantly outperformed by residents who had undergone simulation training (3). Given the high rates of improper vascular access, proper training is critical to teaching technique. As an alternative to initial training on actual patients, simulation prior to traditional procedural training has been utilized to reduce the time required to acquire procedural skills and to reduce the number of errors occurring on patients during the learning period (4).

Current commercially available training models for ultrasound-guided vascular access can simulate palpable and ultrasound anatomic landmarks. These mass-produced models primarily simulate normal anatomy. Recently, 3D printing of medical models from patient-specific diagnostic imaging has been utilized for preprocedural evaluation of complex anatomy in interventional radiology (IR) and in surgical specialties (5, 6). The increasing availability of 3D printing and decreasing costs allow for the creation of patient and disease-specific models. To our knowledge, 3D printing has not been utilized in the creation of a patient specific US-compatible vascular access model (3DP-VAM).

We propose the development of a 3DP-VAM of normal anatomy with complementary vascular access simulation experience. The 3DP-VAM will be substantially less expensive to manufacture compared to current models and will be fully customizable and reusable. We hypothesize that trainees using a currently available model and the 3DP-VAM will demonstrate improved vascular access competency compared to trainees without simulation experience; we do not expect a significant difference between the standard model and 3DP-VAM groups during the implementation of the initial normal 3DP-VAM. The knowledge gained from this initial normal model will be used to develop more complex future models of variant anatomy or pathology.

## III. Approach

The project will be a collaborative multidisciplinary effort between a Department of Radiology resident physician, Division of Interventional Radiology faculty member, 3D and Quantitative (3DQ) Imaging Laboratory, and Center for Immersive and Simulation-based Learning (CISL). Initial tests have been performed with 3D printed blood vessels embedded in silicone, demonstrating the feasibility of US visualization of simulated vasculature in soft tissue. Rendering of a femoral artery and vein model derived from a CT image of the abdomen and pelvis of a patient without pathology has been generated (**Figure 1**). The rendering will be used to 3D print a cast of the vasculature and bone using materials with appropriate sonographic properties. With the expertise of the CISL, silicone material to simulate soft tissue will be used to fill the cast and a synthetic skin will be placed on the surface of the model. CISL facilities will be used to develop and implement a vascular access simulation experience for trainees with the 3DP-VAM.

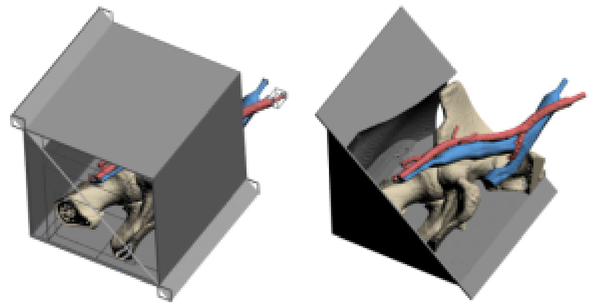

**Figure 1.** Rendering of femoral artery and vein model. Outer housing intact (**left**) and removed (**right**) to demonstrate bony and vascular anatomy.

Currently, trainees on the IR service are evaluated on their ability to obtain vascular access with a Certification of Procedural Competency (CPM) form by a faculty member. Training models are not routinely used. Research conducted in the educational setting is exempt from institutional review board (IRB) review, though initial IRB review will be performed. During the development of the 3DP-VAM, trainees will continue to be evaluated by CPM forms. Once the 3DP-VAM is ready for implementation, prior to beginning on the IR service, half of the trainees will complete a vascular access simulation experience with a standard model, while the other half will be trained with the 3DP-VAM. During clinical rotations, 28 trainees will be evaluated by a CPM form by a single IR faculty member that was blinded to the training group.

## IV. Timeline and plan for implementation

| | Q1 (Sep – Nov) | Q2 (Dec – Feb) | Q3 (Mar – May) | Q4 (Jun – Aug) |
|---|---|---|---|---|
| **3DP-VAM Development** | | | | |
| Cast and vasculature | ■ | | | |
| Soft tissue | ■ | | | |
| Testing and feedback | | ■ | | |
| **3DP-VAM Simulation Development** | | | | |
| User instruction | | ■ | | |
| **Trainee Assessment** | | | | |
| No models | ■ | ■ | | |
| Standard model | | | ■ | ■ |
| 3DP-VAM | | | ■ | ■ |

## V. Anticipated work product

A 3DP-VAM of normal femoral anatomy and associated simulation experience will be developed. The results of the trainee assessment will be used to improve procedural competency of trainees in IR and also shared by conference presentation and a manuscript. These results will also be shared with faculty and trainees in intensive care, emergency medicine, and surgery in order to further increase the impact of the project and vascular access success across disciplines.

## VI. Evaluation plan

User feedback will be incorporated early on in the 3DP-VAM development process and also upon completion of the prototype. CPM forms will be utilized by a faculty member to assess the ability of trainees to obtain vascular access. Comparable competency to commercially available models will support the utility of the 3DP-VAM prior to creation of more complex anatomical models.

## VII. Dissemination of results

We will submit this work for abstract presentation at the Radiological Society of North America, Association of University Radiologists, and/or Society of Interventional Radiology annual meetings; manuscript submission to associated journals will be selected based on feedback from abstract submissions.

## VIII. References

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