Development of an Automated Vascular Access Device (AVAD)

Saif M. Ansari[1], Michael A. Barton[2], Francisco I. Valentín[2], Zachary Soucy[1,3]

1 – Geisel School of Medicine, Dartmouth College; 2 – Creare LLC.; 3 – Dartmouth-Hitchcock Medical Center

Background

Vascular access is a critical and early step in the stabilization and treatment of critically injured soldiers and civilians.[1] Traditional peripheral intravenous (PIV) access and central venous cannulation (CVC) access becomes exceedingly difficult in the field, particularly in patients who are volume-depleted from blood loss or dehydration, vasoconstricted, or hypothermic. Such patients might benefit from interventions like Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA), an emerging choice in the management of non-compressible torso hemorrhages, which requires rapid vascular access.[2]

Introduction

We seek to develop a self-contained device that significantly simplifies IV and intra-arterial cannulation (IAC) by reliably and rapidly automating vascular access. In Phase I, we developed a preliminary design for a prototype system and demonstrated overall feasibility. In Phase II, we will develop a prototype device and will evaluate its effectiveness. In Phase III, we will validate the technology, as needed, through clinical trials and will use that data to obtain FDA clearance.

References

1 - Schmidt GA, Blaivas M, Conrad SA, Corradi F, Koenig S, Lamperti M, Saugel B, Schummer W, Slama M. Ultrasound-guided vascular access in critical illness. Intensive Care Med. 2019 Apr;45(4):434-446. doi: 10.1007/s00134-019-05564-7. Epub 2019 Feb 18. PMID: 30778648.

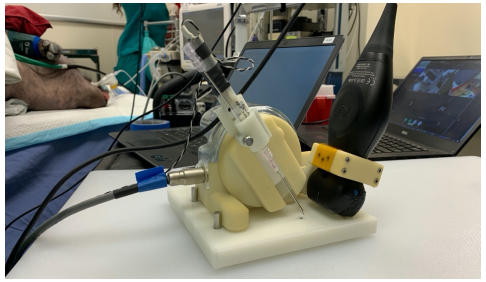
2 - Bulger, Eileen M et al. "Clinical use of resuscitative endovascular balloon occlusion of the aorta (REBOA) in civilian trauma systems in the USA, 2019." Trauma surgery & acute care open vol. 4,1 e000376. 20 Sep. 2019, doi:10.1136/tsaco-2019-000376.

3 - Zhu R., Tu X., Huang J.X. *Deep Learning on Information Retrieval and its Applications.* Department of Computer Science & Engineering, York University, Toronto, Canada.

Mechanical Actuator

Methods

The mechanical component of the AVAD consists of a needle for cannulation, an actuator which directs the needle to an anatomical location specified by the Direct Convolutional Neural Network (DCNN), and an ultrasound probe which provides input to the DCNN to identify the desired anatomical structure. The Phase II prototype uses a simplified layout which is easy to modify during testing on porcine models. A vessel was manually identified the porcine model via ultrasound by the team's medical consultant, Dr. Zachary Soucy, and the needle was directed by the actuator to the vessel.



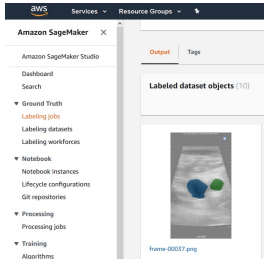
Results

Over several porcine trials, vascular access was achieved a number of times. Various parameters were modulated, including the speed and angle at which the needle approached the desired vessel, and these parameters were optimized through a trial-and-error method.

Deep Convolutional Neural Network (DCNN)

Methods

In order to automate the selection of an appropriate vessel for cannulation, a machine learning algorithm must be developed. Our team opted to develop a Deep Convolutional Neural Network (DCNN), a form of deep learning commonly applied to computer vision. DCNNs operate analogously to the neuronal connections in the human brain, and are designed to identify localized predictive features from a larger image.[3]



Our AVAD is under development through Amazon Web Service's SageMaker, a managed service that helps data scientists build and train machine learning models. A user trained in ultrasonography for the identification of blood vessels, nerves, and other structures identifies and labels such structures on still images parsed from existing ultrasound videos. The labeled still images are then provided to the DCNN, which uses this information to recognize patterns and identify vessels and nerves independent of input from a clinician.

Conclusions

Due to the to tortuous nature of porcine vessels, perfused human cadaver models will be utilized in future trials. The development of the Automated Vascular Access Device is still in its infancy, and represents a new exciting frontier of medical advancement.