

Ultrasound-Guided Robotic Central Line Placement

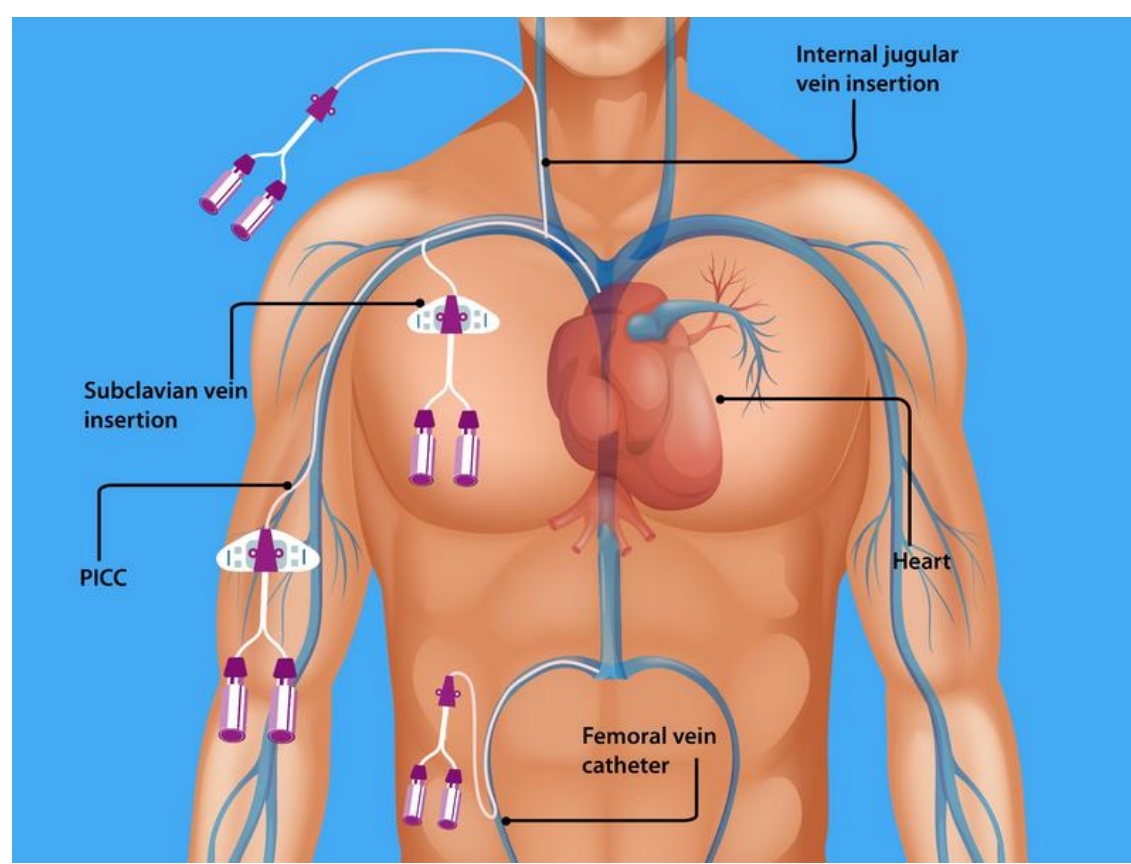
Computer Integrated Surgery II
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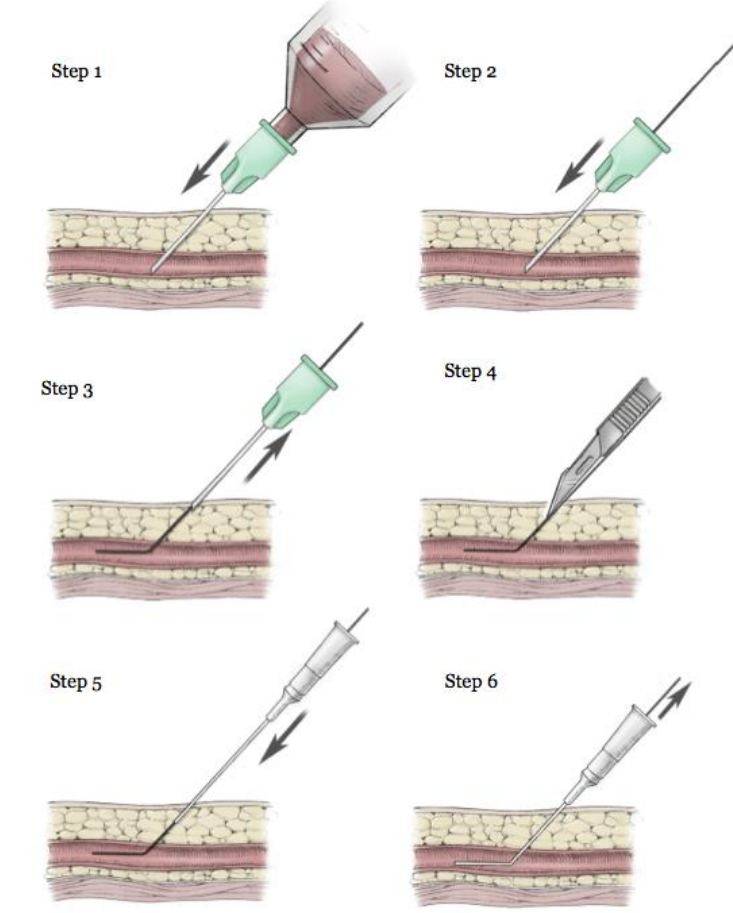
Mentors: Dr. Axel Krieger, Lidia Al-Zogbi, Dr. Vinciya Pandian, Dr. Mathias Unberath, Wenhao Gu

Introduction

- Central line placement, also known as central venous catheterization, is a medical procedure where a catheter is inserted into a large vein, typically in the neck, chest, or groin area.
- The procedure of the central line placement can be summarized as needle insertion, guidewire insertion, needle retraction, catheter insertion, guidewire retraction, and securement.
- Objectives:** Streamlining the needle insertion, guidewire, and catheter advancement process for reduced complications and improved efficiency.



Different access points for Centrally Inserted Central line Catheters



Procedure of central line placement

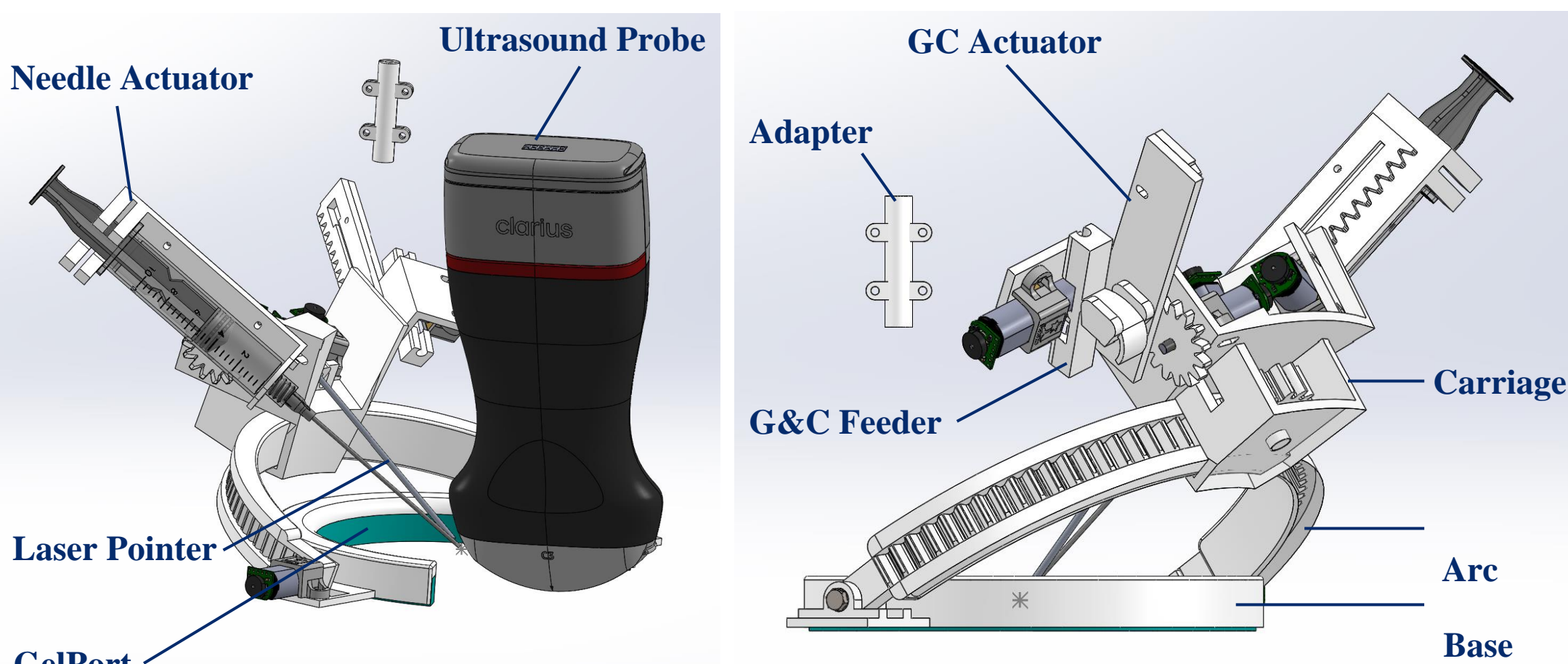
The Problem

- During the operation, clinicians frequently touch and manipulate various instruments. This increased risk of contamination can result in localized site infections or more severe complications, such as bloodstream infections.
- Furthermore, the procedure demands steady hands and precise movements, which can lead to clinician fatigue and negatively impact the procedure's accuracy and safety.
- Hence, the design of a robotic system can enhance the safety and accuracy of central line placement, while reducing risks of infections.

The Solution

We designed and developed a lightweight and patient-mounted robotic system for central line placement to perform needle insertion, and guidewire & catheter advancement via the subclavian vein.

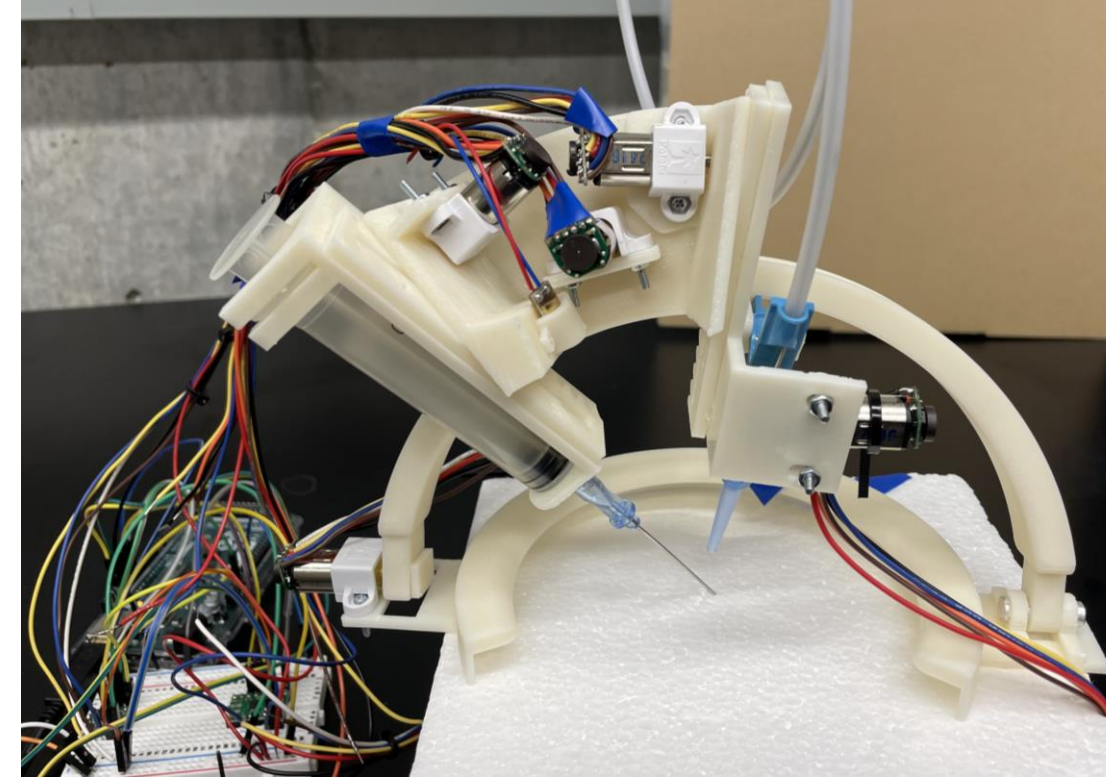
- Our robotic system is a compact design offering 2 rotational and 2 translational degrees of freedom for precise needle insertion and guidewire & catheter advancements.
 - * The adjustable workspace ensures compatibility with diverse patient anatomies.
 - * Angle of insertion: 13 - 50 degrees relative to the skin
 - * Depth of needle insertion: 19.8 - 67.4 mm
 - * Mechanical RCM: 8.5 mm above the skin
- Stable attachment to the patient is achieved using a combination of GelPort material and a rigid base, while the arc and carriage mechanisms provide the required degrees of freedom.



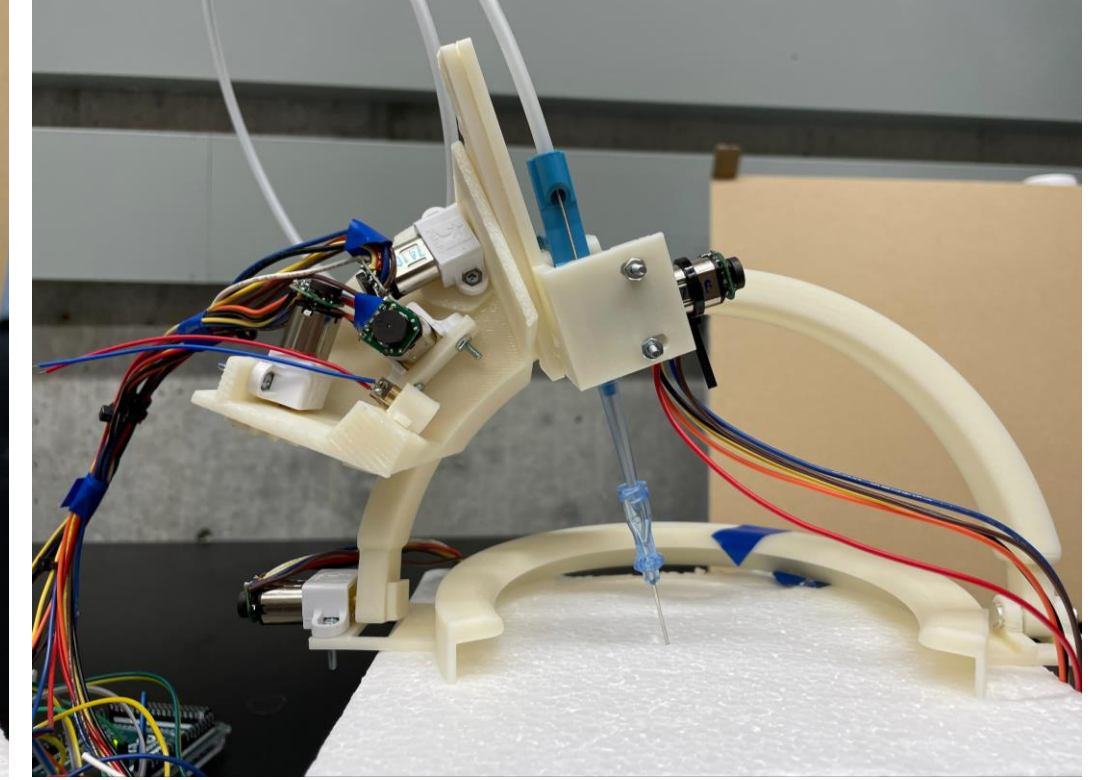
CAD model of the robotic system integrated with the ultrasound system

Results

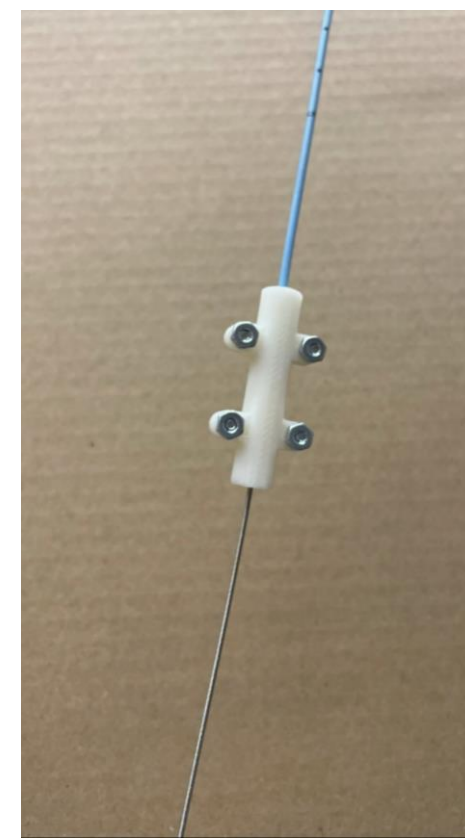
- Developed Prototype:** Successfully designed and assembled the primary structure and components of the robotic system.
- Addressed Challenges:** Optimized mechanism design and improved motor control through iterative design and problem-solving.
- Progress Towards Goal:** Laid a solid foundation for future refinements and functional testing to ensure the system's effectiveness in central line placement procedures.



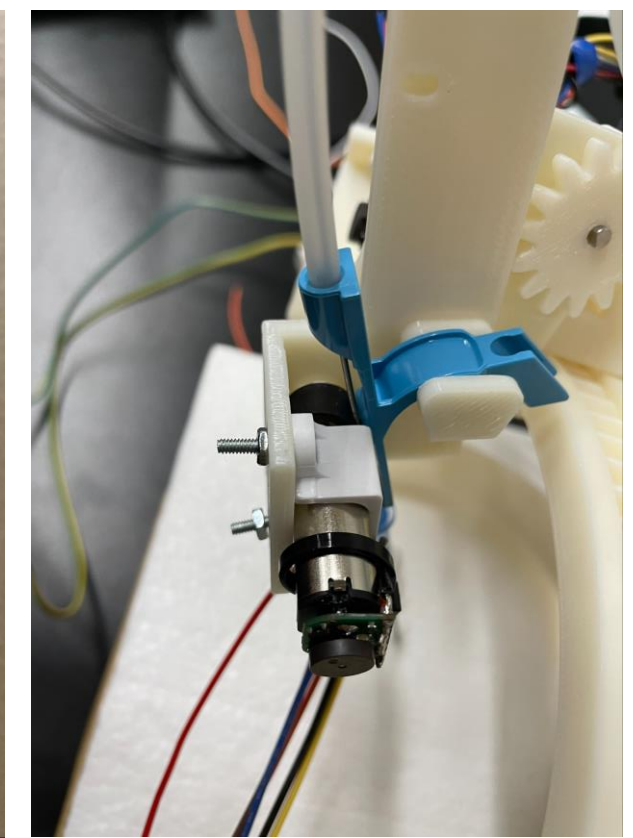
Needle insertion performed by the system



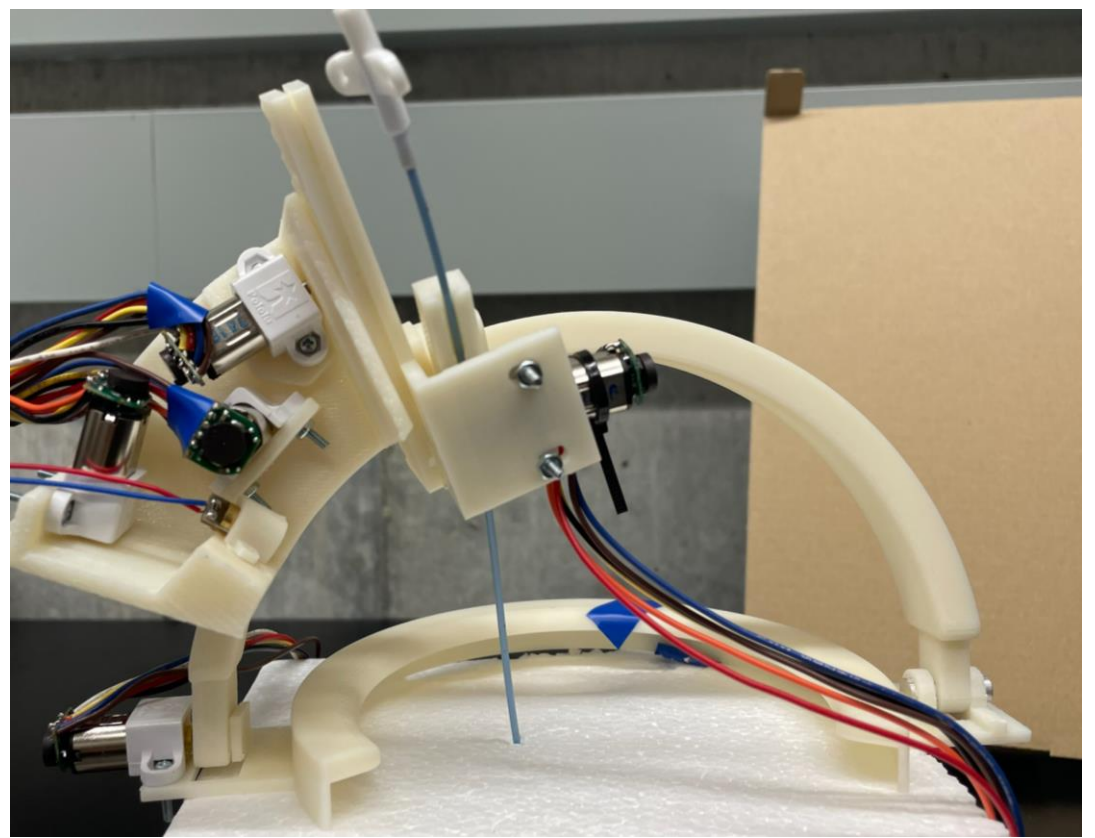
Guidewire advancement performed by the system



G & C Adapter



Guidewire advancement actuator



Catheter advancement performed by the system

Functional measurements:

- Angle of insertion: 15 - 50 degrees relative to the skin
- Depth of needle insertion: 20 - 60 mm
- The error between desired and actual RCM: 3 mm

Future Work

- Achieve full automation
- Software development
- Functional & performance testing

Lessons Learned

- Real-world situations:** Designing a practical and feasible system that meets the needs of clinicians and patients.
- CAD to prototyping:** Considering clearances and structural strength to ensure the device functions as intended.
- Medical device workflow:** Following a multi-stage process for safe, effective, and reliable medical device development.

Credits

- We would like to formally thank our supervisors Dr. Axel Krieger and PhD candidate Lidia Al-Zogbi for all their support.
- Kesi was responsible for mechanism design, Pranathi for kinematic design, and Xuanning for prototyping.

References

- [1] Y. Haddadin, P. Annamaraju, and H. Regunath, "Central line associated blood stream infections," in StatPearls, StatPearls Publishing, 2017.
- [2] J. R. Roberts and J. R. Hedges, Roberts and Hedges' clinical procedures in emergency medicine E-book. Elsevier Health Sciences, 2013.
- [3] F. Y. Wu, M. Torabi, A. Yamada, A. Golden, G. S. Fischer, K. Tuncali, D. Frey, and C. Walsh, "An MRI Coil-Mounted Multi-Probe Robotic Positioner for Cryoablation," Proceedings of the ASME 2013 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference IDETC/CIE 2013, 08 2013.