Automated Device for Rapid Blood Draws and Diagnostic Analysis

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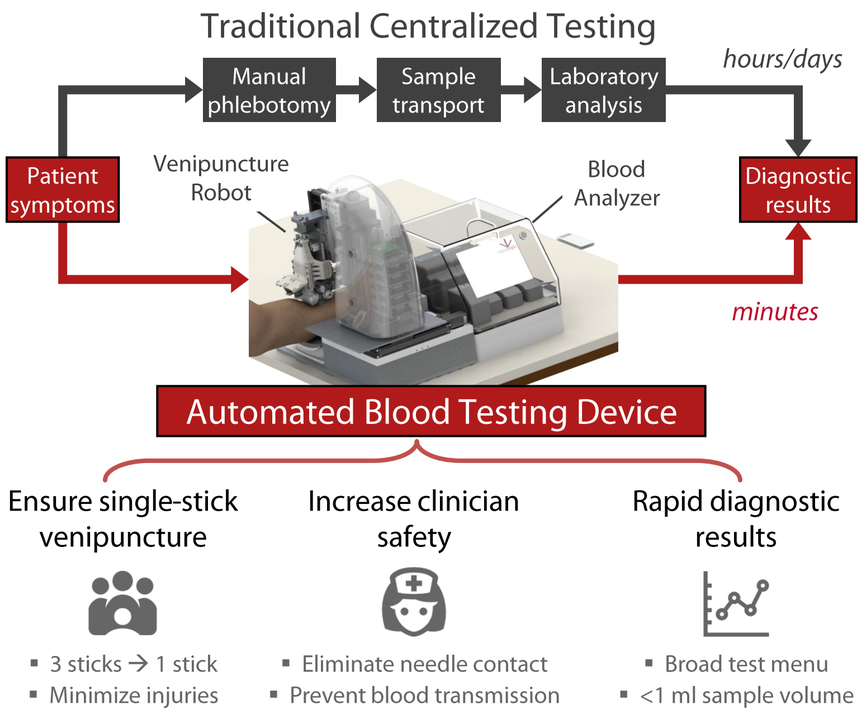
Clinical Problem

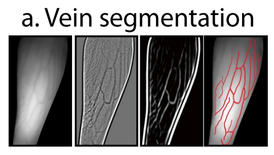
- Blood testing is the most ubiquitous clinical procedure in the world, and accounts for 90% of diagnostic procedures administered in ambulatory and emergency care settings.
- However, manual blood draw success rates depend heavily on clinician skill and patient physiology, and results are generated almost exclusively in centralized labs from large-volume samples using labor-intensive analytical techniques.
- **<u>Project goal:</u> Develop a portable device that enables complete end-to-end blood testing by performing blood draws and providing diagnostic results in fully automated fashion.**



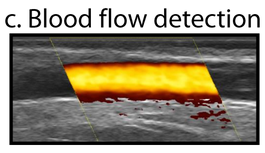
Integrated Blood Draw and Analysis Device

<u>1. 3D Near IR and Ultrasound Imaging</u>

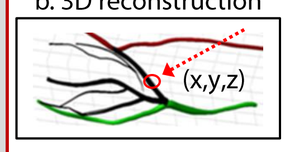
a. Vein segmentation



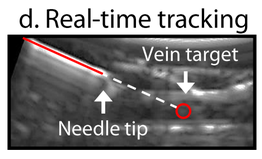
c. Blood flow detection



b. 3D reconstruction

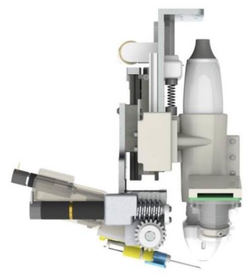


d. Real-time tracking



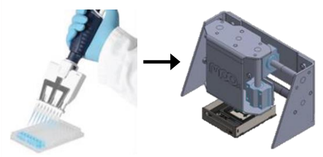
<u>2. Robotic Cannulation</u>

a. 5 DOF positioning unit
b. 3 DOF manipulator
c. Adaptive motion control

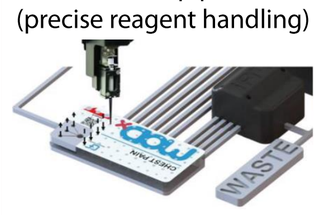


<u>3. Sample Handling</u>

a. Automated sample prep

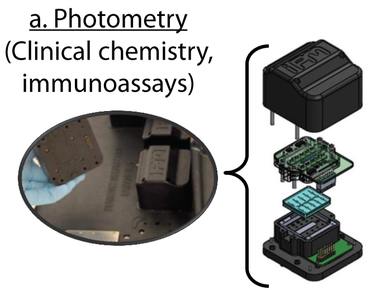


b. Robotic pipetter (precise reagent handling)



<u>4. Analytical Modules</u>

<u>a. Photometry</u>
(Clinical chemistry, immunoassays)

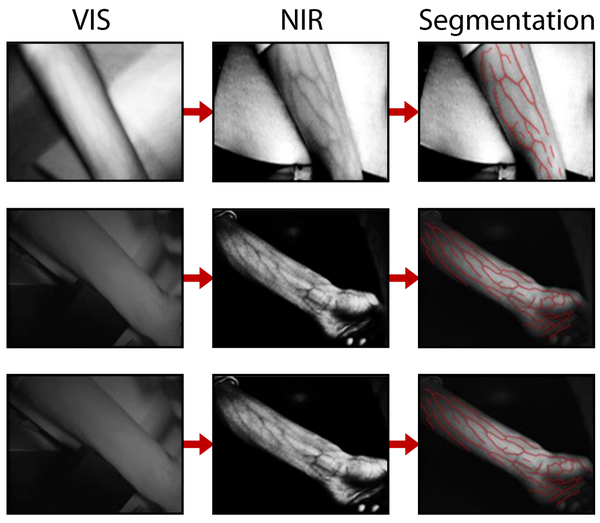


<u>b. Flow cytometry</u>
(Hematology)

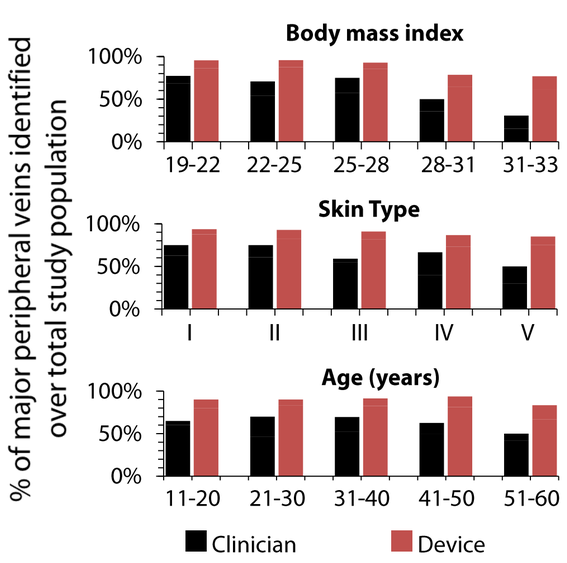
<u>c. Disposable cartridge</u>
Flexible assay menu

Near Infrared Human Imaging Study

1. Human Vessel Segmentation



2. Device Imaging vs Clinician (n=101)

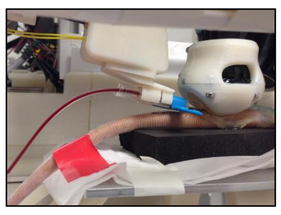


28% increase in total number of veins detected compared to clinical evaluation

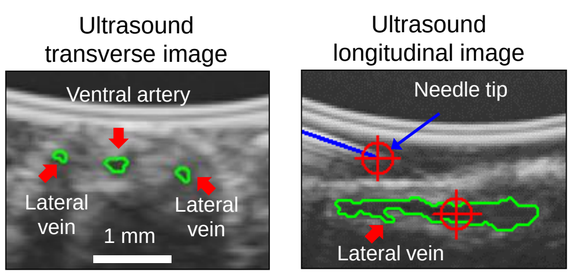
In Vivo Rat Lateral Tail Vein Cannulations

- Rat tail vein diameter ≈ pediatric vein (1 mm)
- Compare automated vs. manual venipuncture
- Evaluate: Success rate, time, 0.5 ml collection

0.5 ml blood draw

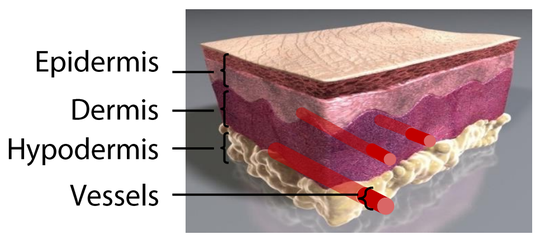


Ongoing Cannulation Results			
Animal (#)	Blood flash	Needle tip error (mm)	Time (min)
1	✓	0.114	1.4
2		0.095	2.2
3	✓	0.152	2.0
4	✓	0.173	1.3
5	✓	–	1.8



In Vitro Device Evaluation

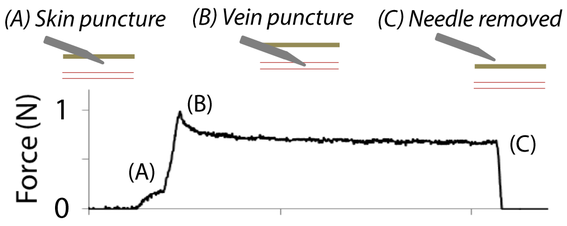
1. Tissue-Mimicking Phantoms



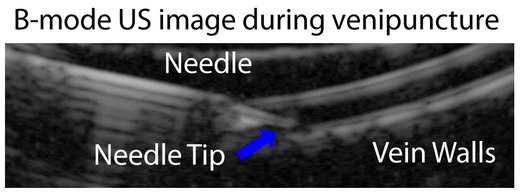
Tissue Layer	Human	Phantom
Epidermis (0.06 mm)	Melanin (2–45%)	India Ink
Dermis (1.1–3.2 mm)	Collagen, elastin	Gelatin, BSA
Hypodermis (1.1–5.5 mm)	Adipose tissue	Gelatin, Intralipid
Veins (0.7–3.5 mm)	Elastin/collagen tubing	Silicone tubing
Whole Blood	8 µm RBCs, blood serum	8 µm beads, glycerol

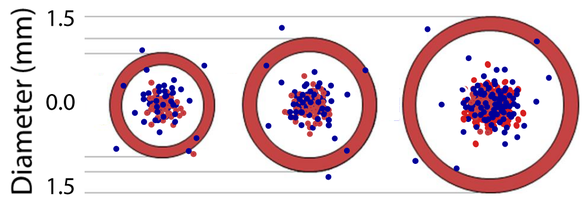
2. Phantom Cannulations (n=288)

Force profile during puncture events



B-mode US image during venipuncture





Manual	75%	80%	92%
Device	95%	100%	100%

- Phantoms simulate optical, mechanical, and acoustic tissue properties
- Force profile indicates needle tip position within tissue
- First-stick accuracy >98% across 288 models; completion time <30 sec

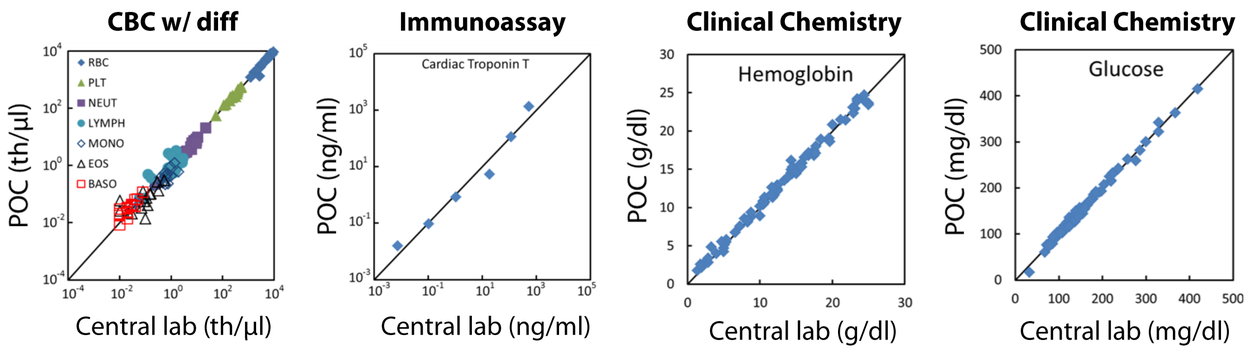
Future Work – Clinical Feasibility

IRB Human Adult Pilot Study

- Demonstrate that the system can be used in humans
- Compare robotic vs. manual venipuncture
- Evaluate: success rate, patient safety, 2 ml collection
- Compare blood results obtained on-board with benchtop instruments on <1 ml sample volume

Automated venipuncture → **Blood draw and collection** → **POCT** / **Lab** → **Diagnostic Tests:** CBC, Hgb, Troponin T

Point-of-Care Blood Analysis



- Capable of running up to 35 tests off of one <1 ml blood sample (most common shown)
- Equivalent performance and dynamic range compared to central lab instruments

Acknowledgements

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