Photoacoustic-based approach to surgical guidance performed with and without a da Vinci robot

Neeraj Gandhi, Margaret Allard, Sungmin Kim, Peter Kazanzides, Muyinatu A. Lediju Bell

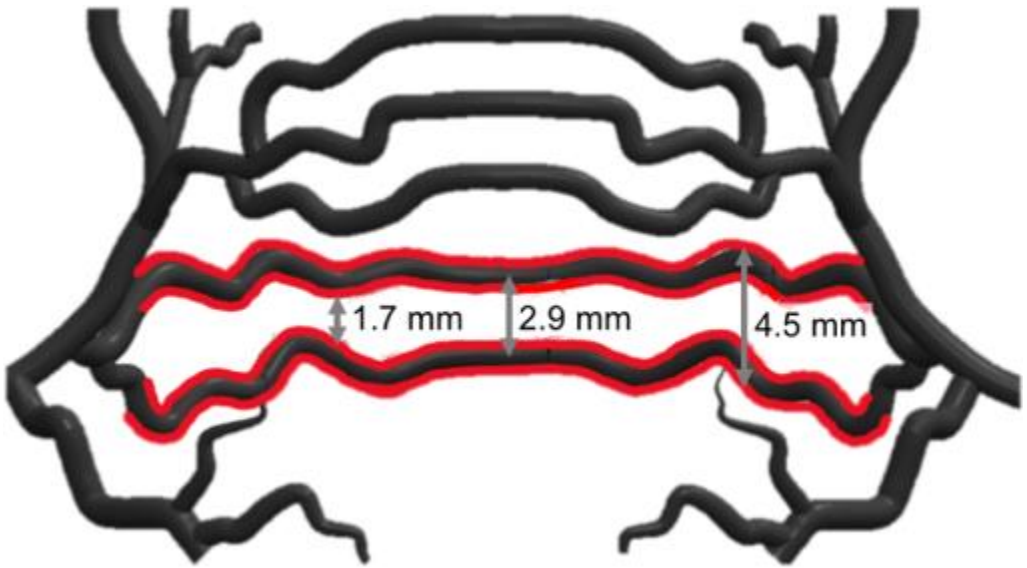
Group 3: Photoacoustic System for Spinal Surgery

Team Member: Blackberrie Eddins

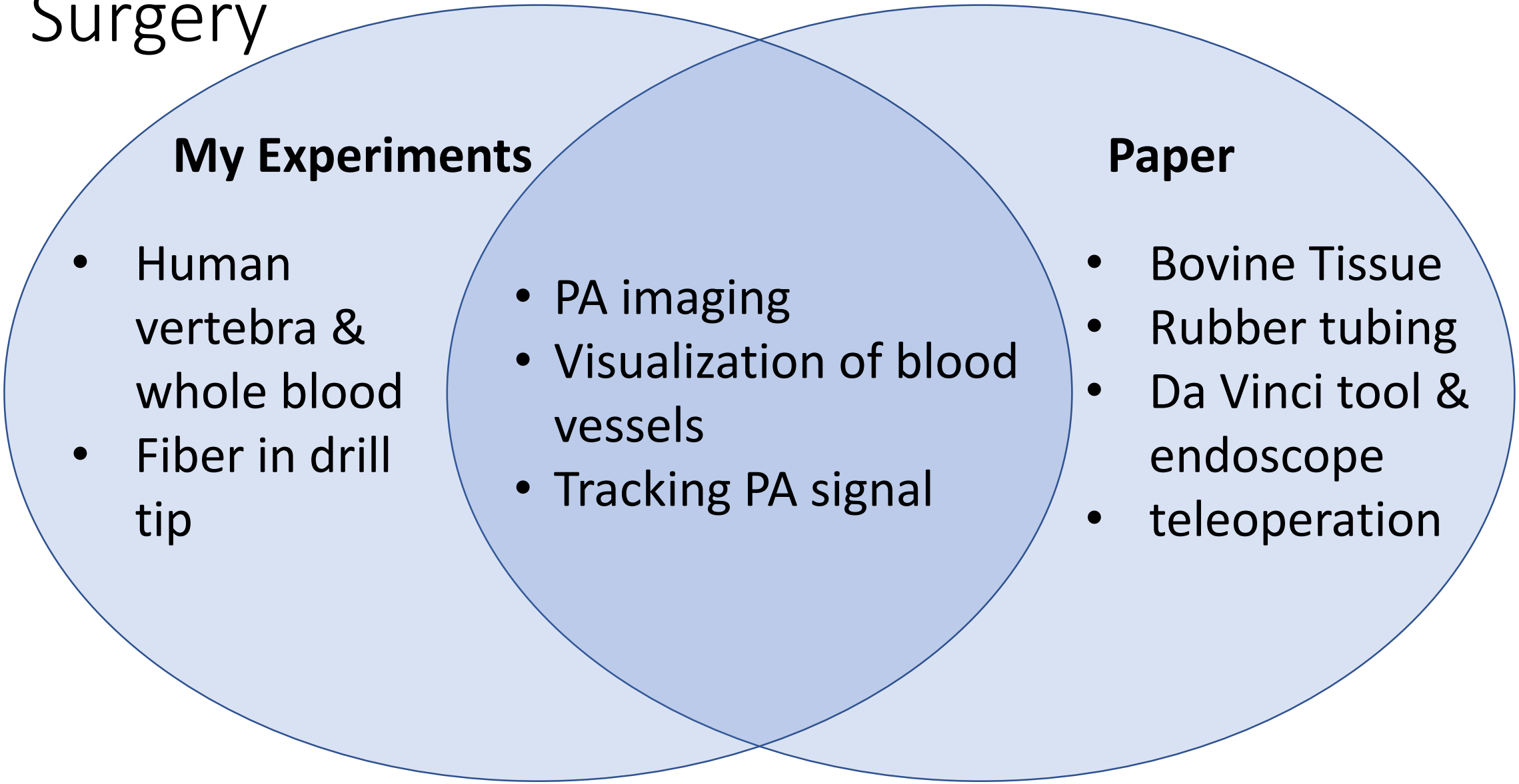
Mentor: Dr. Bell

Photoacoustic-based approach to surgical guidance performed with and without a da Vinci robot

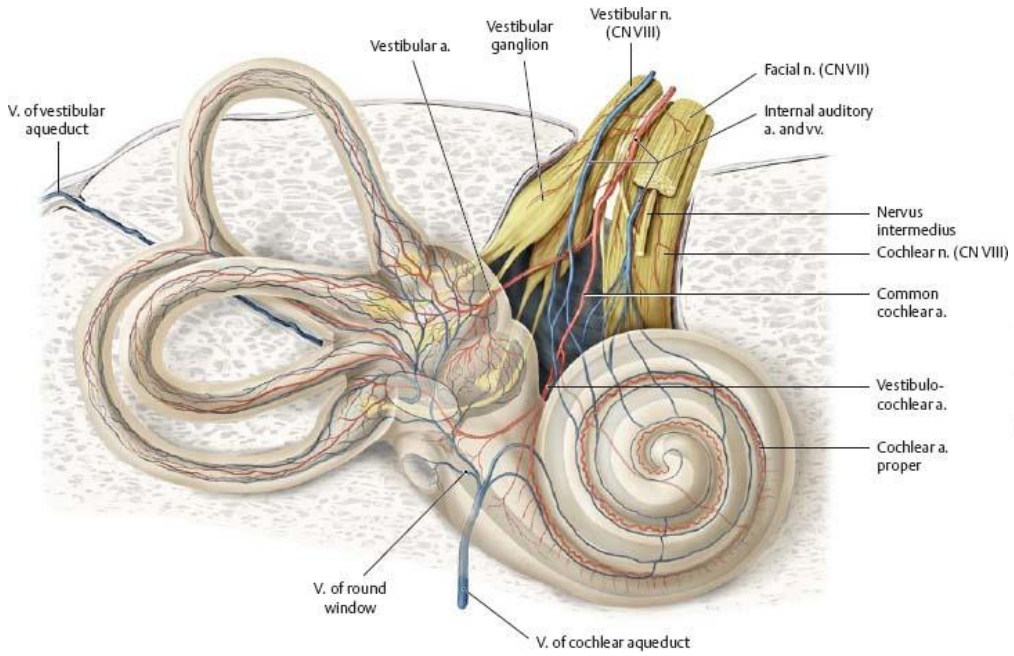
- **Main Goal:** Assess safety zones using PA imaging
- **Measured:** distance between “vessels”
- **Applications:** teleoperated surgeries,
  minimally invasive surgeries



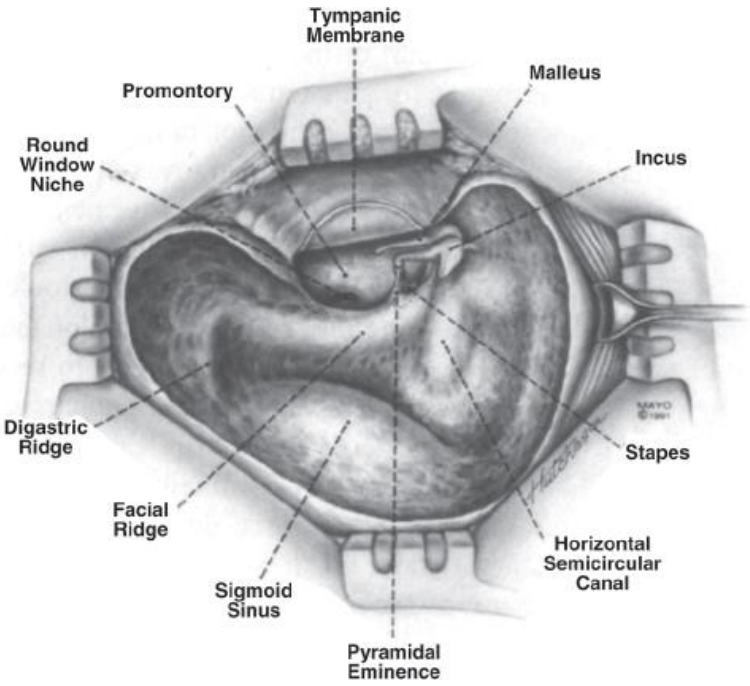
Relevance to Photoacoustic-Guided Spinal Surgery



Clinical Background

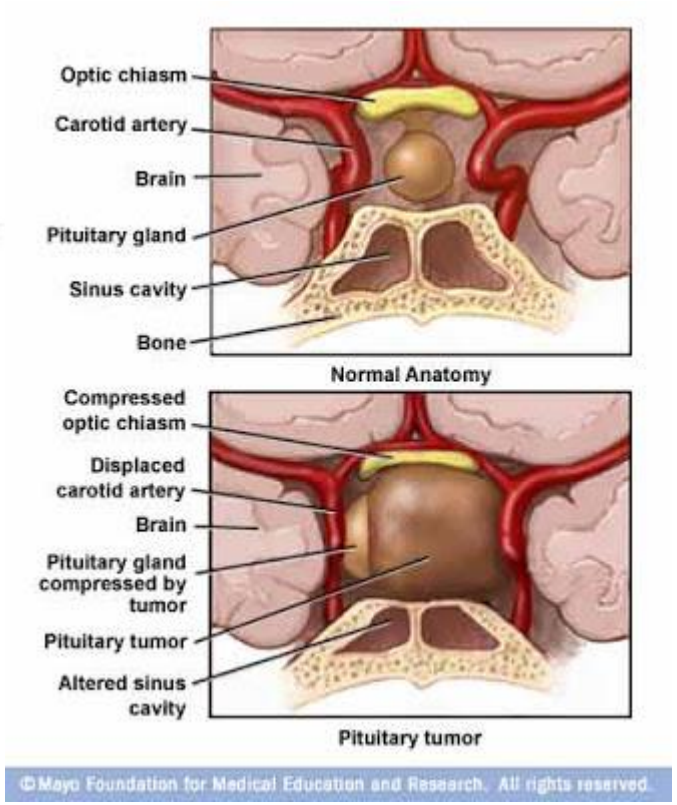


Middle ear nerves and arteries

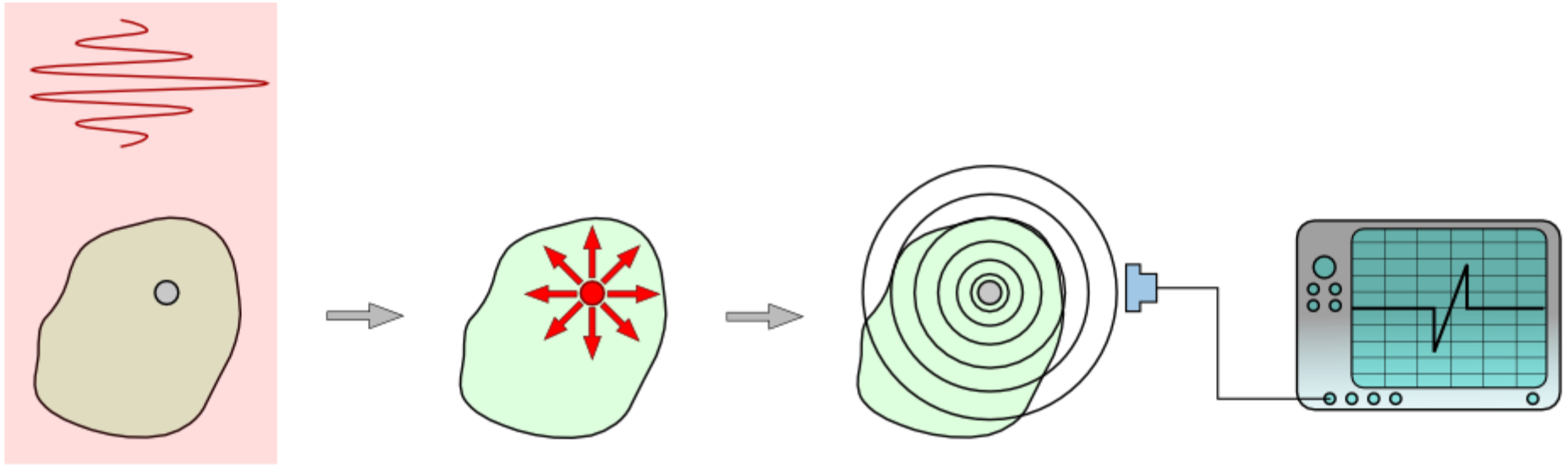


Middle ear view during mastoidectomy

Superior view of structures surrounding pituitary

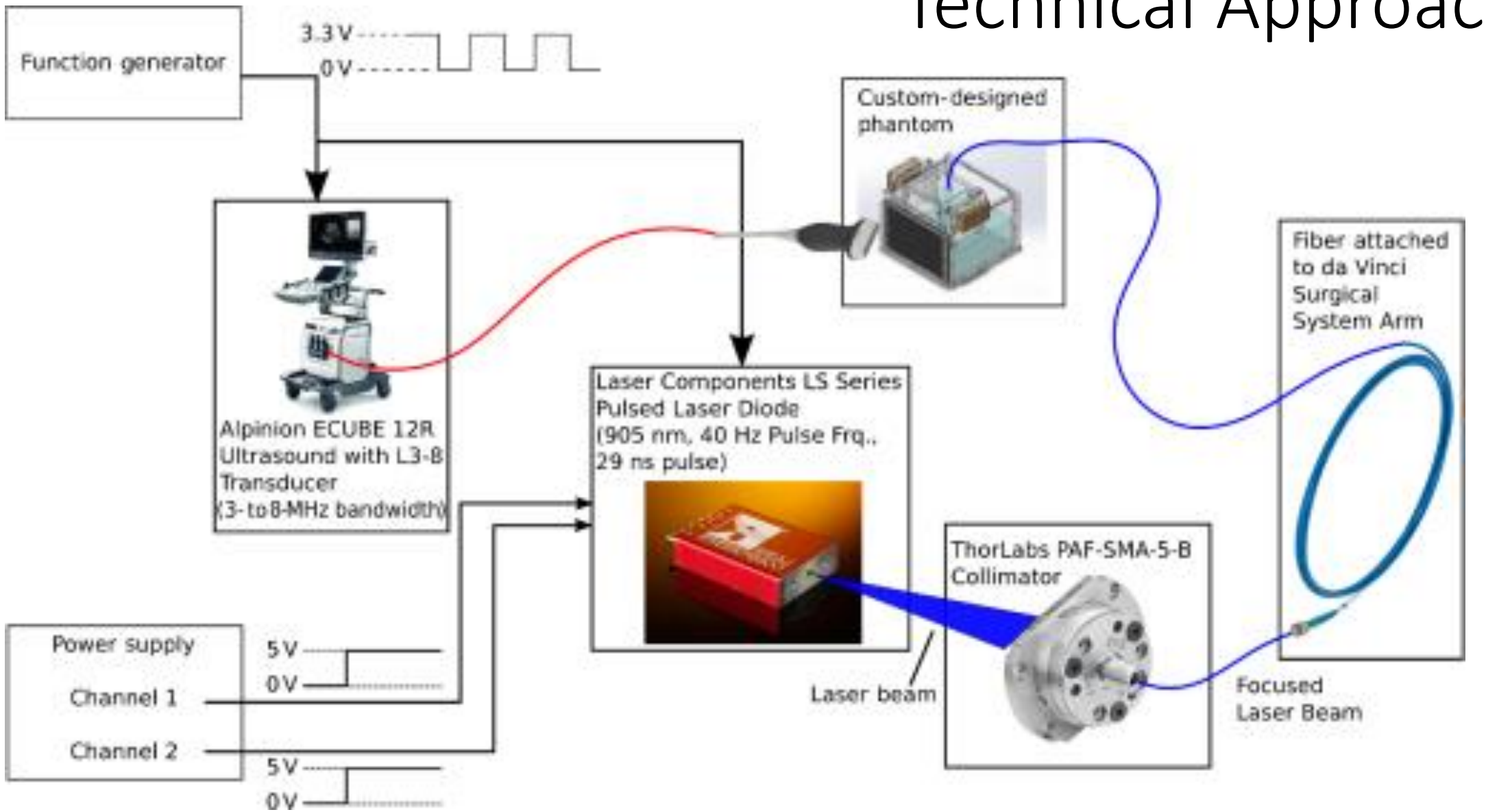


PA Background

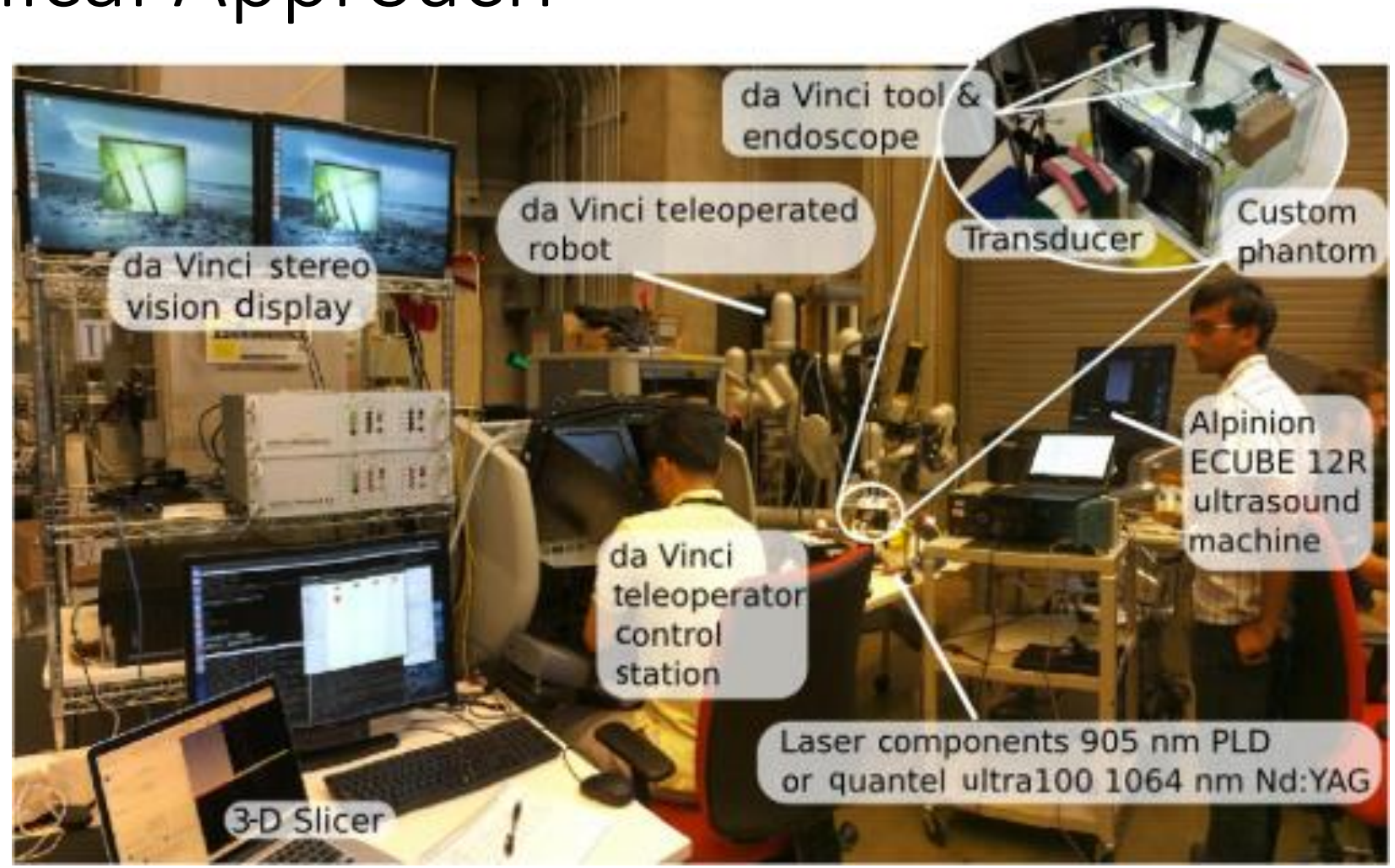


laser pulse → absorption → thermal expansion → acoustic waves → ultrasound detection → image formation

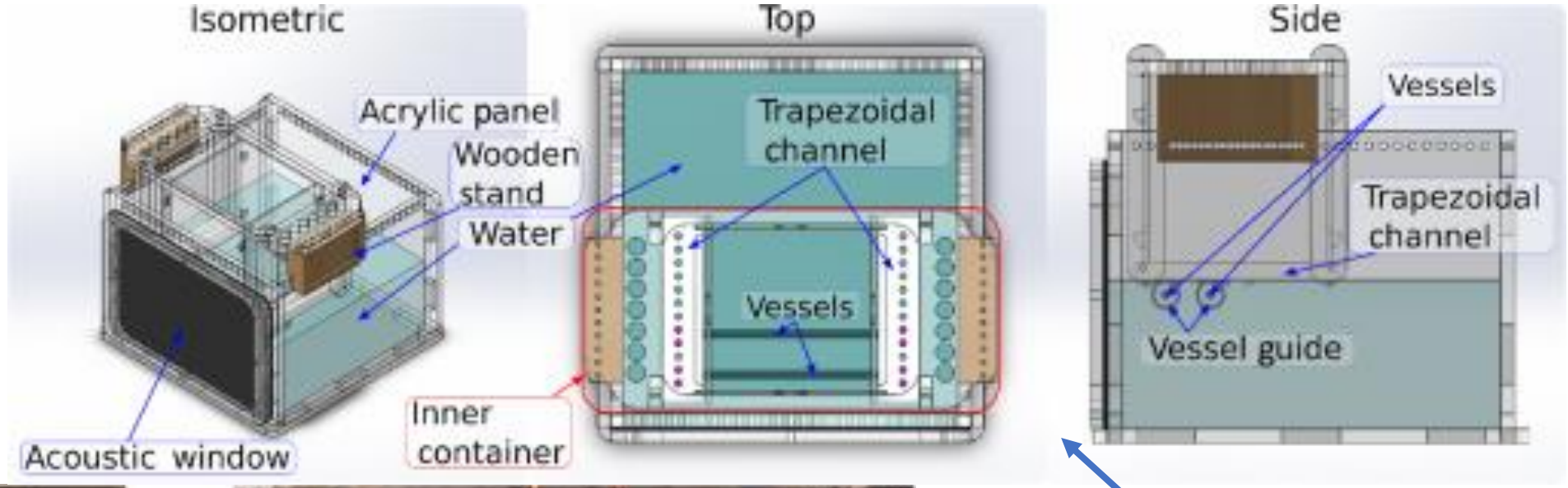
Technical Approach



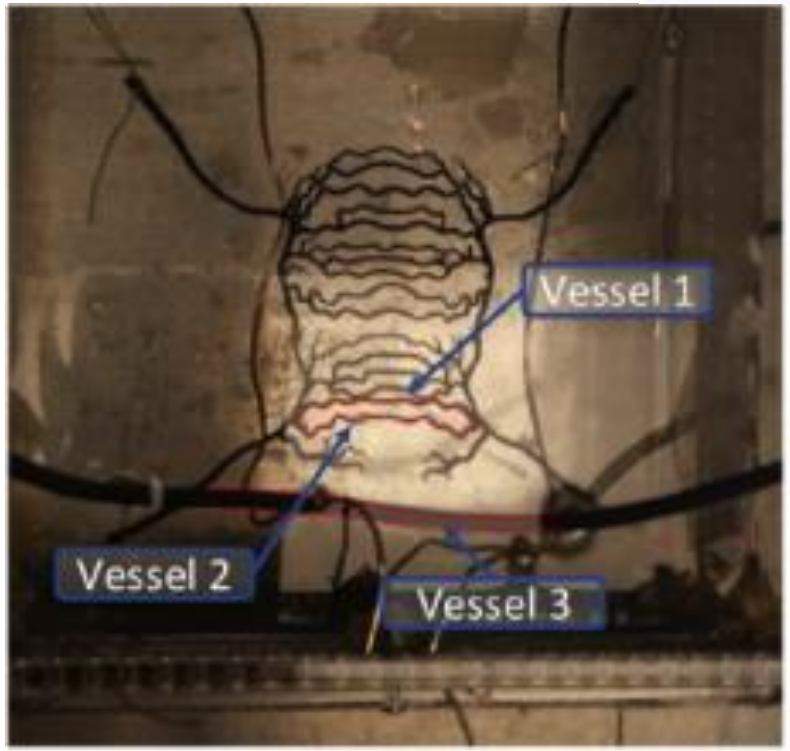
Technical Approach



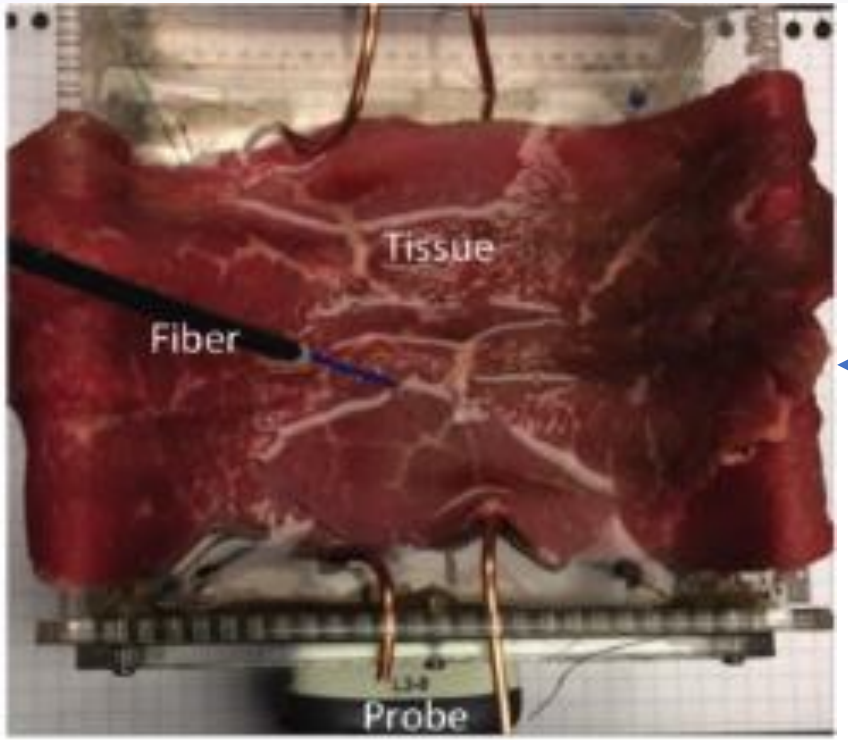
Experiments



Model of carotid arteries



(a)

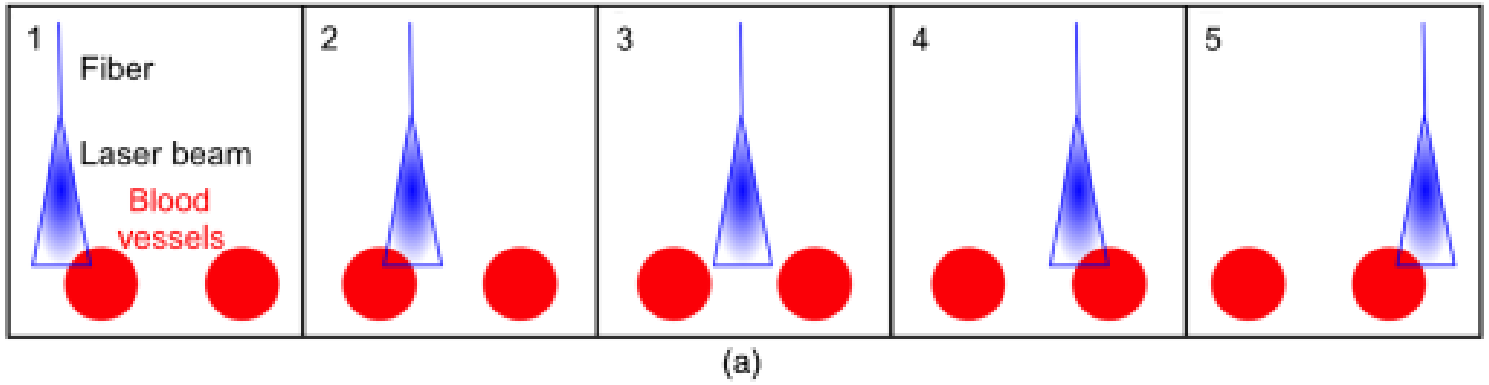


(b)

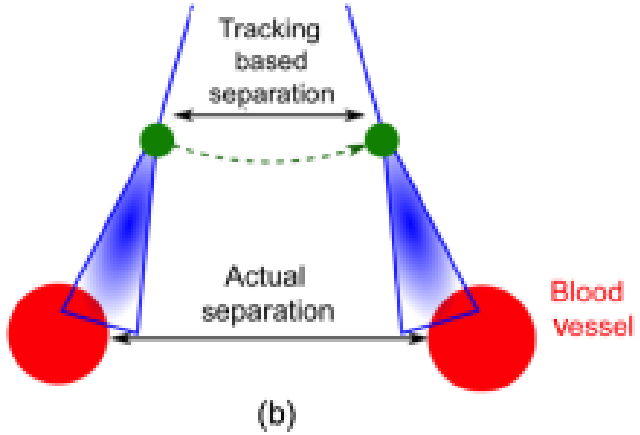
Model of uterus

Data Collection

manual



teleoperated

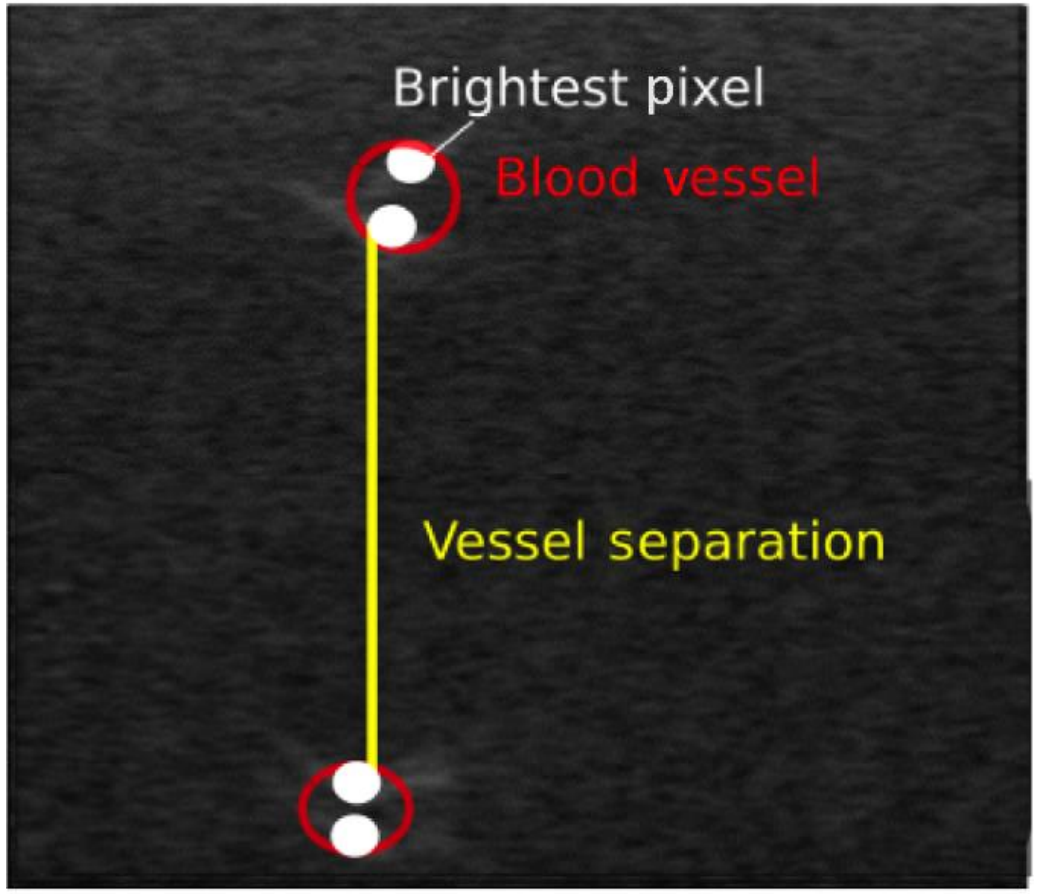


Analysis

$$\text{Distance} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

$$\text{RMS error} = \sqrt{\frac{\sum_{n=1}^{\text{NVS}} \left(\sum_{m=1}^{\text{NVT}_n} D^2 \right)}{\text{TNVT}}}$$

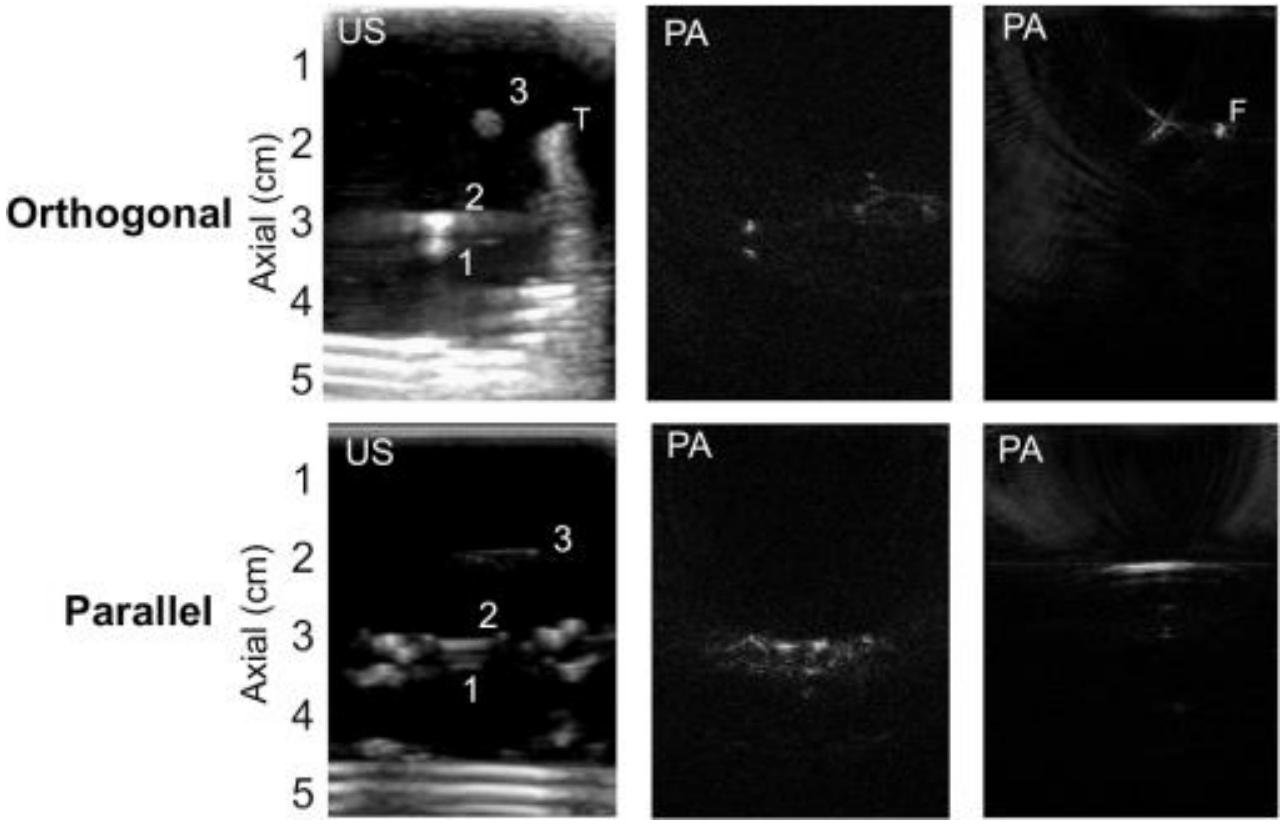
$$\text{MAE} = \frac{\sum_{n=1}^{\text{NVS}} \left(\sum_{m=1}^{\text{NVT}_n} |D| \right)}{\text{TNVT}}$$

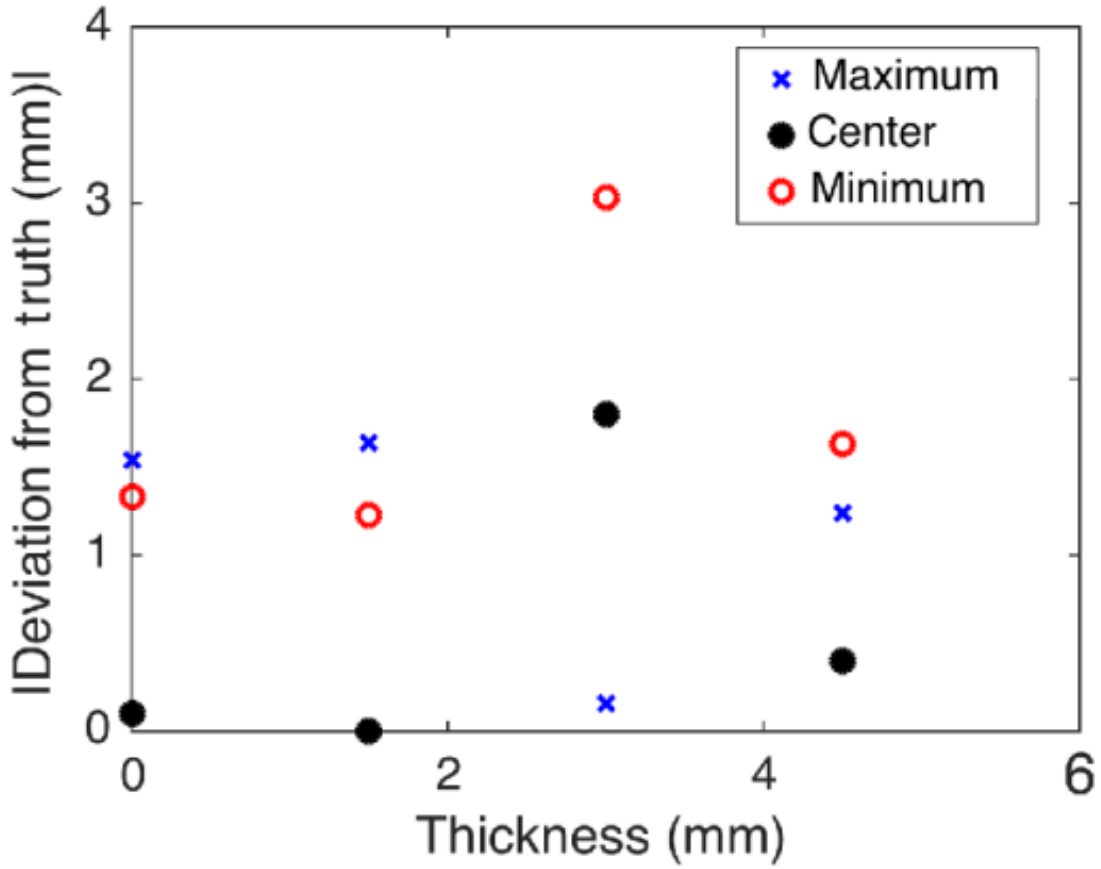


Key Results

1. Accuracy of robotic and hand-held image-based vessel separation measurements
2. Accuracy of manual and teleoperated control of optical fiber
3. Discrepancies between laser, beamforming method, and fiber control
4. Variations with different US probe orientations and tissue thicknesses

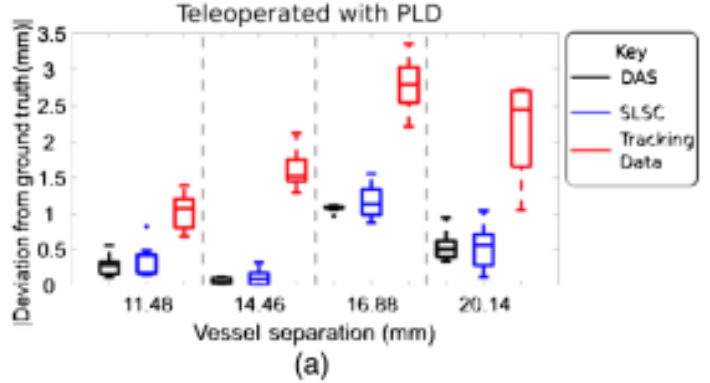
Key Results


Orthogonal
Parallel
US
PA
PA
Axial (cm)
1
2
3
4
5
T
F

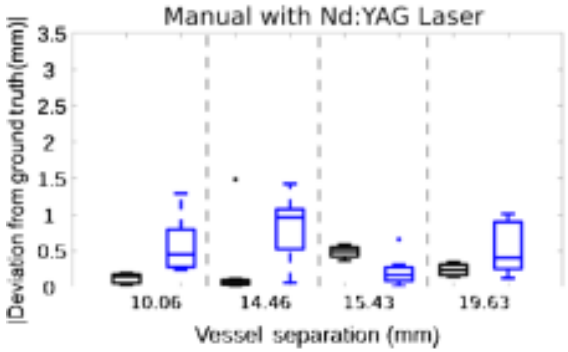

Maximum
Center
Minimum
IDeviation from truth (mm)I
Thickness (mm)
0
1
2
3
4
6

Key Results

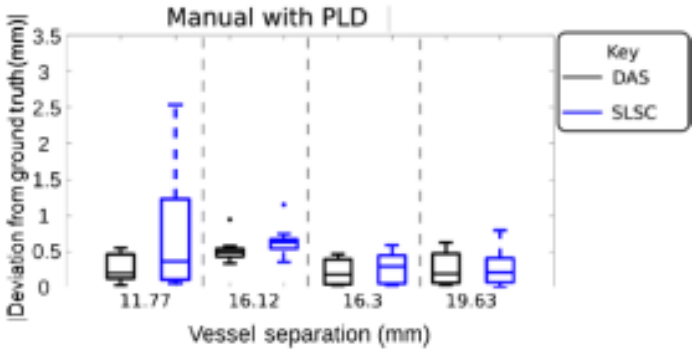
- Manual more accurate than teleoperated
- DAS more accurate than SLSC



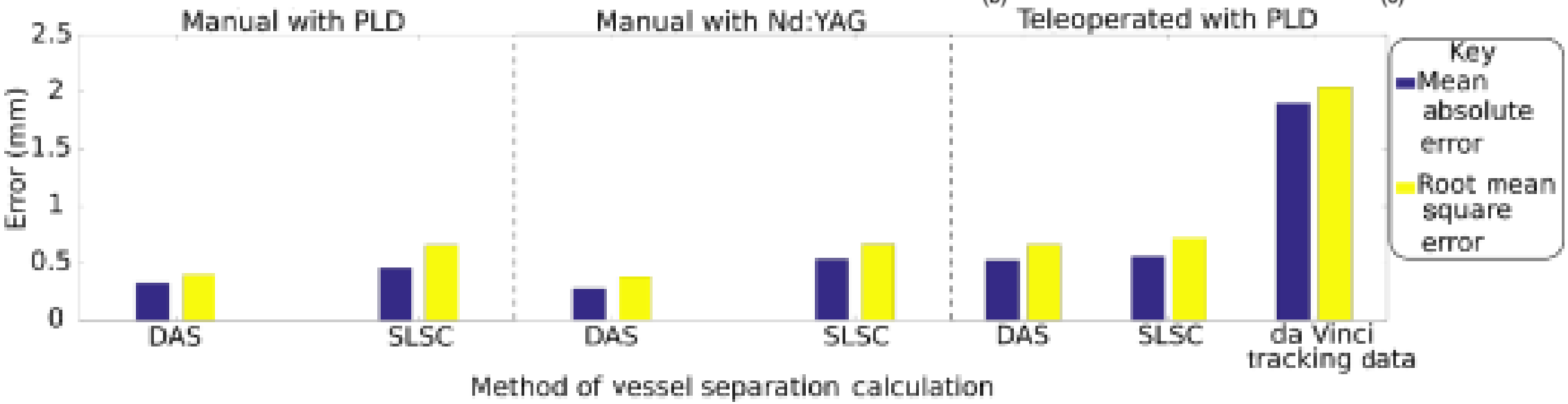
(a)



(b)

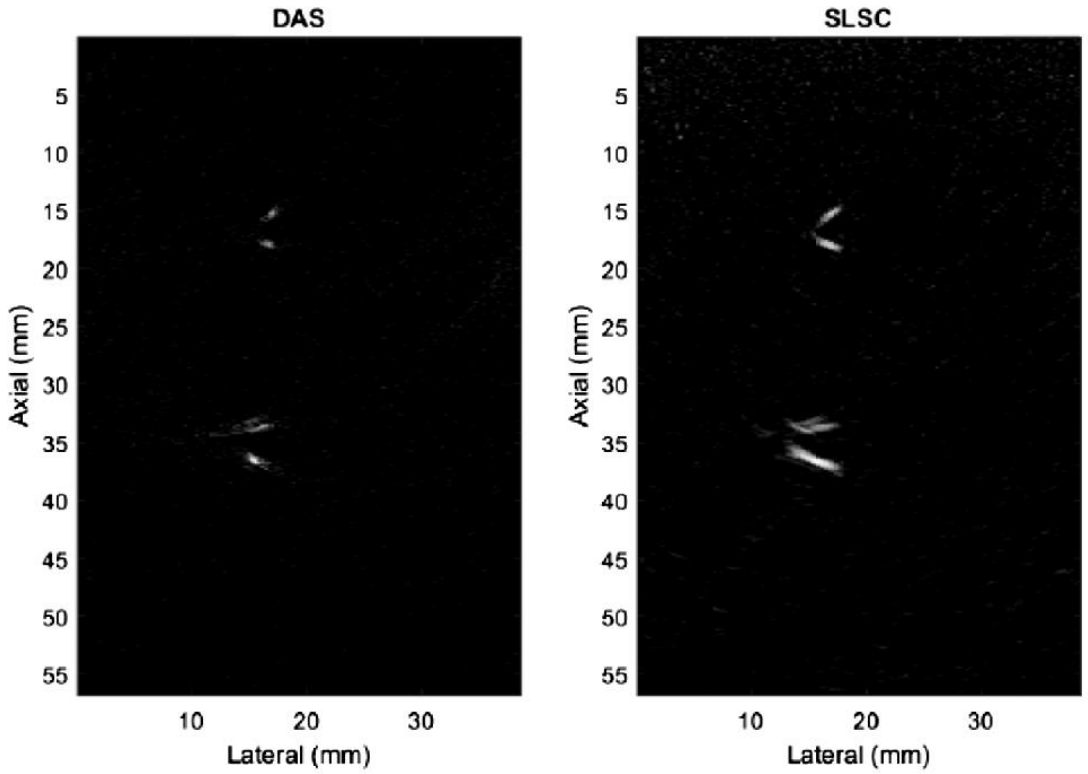


(c)



Main Conclusions

- no definitive trend in the magnitude of error as vessel separation increases
- distances computed from PA data are more precise than da Vinci tracking kinematics
- Submillimeter errors
- SLSC is better for visualization, DAS is better for analysis (based on signal amplitude)



Future Work

- Optimize system for teleoperation
  - Surgical path planning
- Optimize system for different structures (like nerves)
- Use real blood in experiments
- Investigate algorithms that aren’t amplitude based to improve SLSC imaging accuracy

Pros	Cons
Detailed Background	No bone
Detailed Technical Approach	No blood
Versatility of PA method	Simple measurement algorithm
Image Processing	Tool wasn’t visualized

Citation

- Gandhi, N., Allard, M., Kim, S., Kazanzides, P., & Bell, M. A. (2017). Photoacoustic-based approach to surgical guidance performed with and without a da Vinci robot. *Journal of Biomedical Optics, 22*(12), 1-12. doi:10.1117/1.jbo.22.12.121606