Advanced Computer-Integrated Surgery

Bioelectric Guidewire Literature

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March 2, 2017

Computer Aided Medical Procedures

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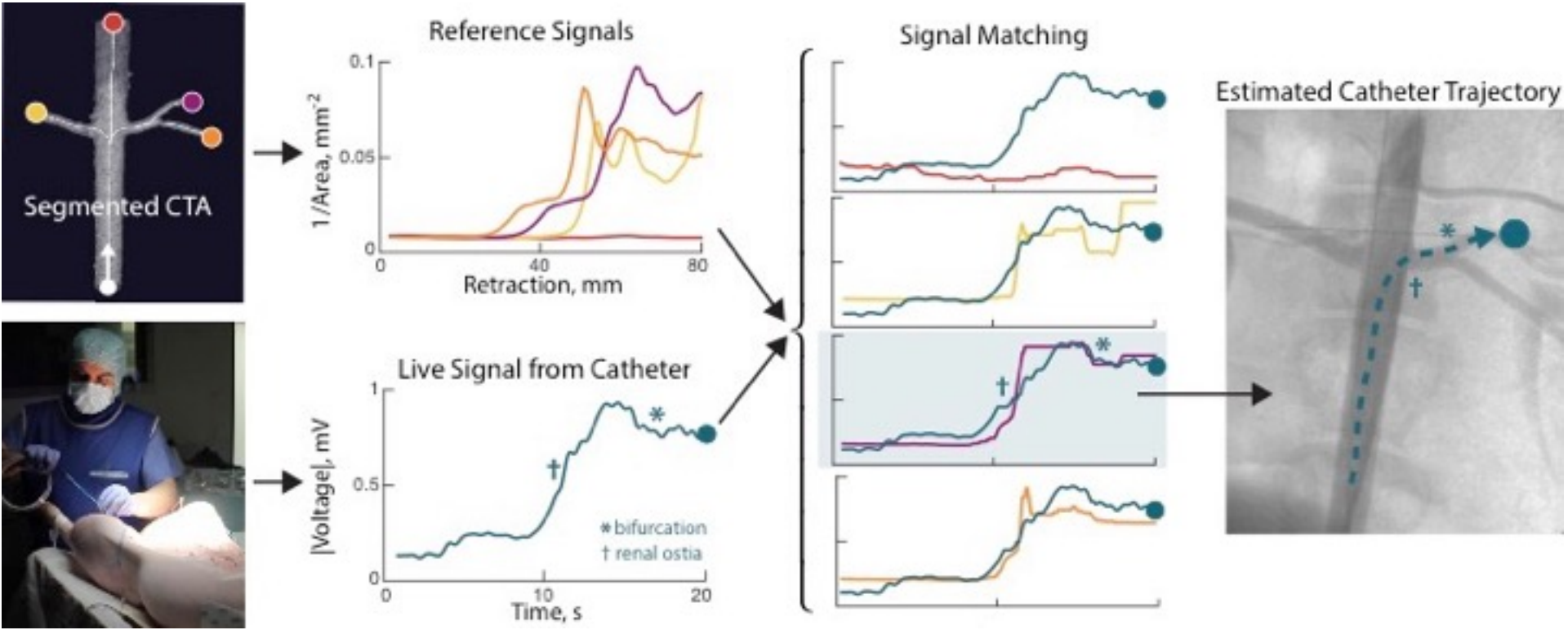
Bioelectric Navigation



Project Goal

The state of the art for intravascular navigation is to first navigate a guidewire under fluoroscopy to the area of interest then advance a catheter over the guidewire. The current BN prototype uses a commercially available, non-irrigated 6F catheter, too large to be used as a guidewire. The goal of this project is to create a guide wire based on the BN technology.

Model and *In Vitro* Test of Conductance Catheter

- Kassab GS, Lontis ER, Gergersen H. “Measurement of coronary lumen area using an impedance catheter: Finite element model and in vitro validation.” *Ann Biomed Eng*. 2004; 32(12):1642-1653.

- Goal: Develop accurate and reproducible method of vessel CSA measurement with a conductance catheter
- Key Results:
  - a four-electrode catheter measured the vessel cross-sectional area *ex vivo*
  - equations for vessel and catheter diameter relationship

Background

- CSA measurement important to size stents
- Conductance catheters widely used to determine ventricle volume
- Major issue is parallel conductance G_p -- current leakage through vessel wall and surrounding tissue
- Solve with 2 saline injections at known conductivities
  1. Position catheter
  2. Inject saline 1, measure G1
  3. Inject saline 2, measure G2
  4. Compute CSA

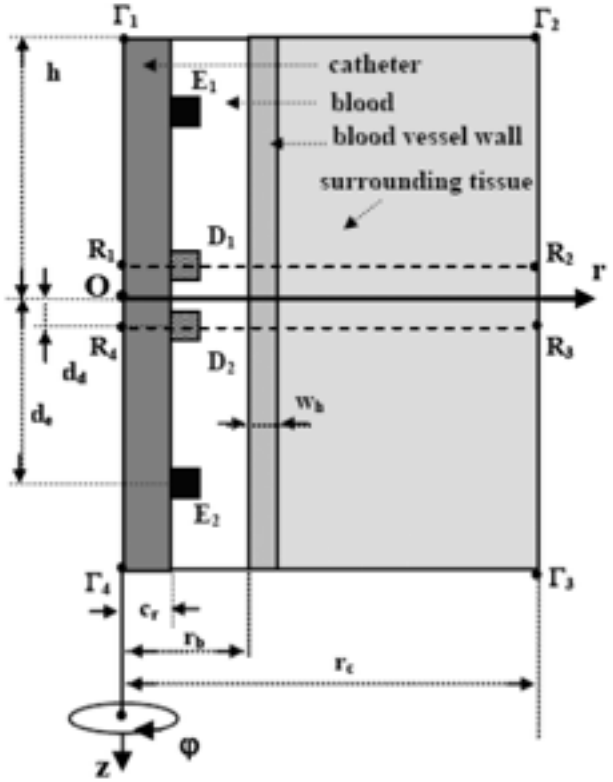
$$G(t) = \frac{CSA(t) \bullet \sigma}{L} + G_p(t)$$

G: conductance
σ: conductivity
L: electrode spacing

$$CSA(t) = L\frac{\Delta G}{\Delta \sigma}$$

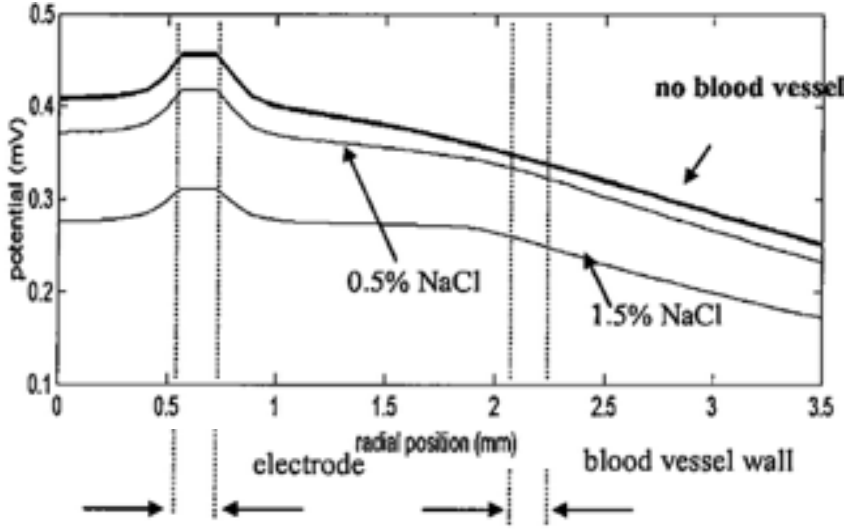
$$G_p(t) = \frac{[\sigma_2 \bullet G_1(t) - \sigma_1 \bullet G_2(t)]}{[\sigma_2 - \sigma_1]}$$

Experiment: FEA

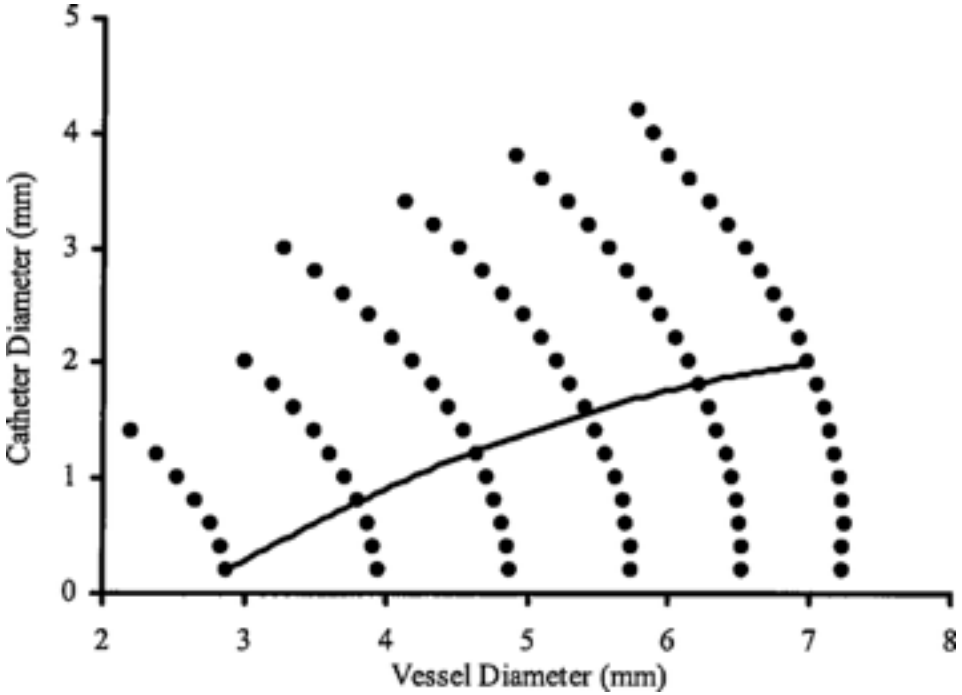


- Input current to E1 and E2
- Measure voltage distribution
- Vary size of vessel relative to catheter

Results: FEA



uniform potential within vessel

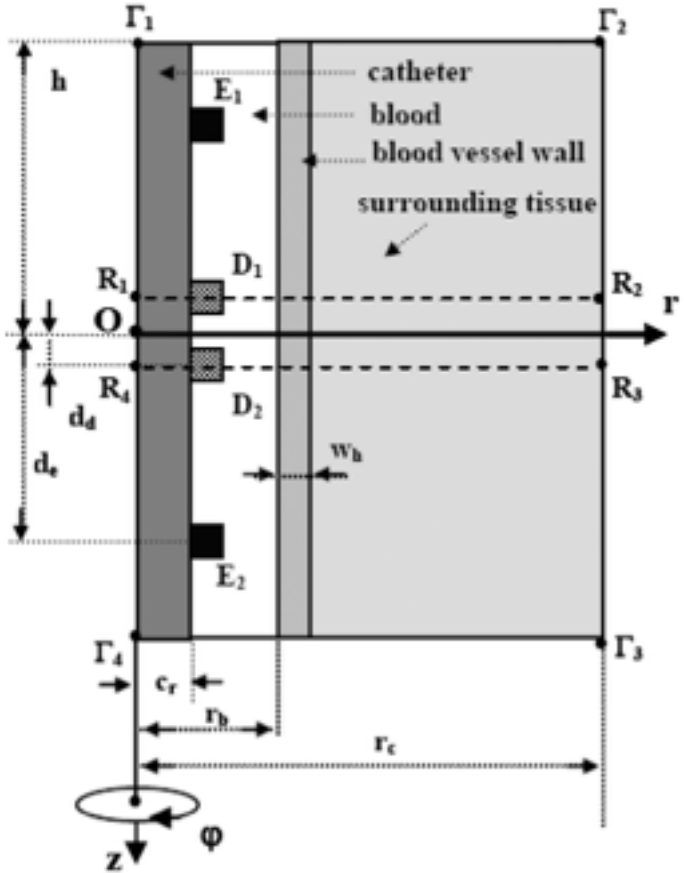


optimized relationship between vessel and catheter diameter:

$D_c = -0.064\ D_v^2 + 1.07\ D_v - 2.35$

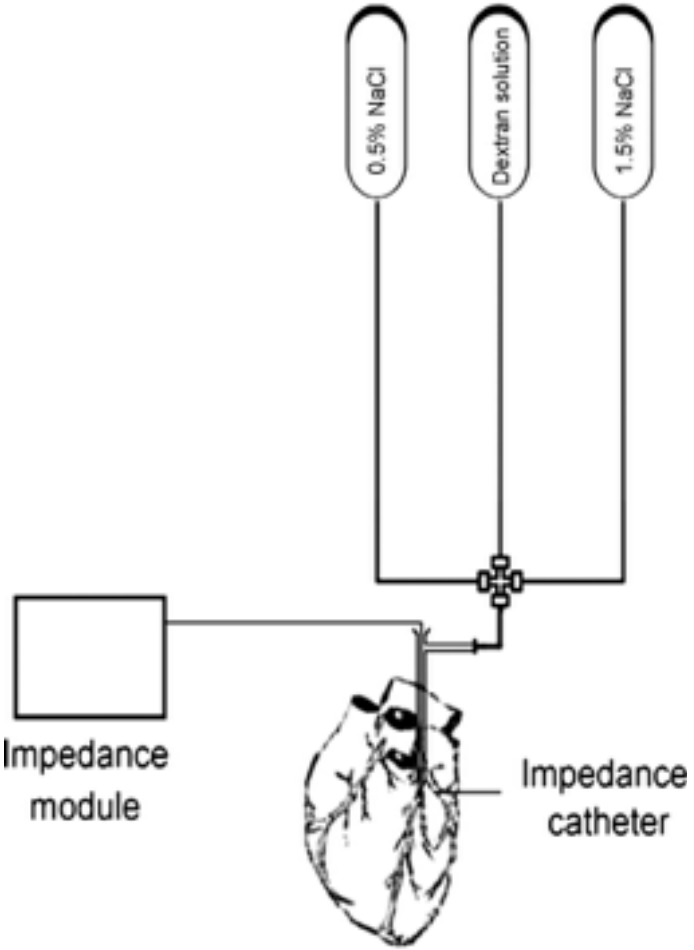
Results: FEA

- Detection electrodes equidistant from excitation electrodes
- Distance between current excitation electrodes >> distance between voltage detection electrodes
- Distance between detection and excitation electrodes approx equals vessel diameter



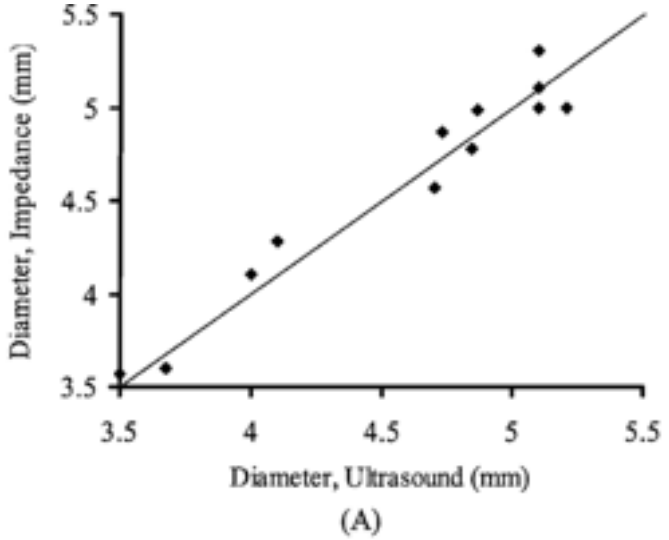
Experiment: Ex Vivo

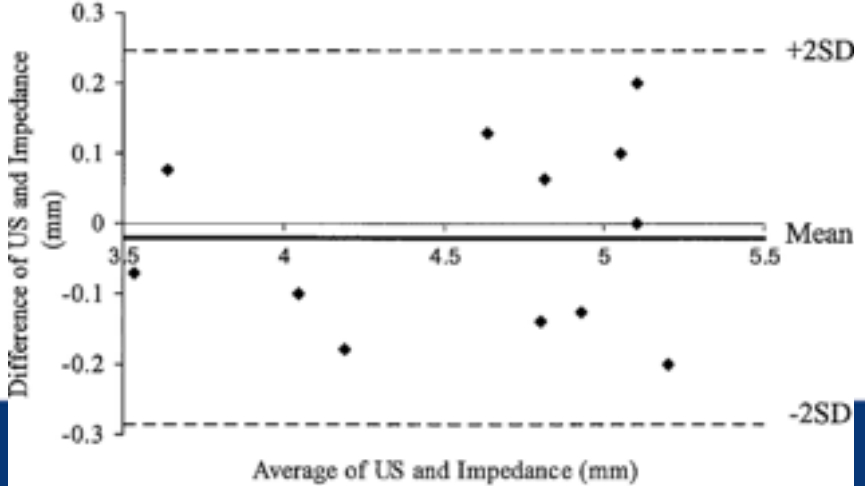
- 6 *ex vivo* pig coronary arteries
- 2 diameter measurements, 1 cm apart
- compared impedance-derived diameter to A-mode US



Results: Ex Vivo

- excellent agreement between US and conductance
- mean of the difference between US and conductance = 0.02 mm
- std dev = 0.13 mm





Limitations

- What catheter used for ex vivo experiments?
  - diameter?
  - material?
- Very little information about *ex vivo* study
- A-mode US diameter measurement accuracy unreported
- How did authors ensure that the A-mode measurement was taken at the same location as the conductance measurement?
- 2-injection method cumbersome, limits applicability

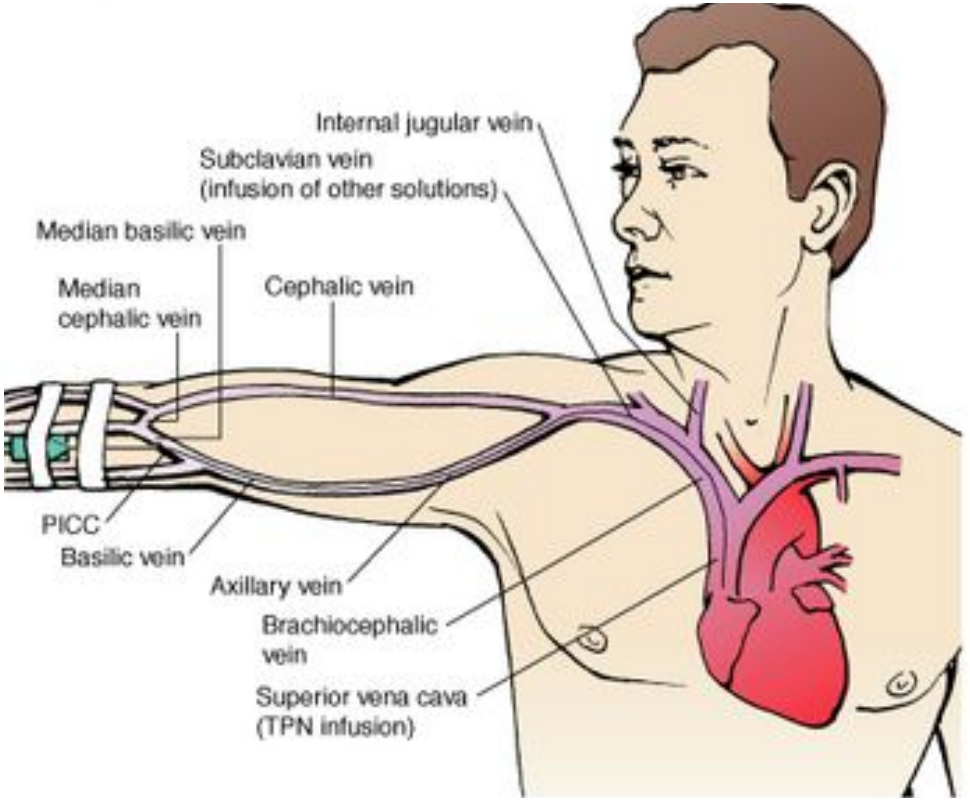
Bioimpedance Guidewire for Catheter Placement

- Svendsen MC, Birrer D, Jansen B, Teague SD, Combs B, Shears GJ, Kassab GS. “Accurate nonfluoroscopic guidance and tip location of peripherally inserted central catheters using a conductance guidewire system.” *J Vasc Surg Venous and Lym Dis*. 2013;1(2):202-208.

- Goal: Validate conductance guidewire’s placement of PICC i*n vivo*
- Key Results:
  - important anatomical landmarks can be accurately and repeatedly located solely with the CGW system
  - improve accuracy, decrease the wait time prior to therapy delivery, decrease cost, and minimize the need for X-ray

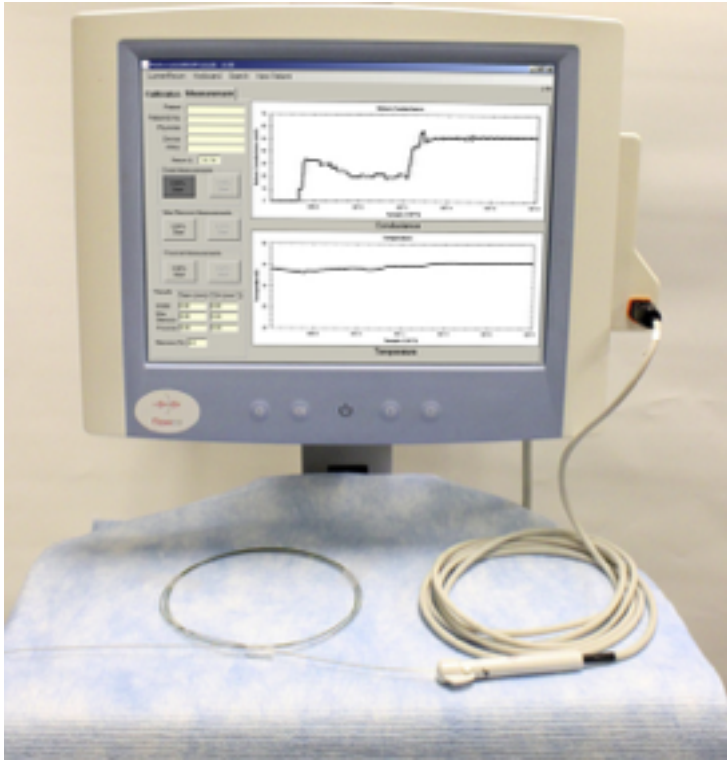
PICC Line

- Peripherally Inserted Central Catheter
- long-term central venous implant for drug administration, blood sampling, and hemodialysis
- Majority placed by nurse at bedside, confirmed with x-ray
- 30% misplaced into jugular vein

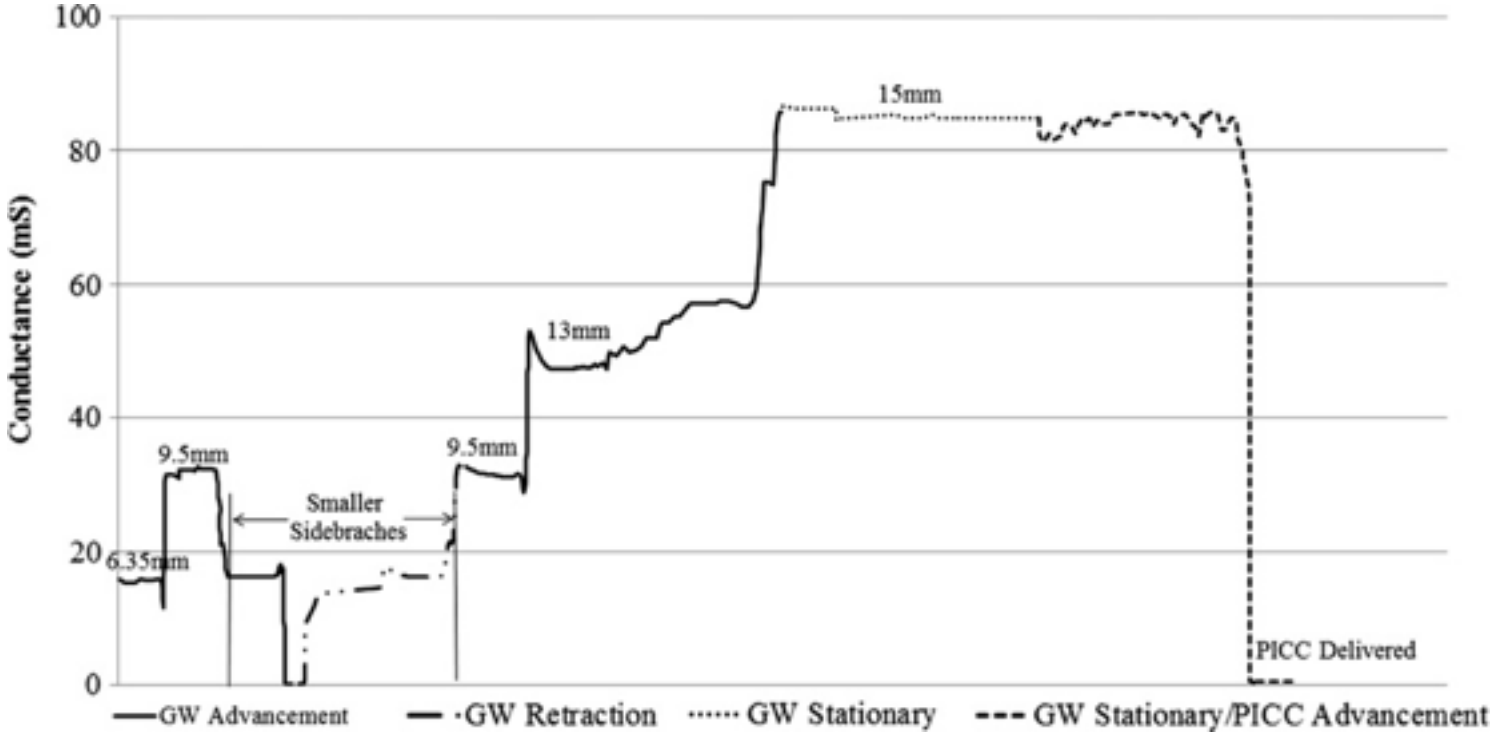


Experiment: Phantom

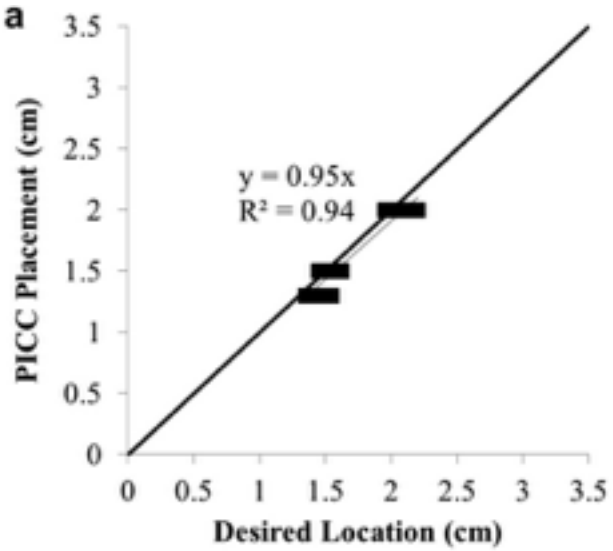
- 0.035” conductance guidewire
- Step increases in conductance while entering larger vessel (correct direction)
- Rigid segments 6.4-15 mm diameter, side branches 6.4 mm
- Aim for 3 targets using only conductance



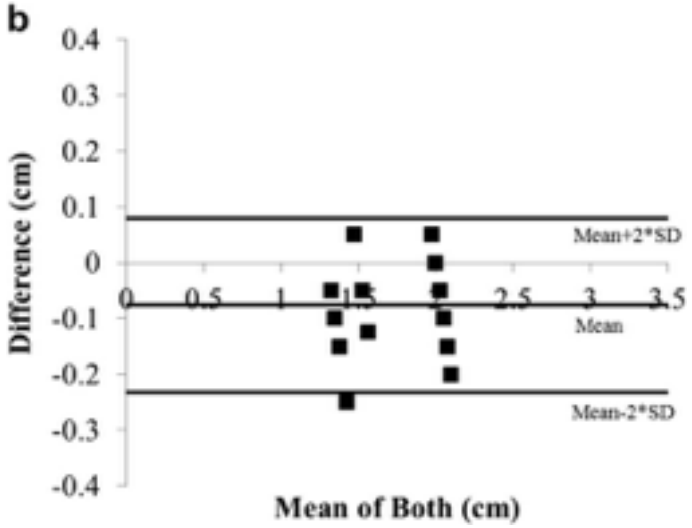
Results: Phantom



Results: Phantom



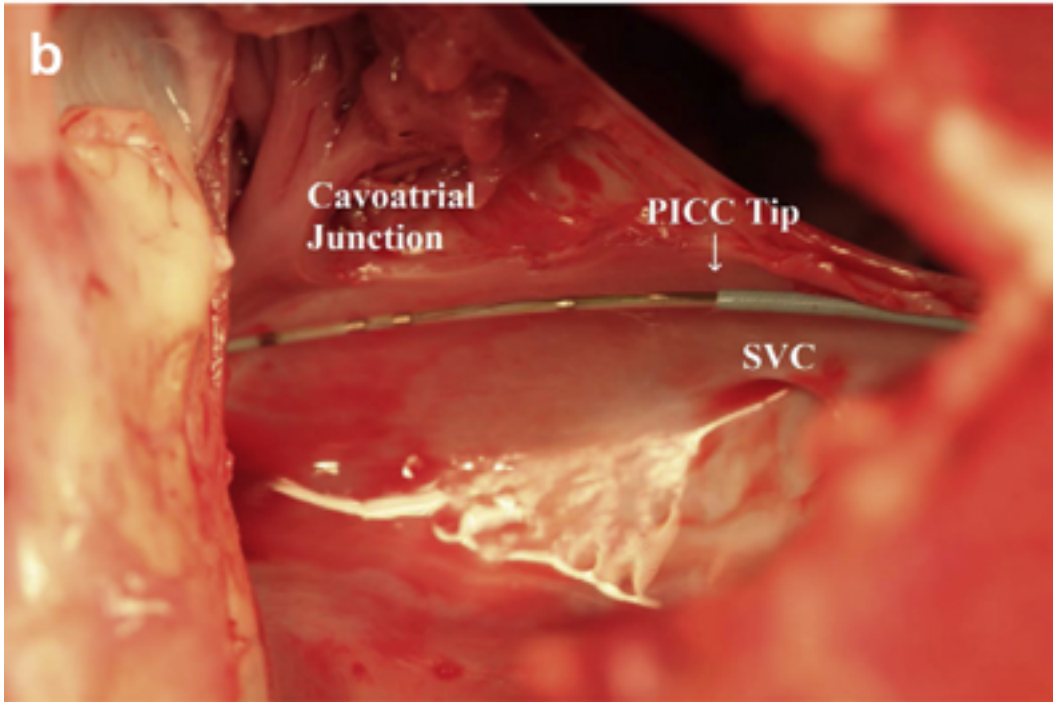
3 wires consistent



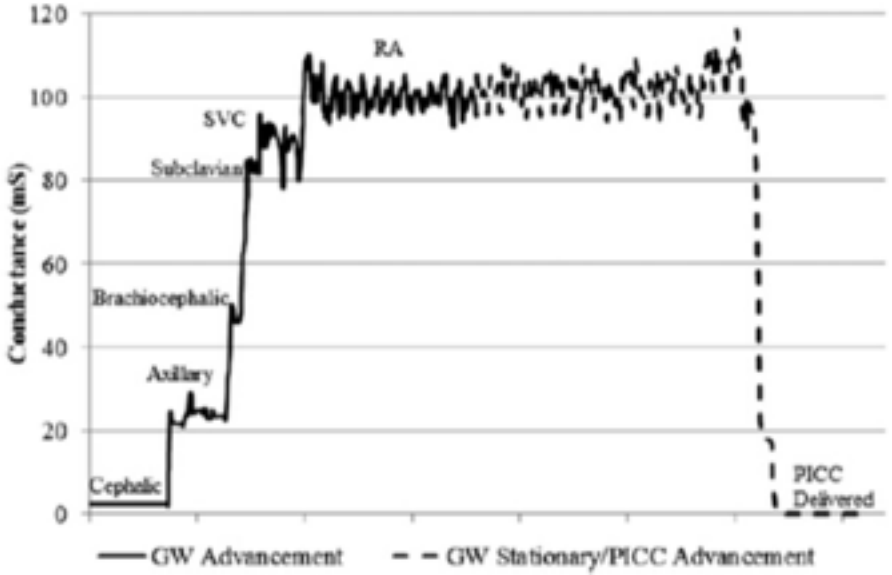
repeatable with several wires at a range of placement locations

Experiment: Animal

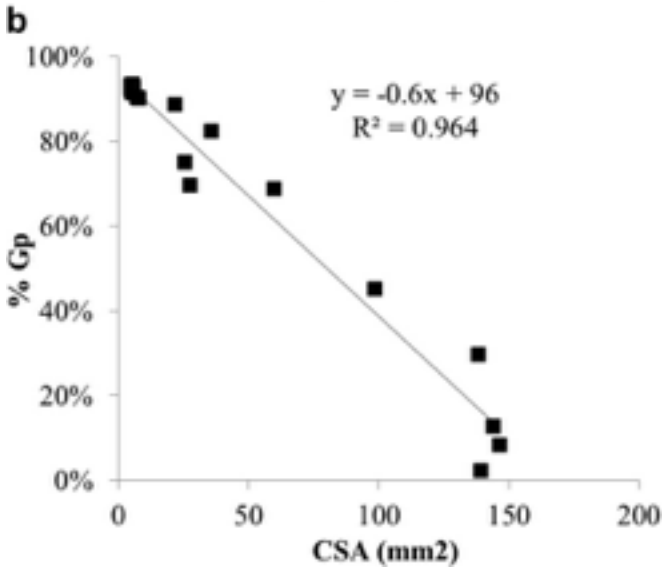
- 6 pigs
- Puncture cephalic vein
- Aim for 2 cm from cavoatrial junction
- Open chest and heart to check position



Results: Animal



matches expected profile



linear relationship between G_p and CSA

Limitations

- No information about guidewire construction, materials, electrode configuration
- No photo or CAD of phantom
- phantom material not given
- Guidewire could have moved between placement and confirmation during *in vivo* testing
- Low impact factor journal (0.833)
- Funded by a private company owned by last author
- Most PICCs are only compatible with 0.018” guidewires, many PICCs placed at beside with only a stylet, not a wire

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Thanks!

Computer Aided Medical Procedures

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Johns Hopkins Whiting School of Engineering