Advanced Computer-Integrated Surgery

Bioelectric Guidewire Literature

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March 2, 2017
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


- **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 $G_1$
  3. Inject saline 2, measure $G_2$
  4. Compute CSA

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

$G$: conductance
$\sigma$: conductivity
$L$: electrode spacing

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

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


- Goal: Validate conductance guidewire’s placement of PICC *in 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!