Utility of Ultrasound/Photoacoustic Imaging for Accurate Catheter Tracking and Temperature Monitoring During Endovenous Laser Ablation

Ayushi Jharia1 | Keerthana Polani2 | Yan Yan1 | Loay S. Kabbani2 | Nicole Kennedy2 | Mohammad Mehrmohammadi1

1Department of Biomedical Engineering Wayne State University, Detroit, MI
2Department of Vascular Surgery, Henry Ford Hospital, Detroit, Michigan

Introduction

• Laser ablation is a treatment method that uses light energy through a catheter inserted into a vein to induce localized heat to close the diseased blood vessels.
• Ultrasound (US) imaging has been used for catheter visualization and tracking. US has limitations for tracking the accurate location of the fiber tip inside small perforating veins such as angular dependency and comet tail artifacts.
• We propose a robust and accurate method for fiber tip tracking using combined US and Photoacoustic (PA) imaging to overcome the existing limitations.

Results and Discussions

Ultrasound and Photoacoustic for Catheter Localization

(a) Normalized Mean Intensity (Signal)

(b) Normalized Standard Deviation (Noise)

(c) SNR (Linear)

Methods & Experimental Set Up

Experimental Setup:

• PA experiments were performed with a pulsed laser (SpectraPhysics - Pro290) laser energy at 3.760 mJ/pulse.
• A linear array ATL L7-4 US transducer was utilized for acoustic signal acquisition.
• The optical fiber (multimode, 1000 µm core) was used to transfer the laser energy into the system and a custom-designed mechanical arm was used to tilt the fiber at 0, 5, 10, 15, 20, 30, 40, 50, and 60 degrees.
• Imaging medium was sterilized, heparinized sheep blood.

Data collection:

• A programmable digital US research platform (Verasonics, Vantage128) was used to record PA and US data.
• Data processing include selecting the ROI of each US and PA image, calculating the signal strength and the background noise.

Figure 1: Image of ultrasound-guided catheter insertion between anterior (ASM) and middle (MSM) scalen muscles. BP stands for the anatomical structure brachial plexus. (Adopted from NYSORA)

Figure 2: (Left) Diagram of experimental setup for fiber tracking. (Right) Photograph of the setup

Figure 3(a) Normalized mean, (b) Normalized standard deviation (noise), and (c) SNR comparison between US and PA imaging for localizing fiber optic with angular variation of 0 to 60 degrees.

Figure 4: Photoacoustic signal amplitude increment by increasing ambient temperature.

• Quantitative comparative analysis between US and PA methods indicate that the photoacoustic has superior abilities for laser ablation catheter localization and tracking.
• Photoacoustic images of fiber optic are shown to be independent from the angle of the fiber with respect to US transducer.

Conclusion

• Combined US and PA imaging can provide a suitable platform for visualizing tissue structure and the location of the ablation catheter.
• Robust and highly localized temperature monitoring by PA is a promising tool for more accurate management of therapy procedures.
• Our results show that PA provides more accurate platform for tracking laser ablation catheter
  • Angular independent
  • Speckle-free
  • No comet-tail artifacts
• Since laser ablation catheter includes fiber optic, the choice of PA for tracking the fiber does not require major change in existing ablation catheters.

References