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Photoacoustic imaging of intracardiac medical devices using internal illumination of carbon nanotube/PDMS composite coatings

Wenfeng Xia[a,*], Sacha Noimark[b], Efthymios Maneas[a], Ivan P. Parkin[b], Sebastien Ourselin[a], Malcolm Finlay[c], and Adrien E. Desjardins[a]

[a] Department of Medical Physics and Biomedical Engineering, University College London, United Kingdom.
[b] Department of Chemistry, University College Hospital London, United Kingdom.
[c] William Harvey Research Institute, Queen Mary University of London, United Kingdom.
* Email: wenfeng.xia@ucl.ac.uk

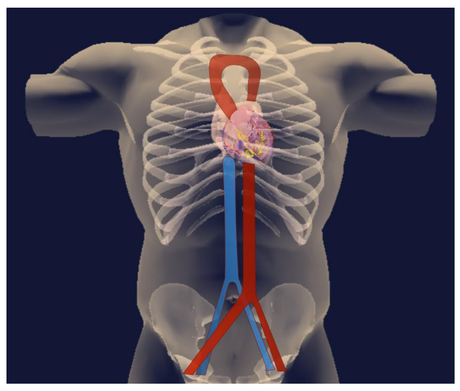
UCL Photoacoustic Imaging Group

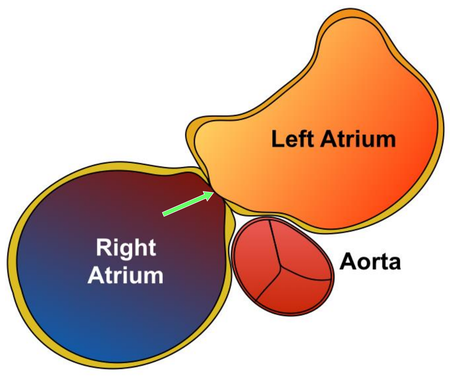
UCL Interventional Devices Lab

Abstract

Accurate localisation of medical devices is of crucial importance for a wide range of ultrasound-guided interventions. In this study, we investigated visualisation of medical devices by photoacoustic excitation of optically absorbing coatings. Photoacoustic excitation light was provided through optical fibres positioned within a needle. Using a swine heart model, photoacoustic and B-mode ultrasound images were received with a clinical ultrasound scanner in conjunction with a linear array imaging probe. In the photoacoustic images, prominent signals were obtained from the coatings. This study demonstrated that photoacoustic imaging could play a useful role with medical device imaging.

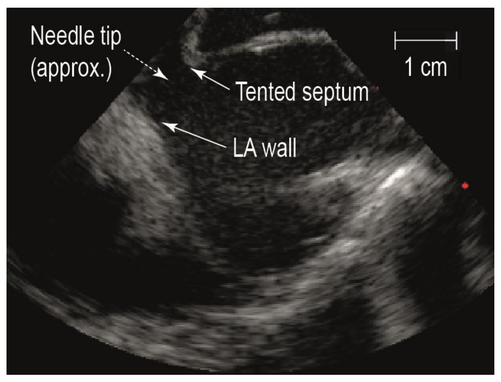
Transseptal puncture





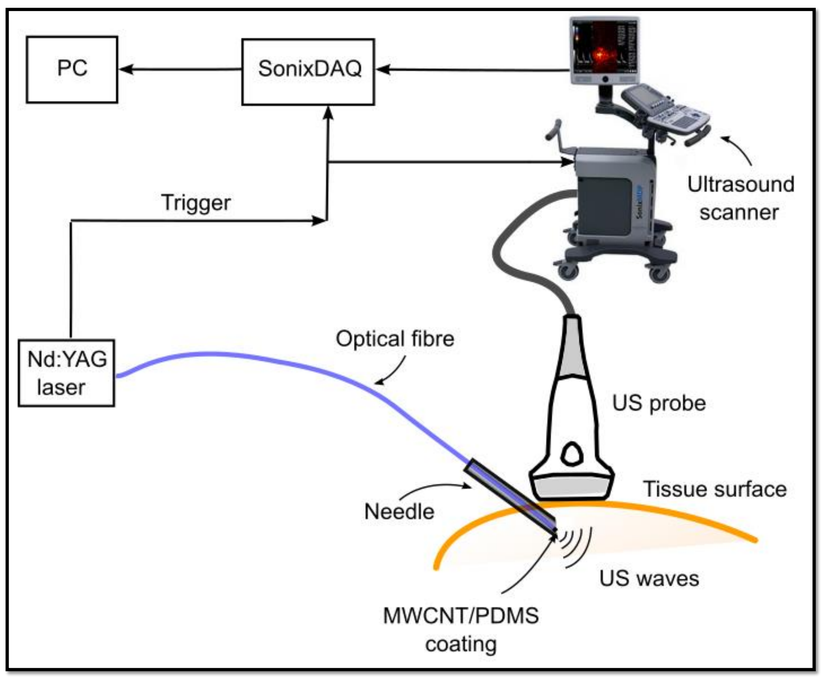
- Provides access to the left side of the heart
- A necessary step for therapeutic interventions:
  - ➢Catheter Ablation for Atrial Fibrillation (AF)
  - ➢Percutaneous Mitral Valve Interventions
  - ➢Ablation for Ventricular Tachycardia (VT)

US Image guidance



- Modalities: Intracardiac Echo (ICE); Transoesophageal Echo
- Often challenging to identify needle tip

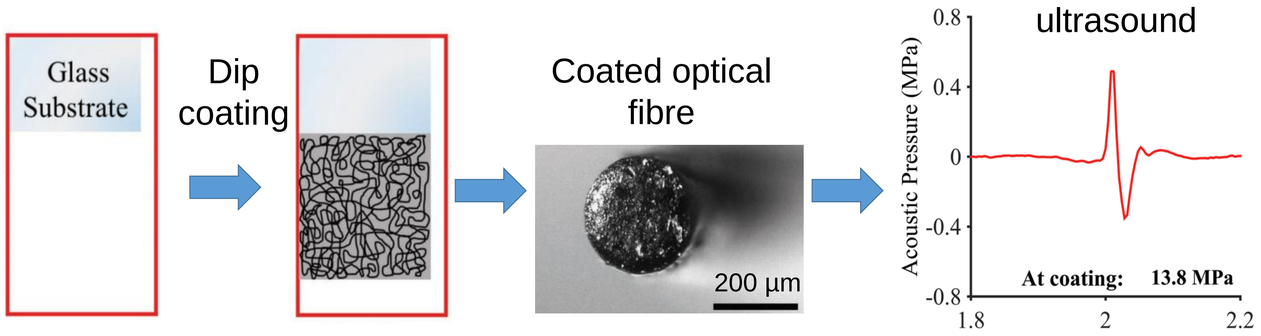
Photoacoustic tracking/imaging system



W. Xia et al, J. Biomed. Opt. 20(8), 086005 (2015)

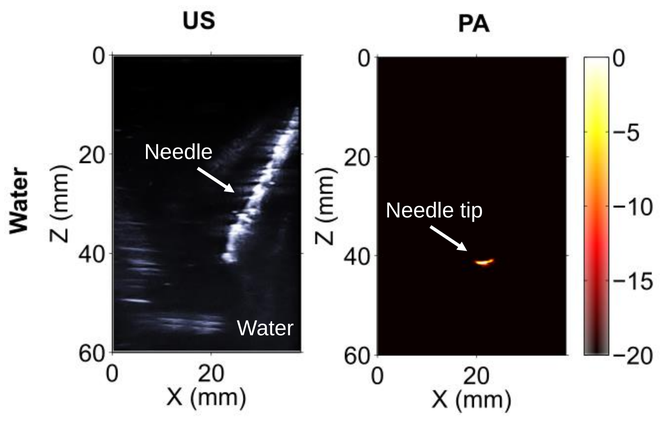
- Multiwall carbon nanotube (MWCNT) / PDMS coating on the tip of the light delivery fibre embedded in a needle
- Clinical US with 14–5 MHz imaging probe (Ultrasonix)
- Excitation light: Nd:YAG (30 µJ/pulse @ 1064 nm)
- Simultaneous pre-beamformed RF data acquisition (SonixDAQ)
- PA tracking at 20 Hz

MWCNT/PDMS coating

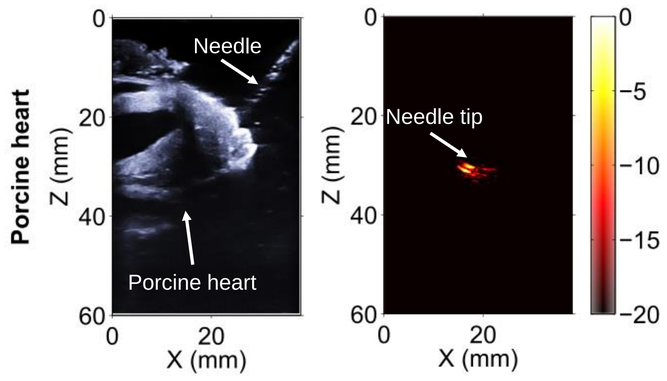


S. Noimark et al. Adv. Func. Mater., (2016) DOI: 10.1002/adfm.201601337

Photoacoustic needle tracking/imaging



- Needle insertion in water
- Simultaneous ultrasound and photoacoustic imaging



- Needle insertion into *ex vivo* porcine heart in a water tank
- Simultaneous ultrasound and photoacoustic imaging

Results

- With needle insertion in water, photoacoustic imaging successfully highlighted the needle tip
- With needle insertion in water, the needle tip position revealed in the photoacoustic image corresponded well to that in the ultrasound image
- With insertion in the porcine heart, photoacoustic imaging highlighted the needle tip that was not visible in the corresponding ultrasound image

Conclusions

- First photoacoustic needle tracking/imaging system based on laser-generated-ultrasound from MWCNT/PDMS coatings
- Photoacoustic imaging provided unambiguous indication of the needle tip position as the needle tip is the only object in the image
- Photoacoustic needle tracking/imaging could be useful in various minimally invasive procedures by tracking the surgical devices

Future plans

- *In vivo* validation of the photoacoustic tracking system in the context of transseptal puncture

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