SPIE. PHOTONICS WEST

Paper No: 10064-102

UCL

Interventional multispectral photoacoustic imaging of the epidural space

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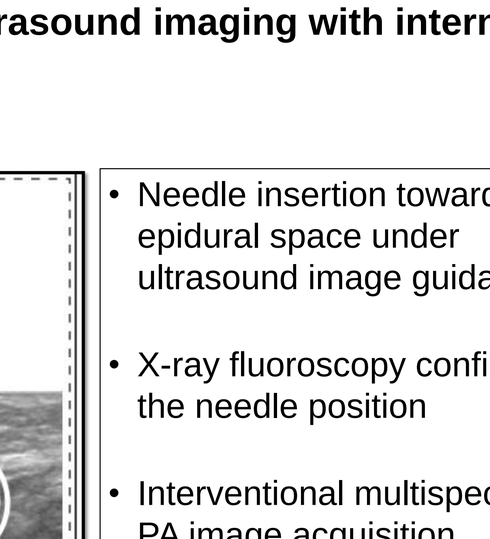
Abstract

Injections of anaesthetics into the epidural space are widely performed to relieve pain. Here, for the first time, we investigated the use of photoacoustic imaging to identify the epidural space using an interventional multispectral photoacoustic (IMPA) imaging system. Excitation light was delivered through an optical fibre positioned within a needle to illuminate the epidural space in a swine model. Spectral unmixing of the images revealed prominent distributions of lipids and haemoglobin in the epidural space at a depth of 35 mm. We conclude that IMPA could be a useful imaging modality to guide placement of needles into the epidural space.

Epidural anesthesia

- Epidural anesthesia performed to perform block pain locally
- A local anesthetic is injected through a spinal needle into the epidural space



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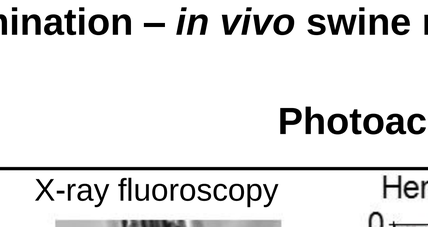
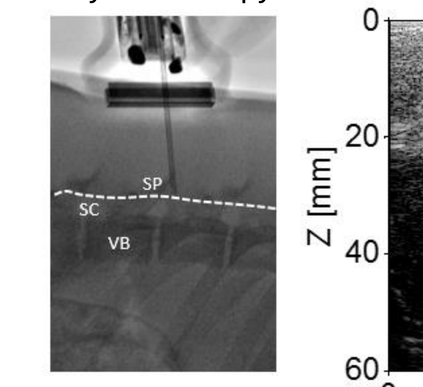
Ultrasound guidance [1]





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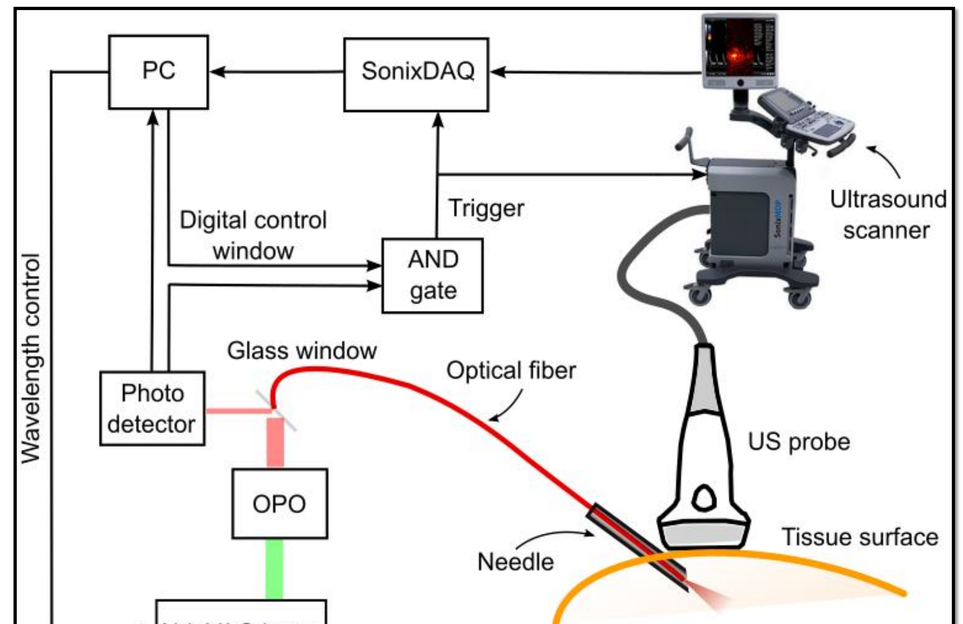
I. **Standard method** (without ultrasound): "loss-of-resistance" technique.

II. **Ultrasound image guidance**

- Good at visualising anatomical structures
- Suffers from anatomical constrains such as bones and obesity
- Poor soft tissue contrast

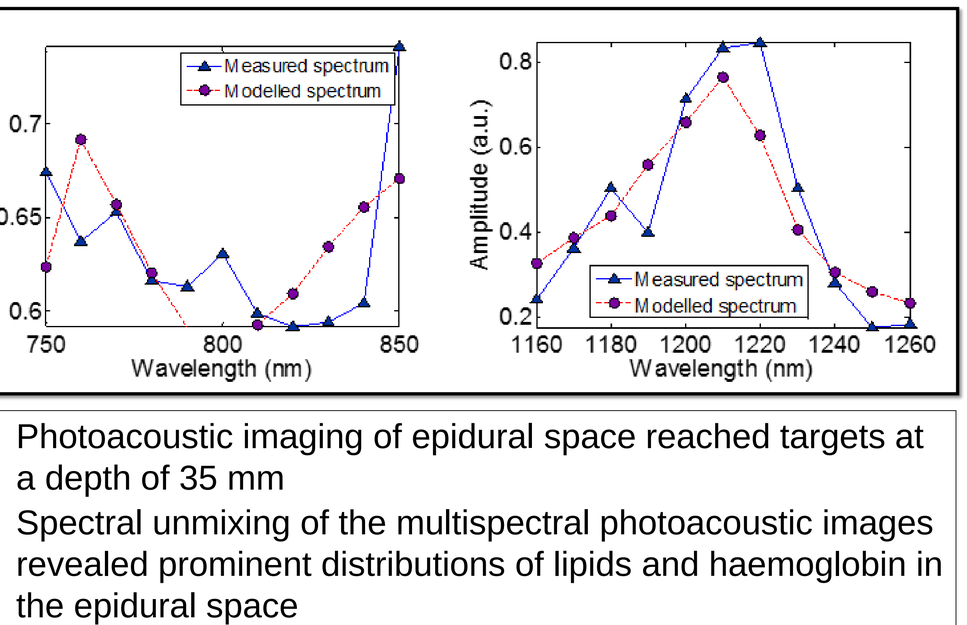
Photoacoustic/ultrasound imaging with internal illumination – *in vivo* swine model

Concept



- Needle insertion towards the epidural space under ultrasound image guidance
- X-ray fluoroscopy confirmed the needle position
- Interventional multispectral PA image acquisition
- Spectral unmixing [7,8]

Photoacoustic imaging



Implementation

- Clinical US system with 14 – 5 MHz imaging probe (Ultrasonix)
- Excitation light: OPO (Spectra Physics/GWU)
- Signal: 750-900 nm; Idler: 1150-1300 nm
- Simultaneous pre-beamformed RF data acquisition (SonixDAQ)
- PA imaging at 10 Hz

Photoacoustic spectra

- Photoacoustic imaging of epidural space reached targets at a depth of 35 mm
- Spectral unmixing of the multispectral photoacoustic images revealed prominent distributions of lipids and haemoglobin in the epidural space
- A needle-to-target distance up to 1 cm was achieved

Conclusions

- First study on photoacoustic imaging of epidural space
- Multispectral photoacoustic imaging is capable of revealing lipid and haemoglobin distributions in the epidural space in front of the spinal needle
- Interventional photoacoustic imaging could be a useful imaging modality to guide placement of needles into the epidural space, by providing information complementary to conventional B-mode ultrasound imaging, X-ray fluoroscopy, and loss-of-resistance

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Supported by wellcome trust
GIFT-Surg
Wellcome Trust/EPSRC
WT101957

EPSRC Engineering and Physical Sciences Research Council
NS/A000027/1,
EP/J010952/1

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ERC-2012-StG: 310970 MOPHIM