Raman Spectroscopy Identifies Each Tissue in the Path of an Epidural Needle

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Background: Neuraxial anesthesia and epidural steroid injection techniques require precise anatomical targeting to ensure successful and safe analgesia. Previous studies suggest that only some of the tissues encountered during these procedures can be identified by spectroscopic methods, and no prior study has investigated the use of Raman, diffuse reflectance, and fluorescence spectroscopies. We hypothesized that real-time needle-tip spectroscopy may aid epidural needle placement and tested the ability of spectroscopy to distinguish each of the tissues in the path of neuraxial needles.

Methods: For comparison of detection methods, the spectra of individual *ex vivo* paravertebral and neuraxial porcine tissues were collected using Raman spectroscopy (RS), diffuse reflectance spectroscopy (DRS), and fluorescence spectroscopy (FS). Real-time spectral guidance was tested using a 2.7-mm outer diameter fiber optic probe-in-needle device. RS spectra were collected during the needle's passage through intact paravertebral and neuraxial porcine tissue and analyzed afterward. The RS tissue signatures were verified as mapping to individual tissue layers using histochemical staining and widefield microscopy.

Results: Raman spectroscopy revealed a unique spectrum for all *ex vivo* paravertebral and neuraxial tissue layers (Figure 1); DRS and FS spectra were not distinct for all tissues. Moreover, real-time Raman spectra gathered during needle insertion also permitted identification of each paravertebral and neuraxial porcine tissues.

Conclusions: This study demonstrates Raman spectroscopy can distinguish all tissues encountered during epidural needle procedures. This technology may prove useful during needle placement by increasing the confidence of its anatomical localization.

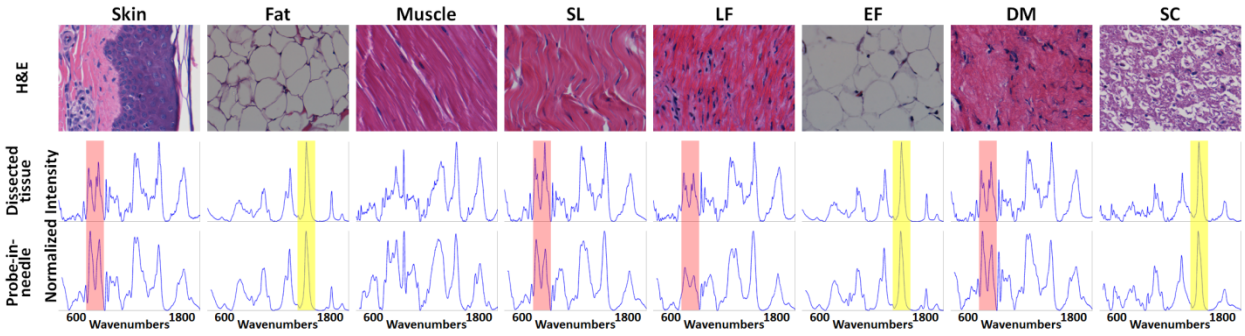

Figure 1. Each tissue from the skin to the spinal cord has a unique Raman spectrum. Hematoxyline and eosin stained tissue scanned by RS (top row). Magnification = 40X.

Corresponding Raman spectra from dissected tissues (bottom row). Highlighted band in red color (939 cm^{-1}) indicates collagen-specific Raman signal, yellow color (1450 cm^{-1}) indicates lipid-specific Raman signal.