LAPAROSCOPIC SENTINEL NODE BIOPSY USING DIFFERENTIAL MAGNETOMETRY

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BACKGROUND

When a patient is diagnosed with cancer, it is important to know if the tumor has spread through the body. Sentinel node biopsies are used to determine if the tumor has spread via the lymphatic system [1]. Consequently, patient care will be personalized.

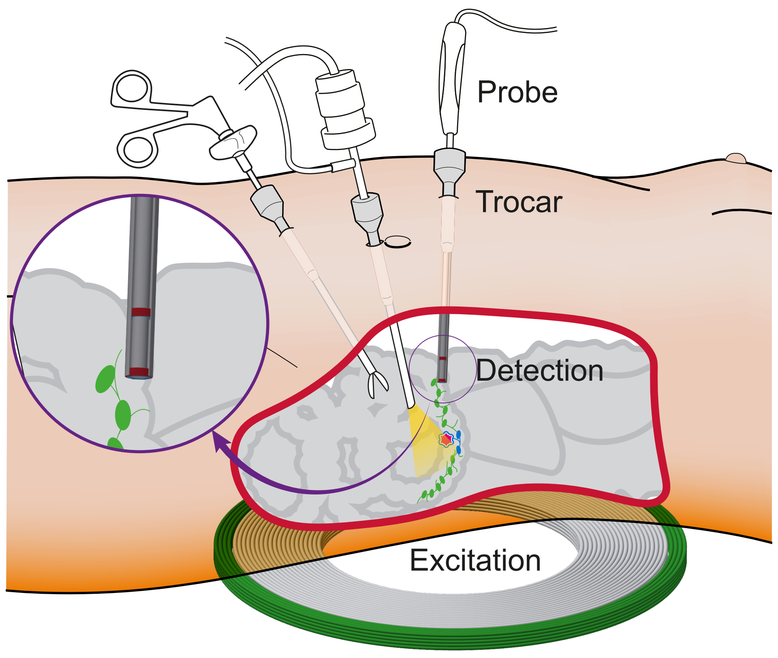

FIGURE 1 A novel laparoscopic probe for sentinel node biopsies. SPIONs are used as a tracer agent. Excitation and detection coils are mechanically separated to increase depth sensitivity.

PURPOSE

Our purpose is to locate superparamagnetic iron oxide nanoparticles (SPIONs) *in vivo* during laparoscopic surgery (**Figure 1**), using Differential Magnetometry (DiffMag) [2]. To achieve this, SPIONs are excited at a frequency between 1 and 10 kHz. To enable laparoscopic (minimally invasive) surgery, the diameter of the inserted instrument needs to be 12 mm or less. To limit loss in depth sensitivity, the excitation and detection coils are mechanically seperated [3].

DIFFERENTIAL MAGNETOMETRY

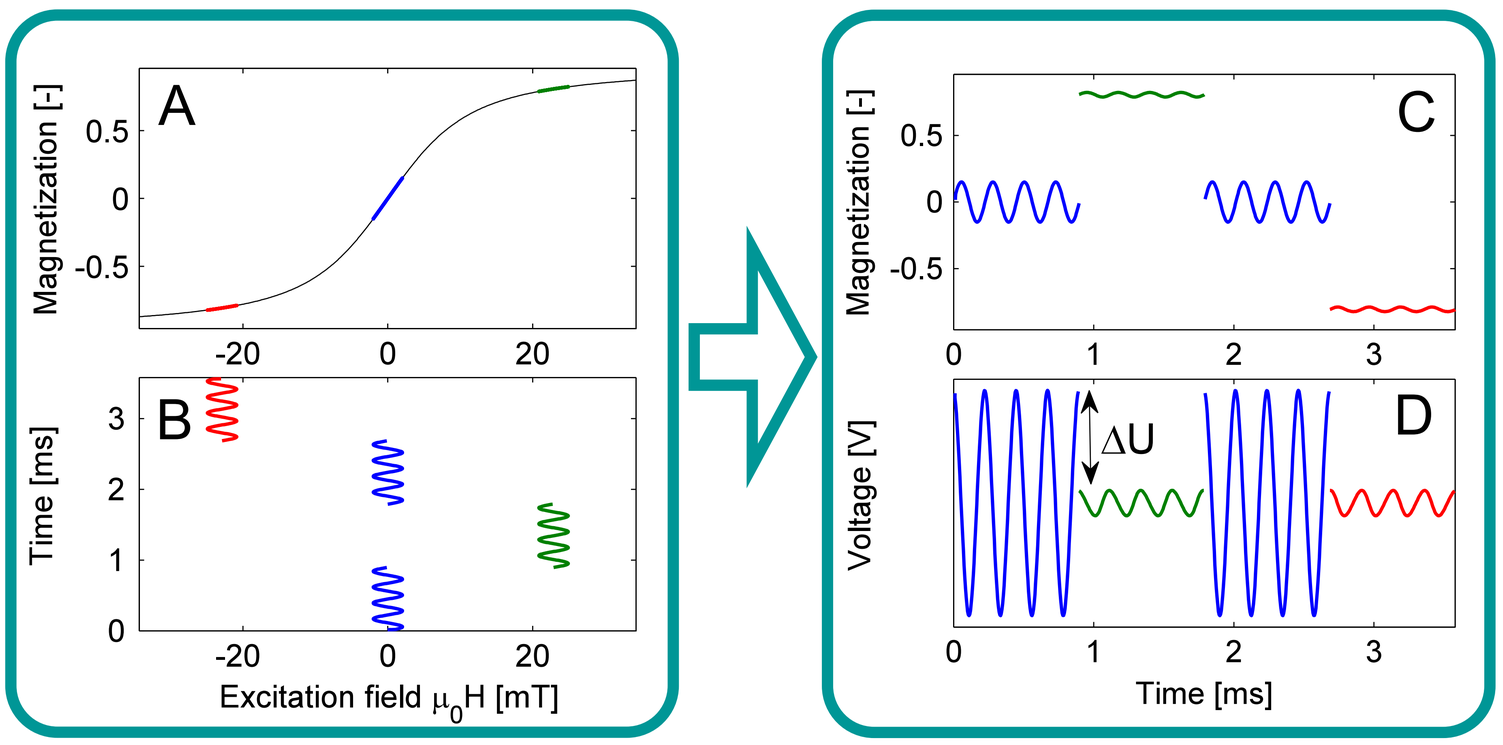

FIGURE 2 The concept of Differential Magnetometry simulated for monodisperse iron oxide particles with 16 nm diameter (A). The alternating excitation field is applied with intervals with a positive and negative offset field amplitude (B). The colors in each panel correspond with the offset field amplitude. Nonlinear magnetic susceptibility results in a reduced alternating magnetization response during periods with offset field (C), which is proportional to the amplitude of inductively measured signal (D). The DiffMag voltage ΔU specifically represents the contribution from magnetic nanoparticles in a sample. The amplitude of the AC field is approximately 1 mT, which is 1000x smaller compared to Magnetic Resonance Imaging and 10x smaller compared to Magnetic Particle Spectroscopy. [4]

ACTIVE COMPENSATION

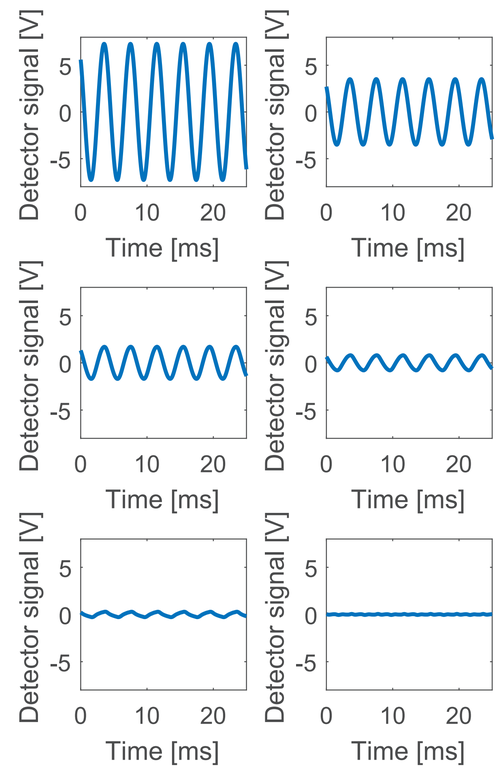

FIGURE 3 The main challenge after separating excitation and detection coils is a varying mutual inductance between these coils. As a result, the detector signal is hindered by the excitation field. To avoid this, we use active compensation with additional coils. This iterative process is demonstrated in this figure.

RESULTS

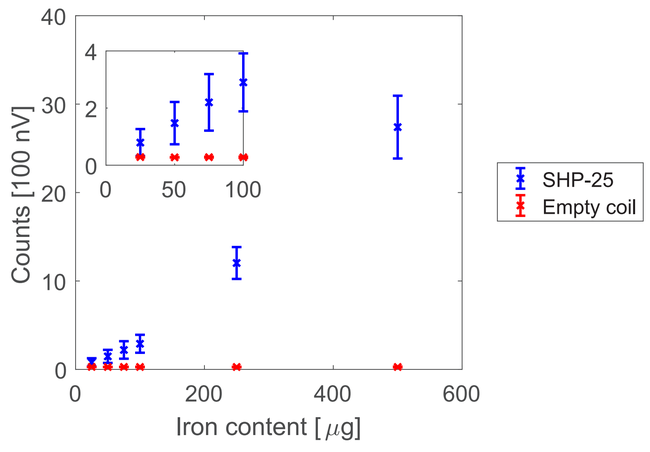

FIGURE 4 DiffMag measurements using our separate coil setup on SHP-25 particles containing various amounts of iron. 20 DiffMag cycles were acquired with an AC amplitude of 0.5 mT, an AC frequency of 2525 Hz, and a DC offset of 49.8 mT. The distance between the excitation and detection coils in this static setup was 5 cm and the sample was placed directly in front of the detection coils.

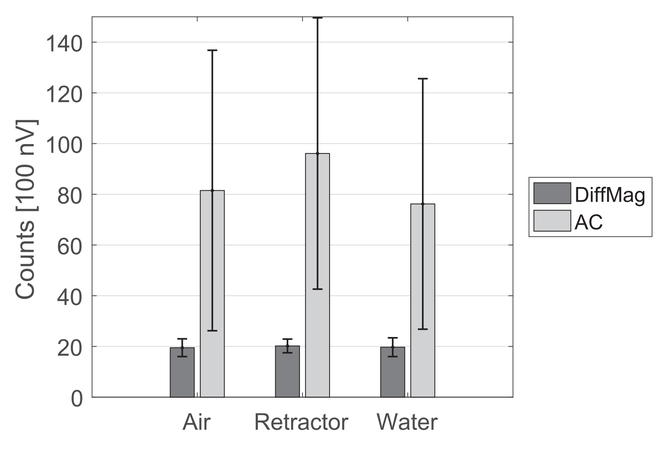

FIGURE 5 DiffMag (left) and AC magnetometry (right) measurements using our separate coil setup on SHP-25 particles containing 500 µg iron in air and in proximity to a surgical steel retractor and water. 20 DiffMag cycles were acquired with an AC amplitude of 0.5 mT, an AC frequency of 2525 Hz, and a DC offset of 49.8 mT. The distance between the excitation and detection coils in this static setup was 5 cm and the sample was placed directly in front of the detection coils.

DISCUSSION

Our next challenge is to enable movement of the detection coils. To achieve this, we will use faster electronics, enabling real time compensation of the excitation signal during DiffMag measurements.

CONCLUSION

Separation of excitation and detection coils is unique and not possible without DiffMag. These first results are promising for sentinel node biopsies, since it is possible to compensate for the excitation field and to measure small quantities of particles.

Acknowledgements
Financial support by the Netherlands Organization for Scientific Research (NWO), under the research program Magnetic Sensing for Laparoscopy (MagLap) with project number 14322, is gratefully acknowledged.

References
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[4] M. Visscher et al. J. Magn. Magn. Mater., vol. 365, pp. 31-39, Sep. 2014.

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