Differential Magnetometry to detect sentinel lymph nodes in laparoscopic procedures

Melissa van de Loosdrecht, Sebastiaan Waanders, Rogier Wildeboer, Erik Krooshoop, Bennie ten Haken
Magnetic Detection & Imaging group, Faculty of Science and Technology, University of Twente, Enschede, The Netherlands

Introduction

- Sentinel lymph node (SLN) procedure to diagnose metastasis
- Clinical practice in breast cancer and melanoma [2]
- Trend: minimal invasive, laparoscopic interventions
- Laparoscopic routes for SLN
  * Current techniques:
    * Radioisotope tracer + gamma probe
    * Fluorescent tracer + near-infrared camera
  * Our approach:
    * Magnetic tracer (SPION) + DiffMag [3,4]

• DiffMag = zero-dimensional MPI [5]

Goal: Diffmag detection coil in laparoscopic equipment and excitation coil outside the patient.

Laparoscopy

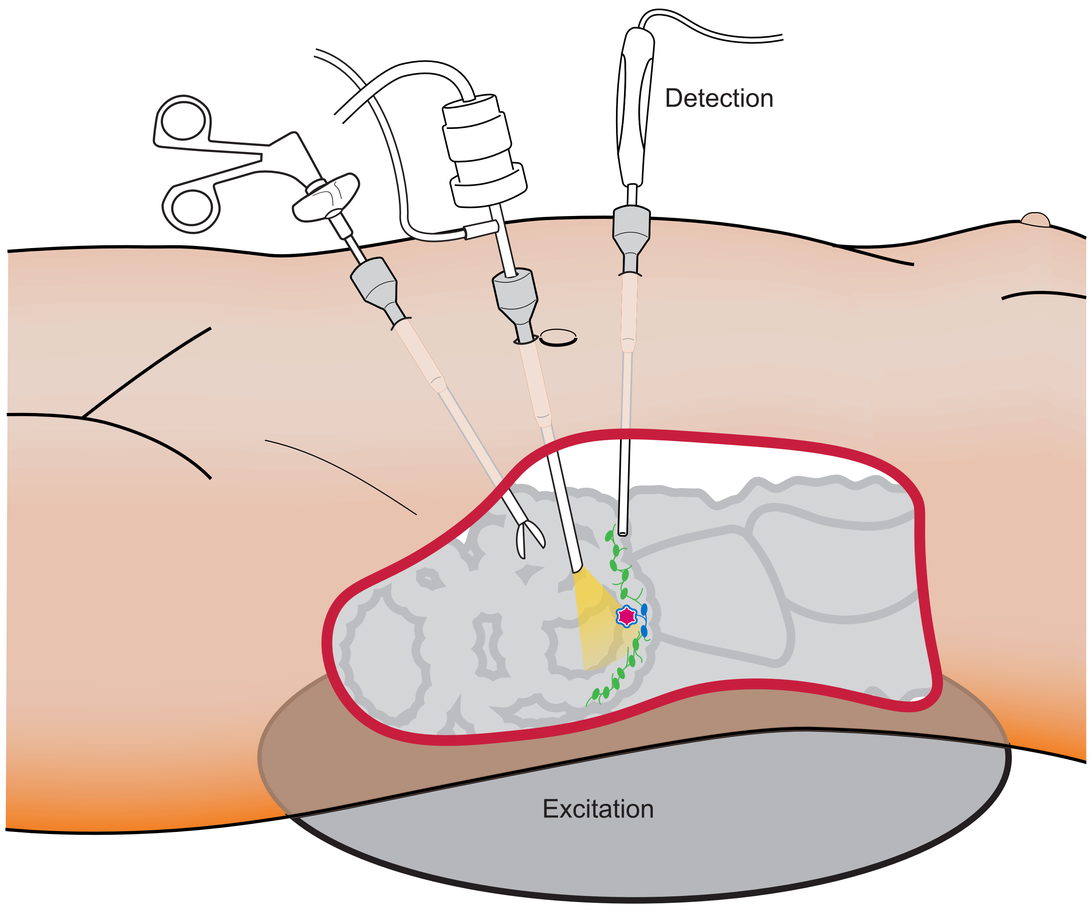

Figure 1 - Laparoscopic detection of sentinel lymph nodes using our DiffMag technique with seperated excitation and detection coils.

Challenges

Separation of the excitation and detection coils comes with several challenges that need to be overcome. Since the coils can move with respect to each other, the mutual inductance between the coils changes. This requires a way to actively balance the coils during the measurement. Furthermore, the DiffMag value is dependent on both the position of the sample in the excitation field and the postition of the detector with respect to the sample. In order to eliminate the effect of the excitation field, we need to compensate the DiffMag value, which leads to relative DiffMag.

• Movement correction (motion during cyclus)

• Active balancing (motion between cycli)

• Relative DiffMag (position of sample)

Acknowledgement
This work is part of the research programme Magnetic Sensing for Laparoscopy (MagLap) with project number 14322 which is financed by the Netherlands Organisation for Scientific Research (NWO).

DiffMag

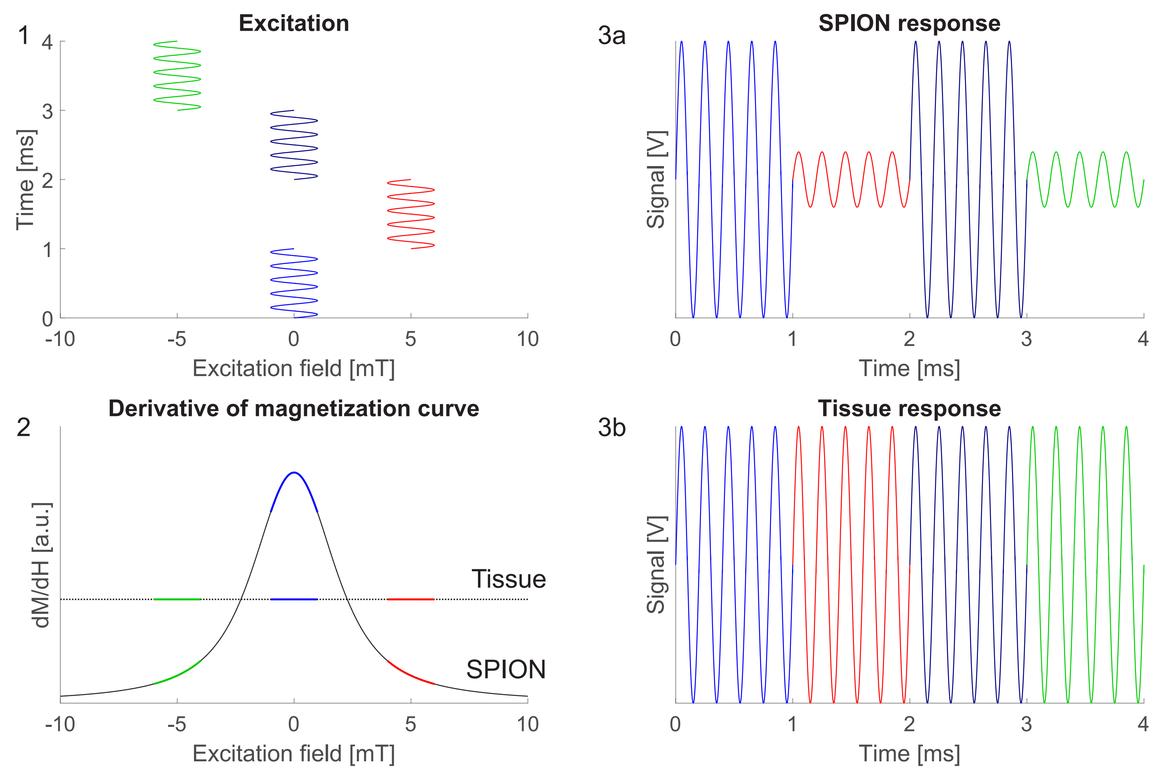

Figure 2 - In DiffMag the nonlinear magnetization characterisctics of superparamagnetic iron oxide nanoparticles (SPIONs) are exploited. The derivative of this nonlinear magnetization curve is shown in step 2, together with the linear diamagnetic magnetization of the human body. The first step in DiffMag is the excitation, which is achieved using a constant AC magnetic field and alternating DC blocks. Due to the nonlinearity, the amplitude of the SPION signal (3a) changes between the different DC offsets. Since the difference of the amplitudes is taken, the linear magnetization of tissue (3b) is discarded in the final DiffMag value.

Particle - detector optimization

In order to get a larger SNR in DiffMag, it is not only important to improve the detector. New particles can improve our technique as well. Two characteristics of the magnetization curve are important, as can be seen in figure 3.

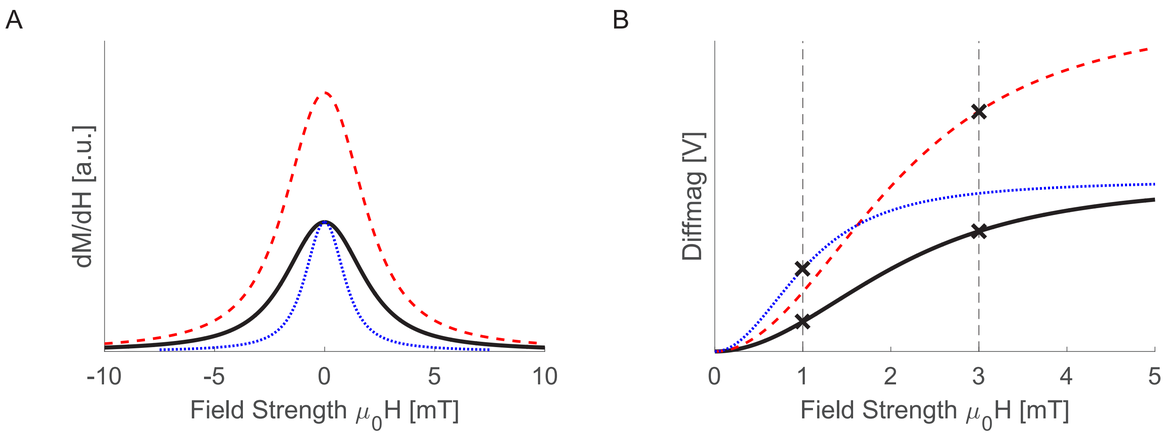

Figure 3 - Important characteristics of the magnetization curve to increase the Diffmag value. A) shows a fictional curve with an increased susceptibility (red) and one with a smaller field of saturation magnetization (blue) compared to the black curve. B) shows the corresponding DiffMag values.

Conclusion

Magnetic detection has promising advantages over other techniques, which make use of radioisotope or fluorescent tracers. The main advantages of a magnetic tracer are a long shelf-life, particles can accumulate in lymph nodes and minimal risk to patient and medical staff.

References

[1] J. J. Pouw, et. al., “Phantom study quantifying the depth performance of a handheld magnetometer for sentinel lymph node biopsy,” Phys. Medica, vol. 32, no. 7, 2016.
[2] S. Waanders, et. al., “A handheld SPIO-based Sentinel Lymph Node mapping device using Differential magnetometry,” 2016.
[3] M. Visscher, et. al., “Selective detection of magnetic nanoparticles in biomedical applications using differential magnetometry,” J. Magn. Magn. Mater., vol. 365, 2014.
[4] J. Weizenecker, et. al., Particle dynamics of mono-domain particles in magnetic particle imaging Magnetic Nanoparticles (Singapore: World Scientific), 2010.