Magnetic techniques for diagnosis and treatment of breast cancer

Masaki Sekino[1], Akihiro Kuwahata[1], Mutsuko Hatano[2], and Moriaki Kusakabe[3]
[1] Graduate School of Engineering, the University of Tokyo, Tokyo 113-8656, Japan
[2] School of Engineering, Tokyo Institute of Technology, Tokyo 152-8552, Japan
[3] Graduate School of Agricultural and Life Sciences, the University of Tokyo, Tokyo 113-8657, Japan

In the treatment of cancer, it is important to identify the lymph nodes involved in metastasis. By administering magnetic nanoparticles to the lymphatic system and detecting accumulation in downstream lymph nodes with a magnetic sensor, lymph nodes involved in metastasis can be identified non-invasively and objectively. To realize this new technique, we developed a handheld device consisting of a permanent magnet and a Hall sensor[1)]. Previous researches on magnetic sensors were mainly based on the approach of detecting small amounts of magnetic nanoparticles using SQUIDs. Those devices were not very suitable for clinical use because the devices reacted to other surrounding magnetic materials due to their high sensitivities. We devised a new mechanism for strongly magnetizing nanoparticles with a permanent magnet and detecting the magnetic field with a small Hall sensor, and developed a prototype handheld device for detecting magnetic nanoparticles. With this mechanism, the influence of external devices was sufficiently reduced and clinical application was realized. Since the power consumption was smaller than that of existing devices, the entire drive circuit can be stored in the grip, making it a compact device. We also reported a technique for quantifying the accumulation of magnetic nanoparticles administered to living organisms by non-invasive imaging using MRI. Animal experiments showed the dose and time dependence of the accumulation. We ensured the safety of the developed magnetic probe by complying with the standards for electrical safety and risk management of medical devices, and proceeded with clinical research. In particular, a multicenter clinical trial was conducted on 200 breast cancer patients, and the new method using magnetic sensors and magnetic nanoparticles is non-inferior in terms of identification rate to the standard RI method[2)]. In addition, in order to expand the application, clinical trials were conducted in 20 and 4 cases of oral cancer and uterine cancer, respectively, and successful results were obtained such as the ability to identify sentinel lymph nodes in all cases. Furthermore, we also developed a prototype device equipped with a diamond quantum magnetic sensor[3)]. Due to the high sensitivity, the sensor could be operated with weak magnetic fields generated from a coil.

Reference

1) M. Sekino, A. Kuwahata, T. Ookubo, M. Shiozawa, K. Ohashi, M. Kaneko, I. Saito, Y. Inoue, H. Ohsaki, H. Takei, and M. Kusakabe, Sci. Rep., **8** (2018) 1195.
2) K. Taruno, T. Kurita, A. Kuwahata, K. Yanagihara, K. Enokido, Y. Katayose, S. Nakamura, H. Takei, M. Sekino, and M. Kusakabe, J. Surg. Oncol., **120** (2019) 1391.
3) A. Kuwahata, T. Kitaizumi, K. Saichi, T. Sato, R. Igarashi, T. Ohshima, Y. Masuyama, T. Iwasaki, M. Hatano, F. Jelezko, M. Kusakabe, T. Yatsui, and M. Sekino, Sci. Rep., **10** (2020) 2483.

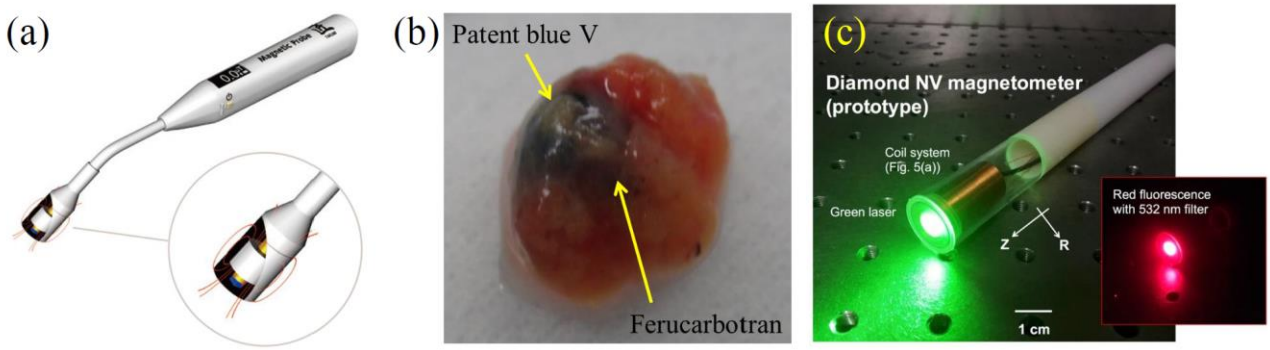

Fig. 1. (a) Handheld magnetic probe for sentinel lymph node biopsy. (b) Extracted lymph node containing magnetic nanoparticles and blue dye. (c) Magnetic probe equipped with a diamond quantum sensor.