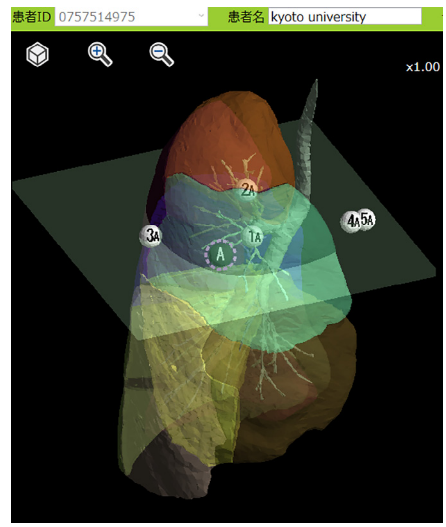
Three-dimensional Navigation for Thoracoscopic Sublobar Resection Using a Novel Wireless Marking System

Yojiro Yutaka, MD,[*,†] *Toshihiko Sato, MD, PhD,*[*,‡] *Koichi Matsushita, PharmD,*[§] *Hiroyuki Aiba, MS,*[‖] *Yusuke Muranishi, MD,*[*,†] *Yasuto Sakaguchi, MD,*[*,†] *Tadao Sugiura, PhD,*[¶] *Minoru Okada, PhD,*[¶] *Tatsuo Nakamura, MD, PhD,*[*,†] *and Hiroshi Date, MD, PhD*[*]

We developed a novel localization technique for small intrapulmonary lesions using radiofrequency identification (RFID) technology. Micro-RFID markers with nickel-titanium coils were designed to be placed from subsegmental bronchi to the peripheral parenchyma. In this preclinical study, thoracoscopic subsegmentectomy of a canine pseudotumor model was performed to demonstrate the feasibility and three-dimensional positional accuracy of the system. To recover subcentimeter pseudotumors, markers were bronchoscopically placed to determine the resection line: (1) next to the pseudotumor; (2) in the responsible subsegmental bronchi as the central margin; and (3) on the intersubsegmental plane as the lateral margin. Specific marker positions were located by wireless communication using a wand-shaped probe with a 30-mm communication range, with the distance to the marker indicated by gradual changes in sound pitch. Thirty-four markers were placed for 10 pseudotumors (14.6 mm from the pleura) in 10 canines. Three markers were placed at a mean distance of 5.5 mm from the pseudotumors, and 11 central and 20 lateral markers were placed at mean distances of 17.2 and 20.7 mm from the pseudotumors, respectively. Central markers (20.5 mm from the pleura) were detected within 16.0 seconds in 2.9-mm-diameter bronchi. All resection stumps were within 5.4 mm (range 2-8 mm) from each marker, and pseudotumors were removed with adequate surgical margins toward the central (11.5 mm; range 7-16 mm) and lateral (12.4 mm; range 9-17 mm) directions. RFID wireless markers provided precise three-dimensional positional information and are a potential viable alternative to conventional markers.

Semin Thoracic Surg 30:230–237



Three-dimensional navigation via radiofrequency identification wireless markers.

Central Message

Three-dimensional surgical navigation using radiofrequency identification wireless markers provided precise orientation with depth in the lung parenchyma.

Perspective Statement

Our surgical navigation system using radiofrequency identification technology provides precise orientation with depth in the lung parenchyma. Clinically, it has the potential to become a viable alternative to conventional markers for deep small lung lesions that are difficult to localize and may facilitate more precise resection in complex segmentectomies.

*Department of Thoracic Surgery, Kyoto University Hospital, Kyoto, Japan
†Department of Bioartificial Organs, Institute for Frontier Medical Sciences, Kyoto University, Kyoto, Japan
‡Institute for Advancement for Clinical and Translational Science, Kyoto University, Kyoto, Japan
§Hogy Medical Co, Ltd, Tokyo, Japan
‖Asahi Intecc Co, Ltd, Nagoya-shi, Aichi, Japan
¶The Graduate School of Information Science, Nara Institute of Science and Technology, Ikoma, Nara, Japan

Conflict of interest statement: Y. Yutaka, T. Sato, and H. Date have a financial relationship with Hogy Medical Co, Ltd, which developed the radiofrequency identification (RFID) system used in this study. Hogy Medical Co, Ltd, provided the RFID system and financial support by means of an institutional research grant.

Author contributions: Y.Y. and T.S. designed the experiment. Y.Y. performed all procedures. Y.Y. collected and analyzed the results and wrote the first draft independent of any sponsor. T.S. contributed to the subsequent drafts. All authors agreed to the final draft and decision to submit the paper for publication.

Address reprint requests to Toshihiko Sato, MD, PhD, Institute for Advancement for Clinical and Translational Science, Kyoto University, 54 Shogoin, Kawahara-cho, Sakyo-ku, Kyoto 6068507, Japan. E-mail: tsato@kuhp.kyoto-u.ac.jp

1043-0679/$-see front matter
https://doi.org/10.1053/j.semtcvs.2018.03.001

Keywords: radiofrequency identification, localization, small lung lesions, video-assisted thoracoscopic surgery, navigation surgery, electromagnetic navigation bronchoscopy

INTRODUCTION

The worldwide spread of lung cancer screening by computed tomography (CT) has increased the number of incidentally detected small pulmonary nodules,[1-4] and thoracic surgeons are being required to manage smaller and fainter lung lesions. The prognosis of patients with ground glass opacity (GGO)-dominant small lung cancer after sublobar resection is reportedly not inferior to the prognosis after lobar resection, which has long been accepted as the standard procedure for primary lung cancer.[5,6] However, during resection of barely palpable GGO lesions, it is challenging to accurately locate the tumors and secure an appropriate surgical margin.[5,7] Particularly in segmentectomy for GGO lesions located near the intersegmental plane or over multiple subsegments, the cutting line for securing adequate surgical margins is expected to be beyond the affected segment; hence, adequate resection requires experienced surgical skills based on knowledge of pulmonary anatomy and correlation of preoperative imaging with intraoperative dissection. Surgeons also have to identify the resection lines in lung parenchyma under thoracoscopic settings where disorientation can occur because of the lack of anatomical landmarks.

To address these problems, we established a novel three-dimensional (3D) surgical navigation system using radiofrequency identification (RFID) technology. Our system uses RFID markers that can provide accurate positional information by wireless communication. In the current study, the feasibility and 3D positional accuracy of our RFID navigation system were evaluated in a canine thoracoscopic subsegmentectomy model of small pseudotumors.

METHODS

Radiofrequency Identification Surgical Navigation System

The RFID system comprises 3 components: (1) a delivery device for loading micro-RFID markers with 5-mm nickel-titanium (NiTi) coil anchors that can fit through the 2-mm working channel of a bronchoscope (Asahi Intecc, Tokyo, Japan) (Fig. 1A, B); (2) a wand-shaped probe (10-mm diameter, 30-mm effective range) (Fig. 1C); and (3) a signal-processing unit with 3D lung imagery software on which anatomical positions of bronchoscopically delivered markers are registered (Welcat, Tokyo, Japan) (Fig. 1C, D). Detailed algorithms and proof of concept of our prototypic system have been reported elsewhere.[8,9] Briefly, the RFID markers (passive transponders with no built-in battery) are activated by the electromagnetic field produced by the probe, which acts as both a power supply and a receiver antenna. The strength of the signal received by the probe is converted to 5 gradual changes in sound pitch by the signal-processing unit, with the pitch becoming higher

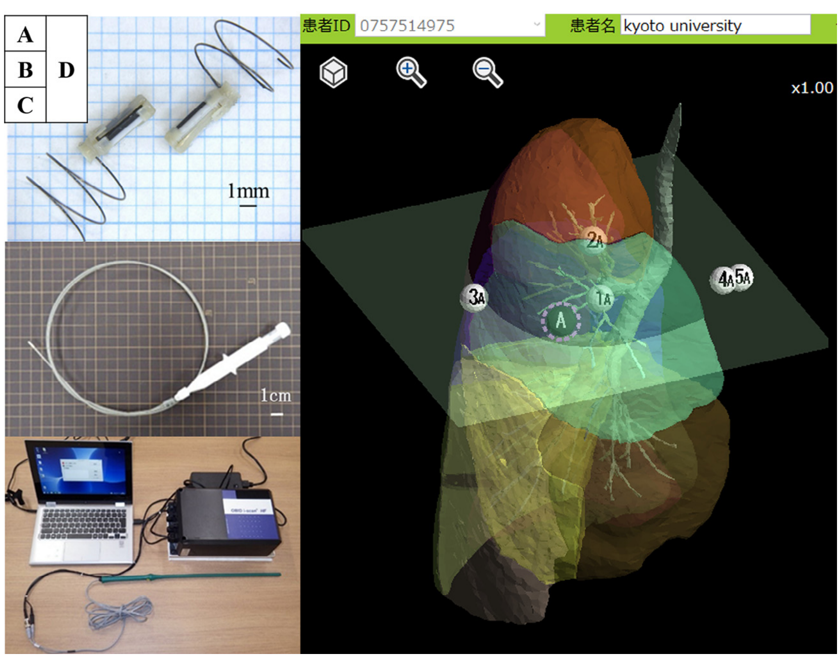


Figure 1. Complete set of components for the RFID lung marking system. This system has 3 components: (A) an RFID marker (3.2 × 1.6 × 0.8 mm) with a nickel-titanium coil anchor (diameter, 5 mm) and (B) bronchoscopic delivery device that can work through a 2-mm working channel; (C) a wand-shaped detection probe with a 30-mm communication range (10-mm diameter); and (D, E) a signal-processing unit with three-dimensional lung imagery software. (Color version of figure is available online.)