

Lung: Short Report

Lung Nodule Marking With ICG Dye–Soaked Coil Facilitates Localization and Delayed Surgical Resection



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ABSTRACT

BACKGROUND Whereas diagnosis and treatment of pulmonary nodules may be combined during a surgical resection, this approach may lead to excision of benign lesions and excessive healthy lung tissue if the lesion is difficult to localize. Bronchoscopy-guided marking of pulmonary nodules before surgery may facilitate this process, but it is limited by current technologies and often challenging as dye marking may dissipate if surgery is performed days later. We present a novel method to address this problem that allows surgery multiple days after lesion marking with accurate localization.

METHODS Four patients with newly identified lung nodules underwent robot-assisted navigation bronchoscopy with lesion marking with a fiducial coil saturated for 10 minutes with indocyanine green (ICG) dye and subsequent thoracic surgery.

RESULTS The novel approach to soaking the fiducial in ICG allowed the lesions to be seen multiple days (0–9 days) later at the time of da Vinci robotic surgery with the Firefly fluorescence imaging system. No evidence of dye dispersion was visualized, and all surgeries were completed without complications.

CONCLUSIONS Methods to improve peripheral pulmonary nodule marking to facilitate surgical resection are imperative as more asymptomatic, smaller lesions continue to be identified. In our initial experience, placement of ICG dye-soaked fiducial coils for lung nodule marking multiple days before thoracic surgery appears to be a viable option to facilitate surgical resection.

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More pulmonary nodules are identified with increasing chest computed tomography use¹ and lung cancer screening efforts.² The percentage of early-stage lung cancer has also increased, with clinical stage IA disease accounting for ~15% of patients with non-small cell lung cancer in developed countries.³ Whereas surgical resection for this stage is the standard of care, lung-sparing surgery, in which there is an increasing interest and literature support for both new lung cancers and secondary metastasis to

IN SHORT

- A novel method using an indocyanine green dye-soaked coil as a fiducial allows appropriate localization and visualization multiple days after lesion marking.
- This approach improves the ability to perform successful lung-sparing surgery, especially for patients at centers with limited access to single anesthesia procedures.

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the lung, requires precise localization techniques to provide optimal outcomes.⁴ Ideal localization procedures will offer multiple options for surgeons to clearly identify these nodules and to allow the best chance of preserving as much lung tissue as possible.

Surgical localization of lung nodules, however, may present multiple challenges. Several tumor factors, including size of the nodule, distance from the pleural surface, nature of the nodule (ground glass, solid, or mixed), associated structural lung disease, presence of anthracotic pigment on the lung surface, and pleural adhesions, have important implications in localization and surgical resection.⁵ Other potential barriers include access to the procedure/proceduralist, logistical challenges within institutions, and reliance on open surgical techniques. We present a novel method for addressing some of the problems in lung nodule localization that adds efficiency between a facilitating marking procedure and subsequent surgery.

MATERIAL AND METHODS

We used a fiducial coil (G10417 Tornado embolization coil, 7 × 3 mm in tapering diameter from widest to narrowest by 8 cm in extended length; Cook Medical) soaked with indocyanine green (ICG) dye (NDC-70100-424-02; HUB Pharmaceuticals) for 10 minutes before placement by robotic bronchoscopy with the Ion endoluminal system (Intuitive) 0 to 9 days before thoracic surgery.

One patient at El Camino Hospital/Palo Alto Medical Foundation in Mountain View, California, and 3 patients at Aurora Medical Center Kenosha in Kenosha, Wisconsin, with incidentally detected lung nodules were selected for this method because of the scheduled time between marking procedure and thoracic surgery (0, 4, 5, and 9 days between ICG dye-soaked coil placement

and surgical resection). Approval was obtained from the institutional review board of Palo Alto Medical Foundation (#1014791-6), and the institutional review board of Advocate Aurora Research Institute waived the need for approval, given the limited number of participants (n = 3).

All patients underwent robot-assisted navigation bronchoscopy by the Ion endoluminal system (Intuitive) with either cone beam computed tomography or 3-dimensional fluoroscopy used for secondary confirmation as an additional tool.⁶ The fixed ceiling-mounted Artis zee cone beam scanner (Siemens Medical Solutions) was used at El Camino Hospital (n = 1), whereas the mobile C-arm Cios Spin (Siemens Medical Solutions) was used at the Aurora Medical Center Kenosha (n = 3). All patients presented with new, incidentally detected nodules (2 with solid nodules and 2 with ground-glass opacities). None of the patients had a history of allergic reactions to contrast dyes. The procedures were planned as diagnostic bronchoscopies with biopsy followed by marking (if intraoperative cytopathologic examination showed atypical cells or confirmed malignant transformation) and subsequent surgical resection (planned for a later date at the Kenosha, Wisconsin, facility and the same day at the Mountain View, California, location).

The procedures were performed by marking the lesions with ICG dye-soaked Cook Tornado coils ([Figure 1](#)) using the robot-assisted navigation bronchoscopy method. With use of a standard 1-mL tuberculin syringe with a Luer lock, 0.25 mL of a prediluted mixture of ICG (25 mg of ICG dye mixed with 10 mL of sterile water, resulting in an ICG dye concentration of 2.5 mg/mL) was drawn and injected into the Cook Tornado coil cartridge sheath, priming the sheath and soaking the coil within it with the ICG dye ([Video 1](#)). The dwell time for the dye to soak the coil completely was 10 minutes (a time chosen to allow adequate soaking of the synthetic fibers of the coil), after which another 0.25 mL of the same mixture of ICG dye was instilled within the coil sheath for additional priming just before ICG dye-soaked coil placement within the targeted nodule. The ICG-impregnated coil was then back-loaded into the super-Dimension delivery catheter (Medtronic), which was used without any modifications, and deployed by pushing the guidewire that is included with the catheter kit ([Video 2](#)).

Once the ICG-soaked coil was deployed within the target lesion ([Figure 2](#), showing cone beam and fluoroscopy images with ICG dye-soaked fiducial coil in nodule), 1 patient was then directly transported to the operating room for robotic wedge resection (da Vinci; Intuitive) on the same day as a single anesthesia procedure in Mountain View, and 3 patients from Kenosha were transported to the recovery room and then

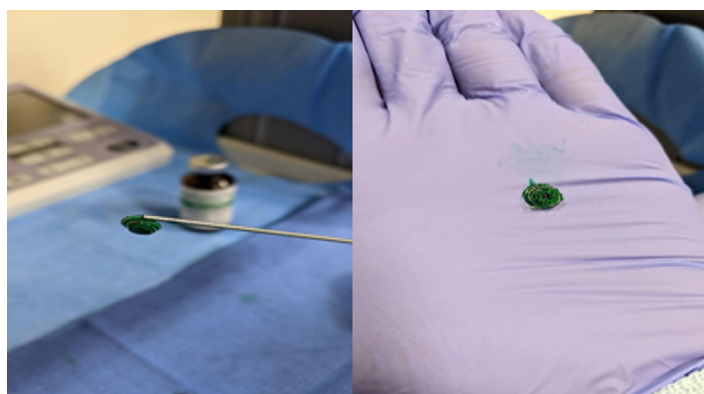
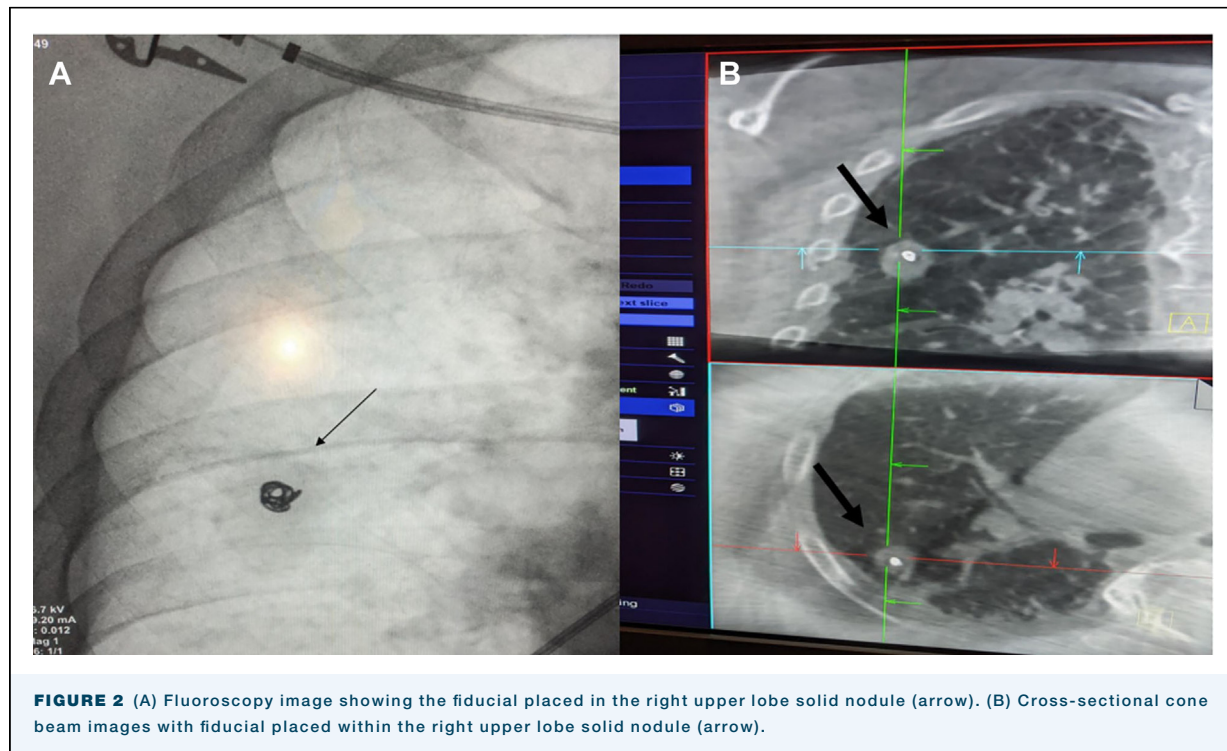


FIGURE 1 Cook Tornado coil soaked with the indocyanine green dye.



discharged home. These patients underwent robotic thoracic surgery 4, 5, and 9 days later, respectively, at another Aurora Medical Center facility where thoracic surgery services were available.

RESULTS

Four patients underwent the described method. All lesions were <2 cm on preprocedure chest computed tomography (2 ground-glass nodules, sizes 12 mm and 15 mm, and 2 solid nodules, sizes 10 mm and 15 mm), located in the outer lung third and without a bronchus sign.

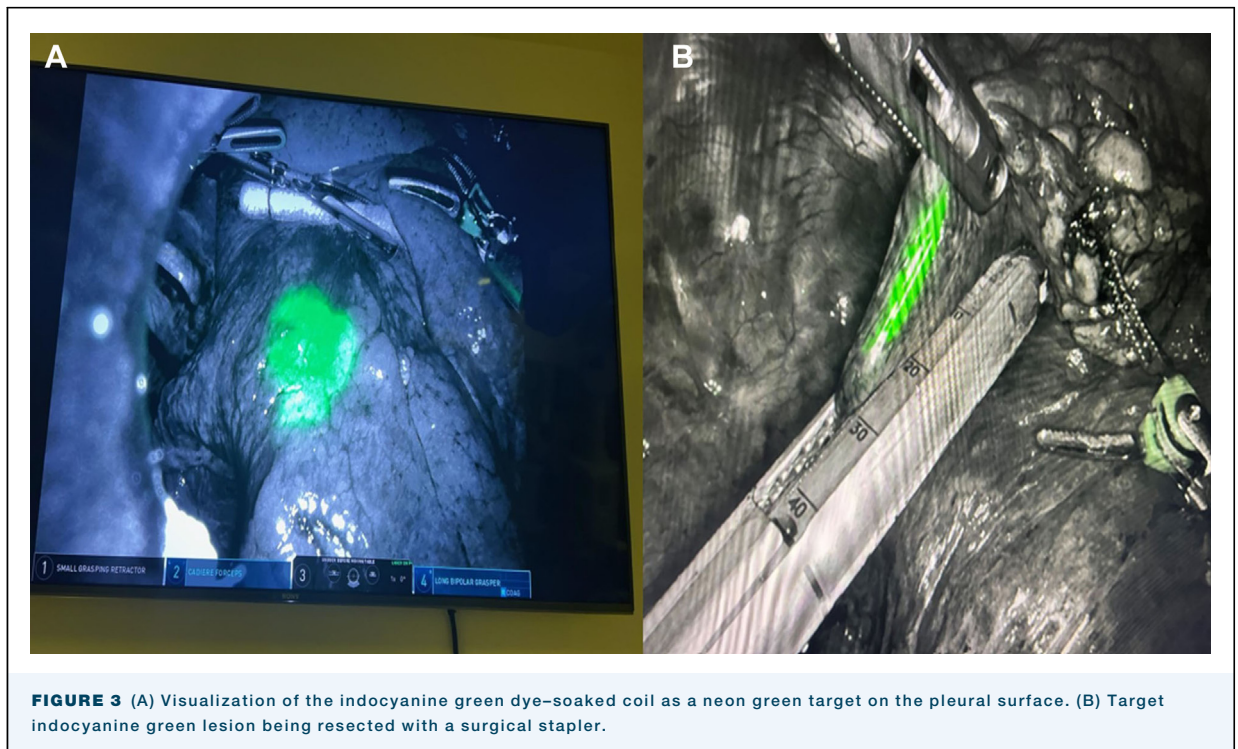
In procedures conducted at the 2 locations, we placed ICG dye-soaked coils in lung nodules of patients preparing for surgery both immediately after the procedure (day 0) and several days later (days 4, 5, and 9). Average procedure time from bronchoscope insertion to removal was 40 minutes, with an average of 5 minutes spent on ICG dye-soaked coil placement. Successful nodule localization was achieved for all nodules with visualization of the dye-soaked coil as a neon green target on the pleural surface (Figure 3; Video 3) using the Firefly fluorescence imaging system (da Vinci Fluorescence Imaging Vision System) of the da Vinci robotic system. A wedge resection with negative margins was successfully performed in all 4 cases using the neon green luminescence provided by the dye-soaked coil with accurate localization and resection (Figure 4; Video 4).

Patients who met the criteria for further anatomic lung resection based on frozen pathologic examination results of the wedge resection then proceeded with further resection during that anesthesia episode. No perioperative or postoperative complications were identified.

COMMENT

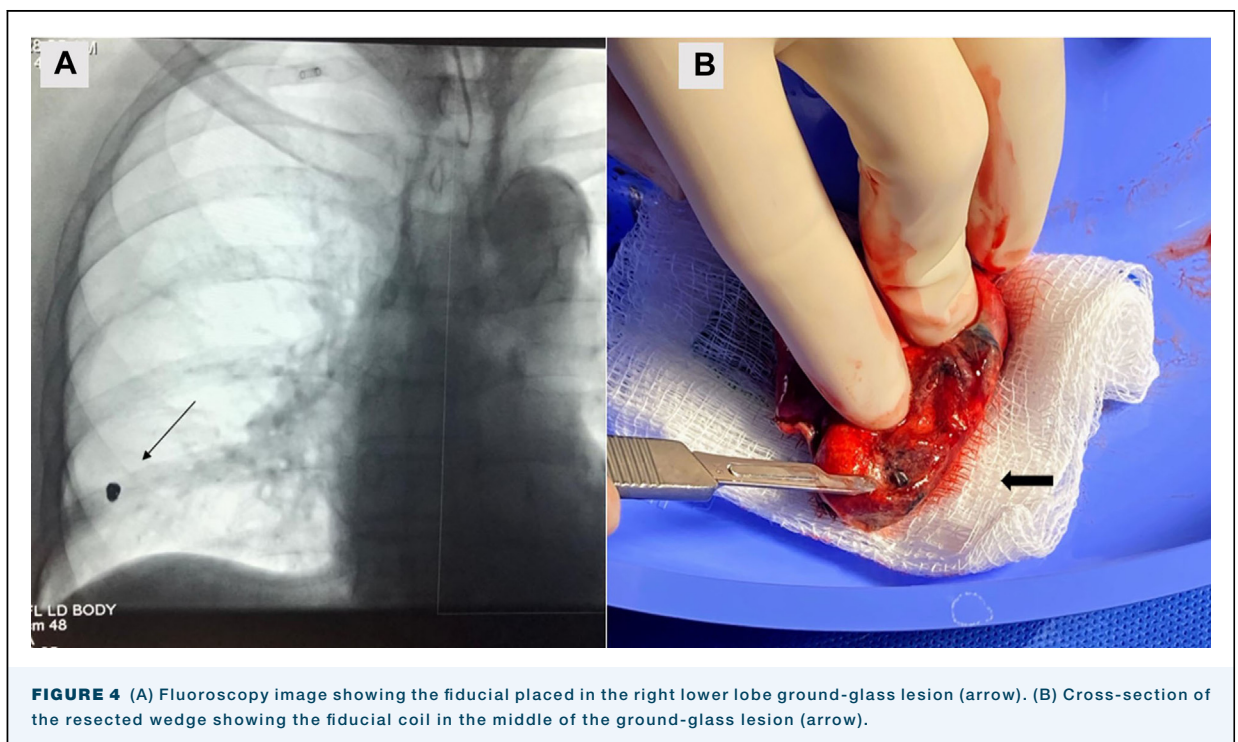
Nodule localization facilitates surgical resection and prevents excision of benign disease and healthy lung tissue.^{7,8} Successful localization lacks a clear definition, however, and is usually subjectively assessed by the proceduralist. Failure may occur if the surgeon is unable to clearly visualize or palpate the lesion, leading to increased procedure time and healthy lung tissue resected, changes in the operative approach, and possible failure to remove the intended target.⁹ Failure to detect pulmonary nodules >5 mm from the pleural surface and <10 mm in size is >60% during a video-assisted thoracoscopic approach.¹⁰ In addition, pure ground-glass lesions are challenging to palpate. In our patients, all lesions were <15 mm, located in the outer lung third, without a bronchus sign, with 2 solid and 2 ground glass. All were localized during surgery up to 9 days after marking without seeing any dye dispersion.

We decided to use a fiducial coil soaked with ICG because these coils are made with platinum and spaced synthetic fibers, which allows the ICG dye to adhere to it.



We believed that this construction would allow the fluorescent and bright neon green dye to still be visible many days later, which was seen in our patients after at least 9 days. The bright green dye luminescence enabled

the thoracic surgeons to know exactly where to resect, potentially decreasing the amount of lung tissue removed. Before this, localizing a nodule 9 days after ICG dye marking (without coil) was not possible as the



dye effect would fade away during several hours because of its metabolism and half-life. The ICG dye-soaked coil marks the nodule location, making it visible under the Firefly fluorescence imaging system of the da Vinci robotic system that allows the surgeon to target the lesion with greater precision, allowing a lung-sparing surgery. The coil is also palpable by surgical graspers and visible by intraoperative fluoroscopy or ultrasound, allowing the surgeon multiple options using the chemical and mechanical properties of a dye-impregnated coil to localize the lesion, depending on experience and expertise.

Although the dye-soaked coils were placed in biopsy-confirmed or suspected malignant lesions in our patients, the technique can also be used for nondiagnostic lesions with high suspicion and planned surgical biopsy or resection, as with our subsequent cases (Supplemental Figure). The extended time allowed before surgery with this ICG dye-soaked fiducial marker method may provide substantial advantages for patients at smaller rural or underserved hospitals with poor access to or limited availability of on-site thoracic surgery. Similarly, larger academic centers, at which a single anesthesia procedure with localization followed by immediate surgery may be

difficult to plan owing to conflicting schedules or procedural logistics, may also benefit from this approach. Patients may also need time to schedule, prepare, and travel to larger medical centers.

Performing surgical resection ranging from 0 to 9 days after robot-assisted nodule marking shows that the intensity of neon green luminescence from the ICG dye-soaked coil remains constant, rather than fading or dispersing over the pleural surface with time. This approach facilitates a surgical procedure at a later date that will allow appropriate localization and visualization to aid in resection by the surgeon. It has the potential to improve our ability to perform successful lung-sparing surgery for both primary and secondary lung malignant neoplasms and warrants further research and consideration for widespread use.

The Videos and Supplemental Figure can be viewed in the online version of this article [<https://doi.org/10.1016/j.atsr.2023.02.010>] on <http://www.annalthoracicsurgery.org>.

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DISCLOSURES

The authors have no conflicts of interest to disclose.

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