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Laser Navigation for Radiofrequency Ablation

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Abstract

A 45-year-old male with renal cell carcinoma secondary to von-Hippel Lindau (VHL) disease presented for radiofrequency ablation (RFA) of kidney tumors. Due to his prior history of several partial nephrectomies and limited renal reserve, RFA was chosen because of its relatively nephron-sparing nature. A laser guidance device was used to help guide probe placement in an attempt to reduce procedure time and improve targeting accuracy. The device was successful at guiding needle placement, as both tumors were located with a single pass. Follow-up CT scan confirmed accurate needle placement, showing an area of coagulation necrosis covering the previously seen tumor.

Keywords

Radiofrequency ablation; Laser guidance; Renal cell carcinoma; von-Hippel Lindau disease

Navigation and guidance devices for CT-guided interventions have been relatively underutilized, however, they show promise for effectively and accurately assisting needle or probe placement. Multiple systems and techniques have been developed to assist CT-guided procedures [5-9], varying from the complex (robotics) [1], to the simple fluid-filled disk, to approximate planned needle angulations [2].

Radiofrequency ablation (RFA) is becoming broadly available in the oncology community, and is being studied for kidney tumors with some degree of success. We have performed nearly 200 kidney tumor ablations, and we often rely upon nearby landmarks for accurate needle angle selection to treat radiographically occult tumors. Laser guidance was used to assist in RFA in a kidney tumor that was difficult to visualize by CT scan without contrast. Local ablative therapies rely upon extreme accuracy for successful outcomes. The device (SimpliCT, NeoRad AS, Norway) is free standing, portable, and independent of the CT gantry. It consists of a laser source mounted on an L-shaped track, which stands on a 3-wheel lockable base (Fig. 1). Laser guidance simplified radiofrequency probe angulation implementation, and also facilitated probe repositioning for a second burn, according to a treatment plan developed with pretreatment CT. The authors have no commercial interest in the device.

Case Report

A 45-year-old male with a history of von Hippel-Lindau disease presented for radiofrequency ablation of 2 left-sided kidney tumors. VHL is an autosomal dominant disorder, characterized by the development of both benign and malignant tumors [3]. This patient had bilateral renal cell carcinoma, and had undergone a left partial nephrectomy in 1995, and a right partial nephrectomy in 1999. During a follow-up hospitalization in 2000, he was found to have regrowth of tumor in both kidneys. Percutaneous RFA of the left-sided lesions was attempted at that time, but the procedure was aborted secondary to inadequate visualization of the tumors.

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They were only visible radiographically during the arterial phase of the CT scan, and were isoechoic and invisible on ultrasound. Since all lesions were <3 cm at the time, they were judged to be small enough to monitor, given their slow growth rate and statistical improbability of metastasis. However, a year later in 2001, the tumors had grown and the patient underwent another left partial nephrectomy followed by another right partial nephrectomy 7 months later. During the surgery, the tumor in question was again invisible with intraoperative ultrasound.

RFA was performed as part of an investigational review board-approved protocol with a single 17 G Cool-tip needle with 3 cm exposure (Radionics, Inc, Burlington, MA). Written informed consent was obtained, general anesthesia was induced, and the patient was placed in a right lateral decubitus position on the CT table. The guidance device was positioned facing the patient's back, to allow the laser light to be directed onto the patient's skin at the intended puncture site. It was then aligned perpendicular to the CT table by bringing the alignment laser in parallel with the CT gantry laser. The alignment laser is a separate laser that matched the CT gantry laser for calibration and alignment purposes. This allows the free-standing device to be exactly parallel (and thus registered) to the CT table. Since the guidance device is not physically connected to the CT unit, this step is necessary to ensure that the laser unit is positioned exactly 90° relative to the CT table.

An initial unenhanced scan [Fig. 2B] was taken with a grid in place and the puncture site was marked on the patient's skin. With the use of electronic calipers on the CT monitor, the angle of needle entry was calculated to be 17° below the horizontal in the axial plane (Fig. 2A). The laser unit slides between horizontal and vertical rails for complete access to the patient. It was then moved to the vertical rail, and the intended 17° was dialed into it. Next, the point of laser light, now projecting at 17°, was positioned exactly on the marked puncture site on the patient's skin. Depth was measured from treatment planning CT scan. Tandem technique was used with a 22-gauge guide needle slowly advanced towards the tumor, taking care to keep the laser light on the hub of the needle throughout needle advancement. Axial CT scans and ultrasound showed the guide needle to be in perfect position, so the RF needle probe was next advanced towards the tumor under similar laser guidance (Fig. 2B).

Respirations were suspended by the anesthesiologist during needle insertions. Once at the required depth, location of the RF needle tip was also checked with axial CT cuts and ultrasound, and was also found to be at the intended position (Fig. 2C). Two cycles of pulsed RF treatment were then administered to this tumor in a manner previously described for kidney lesions [4]. A second lesion was then targeted with the aid of laser guidance, through the same skin entry site at a puncture angle of 23°.

Comparison of the pretreatment scan with one obtained 2 days after the procedure showed effective treatment as evidenced by devascularized tumor consistent with coagulation necrosis (Fig. 2D).

Discussion

Navigation and guidance systems for CT have been studied and utilized primarily for radiation therapy, brachytherapy and neurosurgery, and underutilized for simple biopsy or other body interventions. Frederick et al. [5] reported on a system that utilized planes of intersecting light to guide needle passage, and demonstrated an accuracy of ±1 mm and ±1°. Mechanical stereotactic devices have also been employed with good accuracy, resulting in a 75% decrease in needle manipulations in one study [6]. A simple fluid-filled disk, using the air-fluid meniscus as a reference point from which to measure angles, also proved to be accurate [2], however, this system only permits guidance in the axial plane. Gantry mounted systems, both stereotactic and laser guided, have also been described [7,8].

The SimpliCT device provided accurate radiofrequency needle placement by physician's assessment. Other systems have limitations such as the need for mechanical needle guidance [2,6,7], part of the system being fixed to the patient [6,9], or the laser unit itself being mounted on the gantry [8]. Many of these limitations are overcome by the design of the SimpliCT. By not being attached to the CT unit, it can be positioned away from the gantry, allowing easier access to the skin entry site, as the patient can be pulled out of the scanner. Although not employed in our procedure, it can also provide needle guidance in the cranial-caudal axis, independent of gantry tilt. Finally, it does not require contact with the patient's skin, eliminating a potential source of contamination.

Radiofrequency ablation has recently emerged as a treatment option for cancer. It is extremely dependent upon exact positioning information, and successful outcomes may require optimal probe repositioning. Implementation of a treatment plan requires exact placement at exact angles, which are predetermined from CT.

Tumors are normally located for RFA in our institution under ultrasound and CT guidance. In this case we used laser guidance in conjunction with ultrasound and CT to evaluate the effectiveness of the guidance device. The exact probe angle was implemented without intra-procedural subjective estimation by the operator. Even radiologists with the most experience and aptitude in CT-guided procedures are not able to estimate angles exactly according to plan on every occasion.

This free-standing device does have several important limitations, however. The system cannot account for differences in respiratory excursion, patient motion, organ shift, or kidney motion during capsular penetration, any of which could introduce error. A system that was fully integrated mechanically to the CT table and gantry would facilitate set-up and theoretically decrease error. We are designing one such system with the laser attached to a robot on a CT gantry stereotactic frame.

In summary, we found the guidance device to be an effective adjunct to our RFA procedure, and plan to use it in future treatment sessions. As we gain more experience with the device, we expect potentially shorter procedure times, further confirmation scans and probe manipulations that may translate into improved patient care and outcomes.

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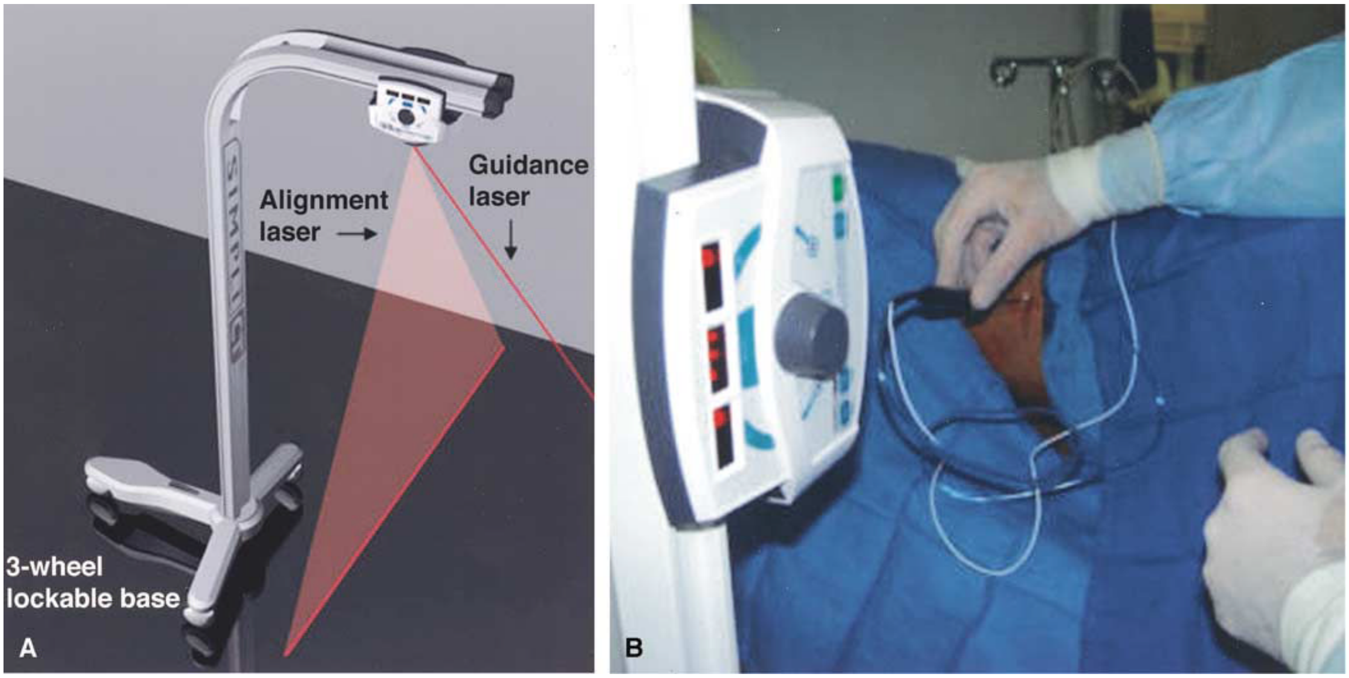

Fig. 1.
A. SimpliCT laser guidance device (reprinted with permission of NeoRad AS, Norway). **B.** Free-standing device placed next to CT table during procedure.

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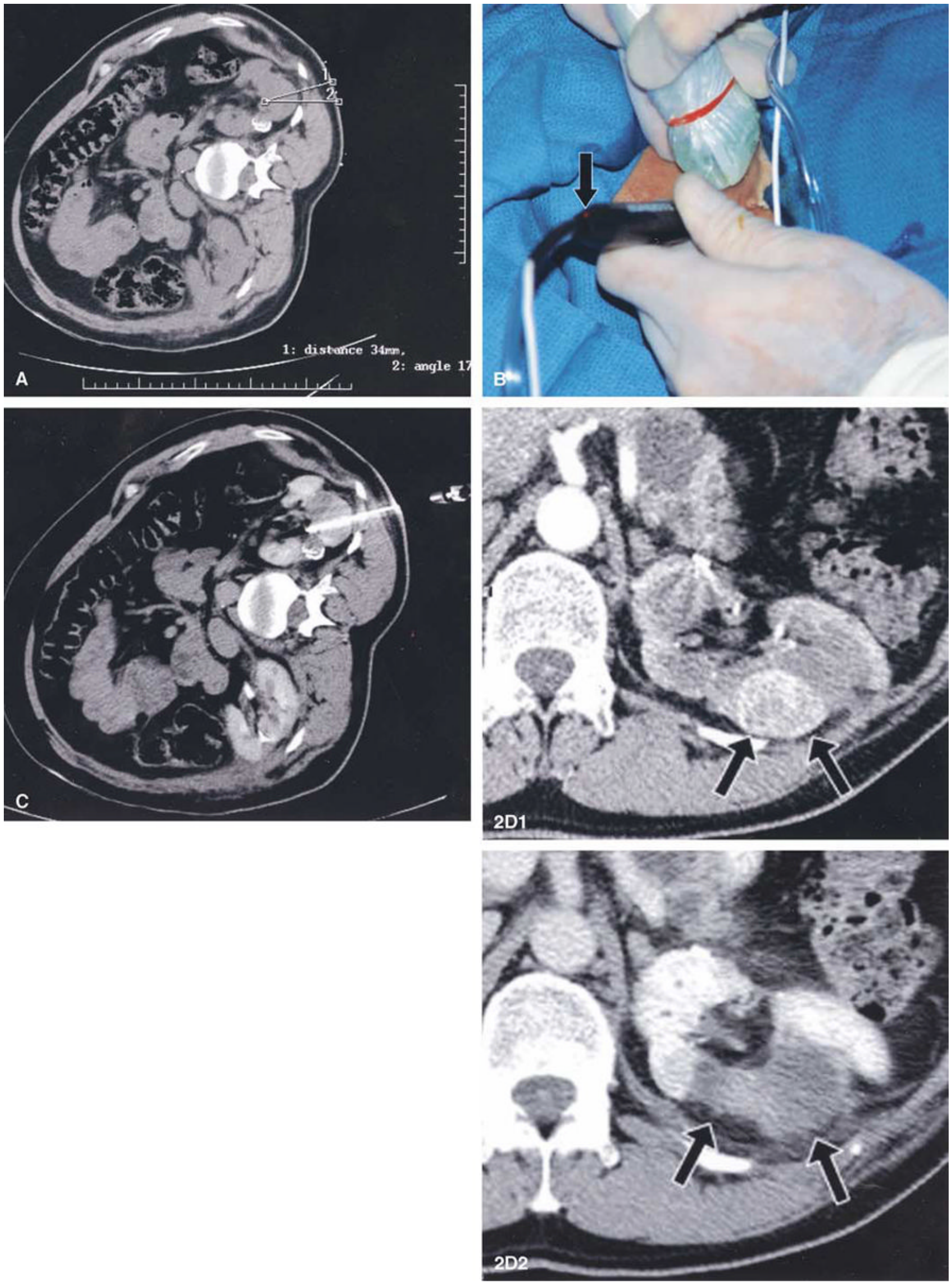

Fig. 2.
A 45-year-old male with renal cell carcinoma secondary to von Hippel-Lindau disease. **A.** Unenhanced planning CT shows a 17° angle selection with electronic calipers. **B.** Radiofrequency probe being advanced towards tumor under laser guidance. Note red point of laser light on probe handle (arrow). **C.** Enhanced CT scan shows tip of radiofrequency needle in tumor after positioning using laser guidance. **D.** Comparison of post (1) with pretreatment (2) contrast-enhanced CT shows lack of enhancement in left kidney, consistent with coagulation necrosis and tumor death (arrows).