Endoscopic Ultrasound–Guided Fiducial Placement for CyberKnife Radiosurgery

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12.1 Introduction

The Synchrony® (Accuray Incorporated, Sunnyvale, CA) Respiratory Tracking System allows the CyberKnife® (Accuray Incorporated, Sunnyvale, CA) to deliver precisely high-dose radiation to targets that move with respiration. Tracking of moving tumors currently requires the use of implanted radiographic markers (or fiducials) as reference points [1, 7]. Several reports describe the placement of fiducials through surgical or percutaneous methods under image guidance (ultrasonography or computed tomography) in the prostate, spine, and lungs [2, 3, 6–8]. Fiducial implantation surgery can be invasive, and the percutaneous approach carries risks and limitations, especially when the lesions are in a deep location such as the posterior mediastinum or the abdomen. Innovations in the fiducial implantation procedure may improve its accuracy and reduce its risks, ultimately enhancing comfort for the patient. We recently described a new approach to placing fiducials in these deep structures using endoscopic ultrasound (EUS) [9]. This chapter briefly describes this approach.

EUS employs an endoscope with an ultrasound and a Doppler function incorporated into its tip. The ultrasound allows precise imaging of the different layers of the GI tract and beyond, into regions such as the posterior mediastinum and celiac area, and imaging of neighboring structures such as the pancreas, the gallbladder, and the left lobe of the liver [10, 11]. The Doppler function allows the visualization of vessels and helps differentiate venous from arterial vessels. Hence, EUS has been used as an imaging modality in the diagnosis and staging of tumors in this region. Linear-array endoscopes can also be used for invasive diagnostic and therapeutic procedures whereby a needle is introduced in the endoscope working channel and advanced into the area of interest under ultrasound visualization [10]. Fine needle aspiration of the tumor or injection of therapeutic substances into a lesion can then be performed [12–14]. The Doppler function verifies that there are no intervening vessels between the tumor and the needle. Real-time sonographic visualization of the needle being introduced into the lesion and the Doppler function both enhance the safety and accuracy of EUS-guided procedures. These same properties make placement of fiducial markers by EUS guidance an attractive approach for tumors in the posterior mediastinum and the abdomen.

12.2 Methods

12.2.1 Patient Selection

CyberKnife radiosurgery outside of the central nervous system is typically used in patients for whom conventional radiation therapy is contraindicated. Patients with a tumor located in the same field of a prior radiation treatment cannot undergo further conventional radiation therapy because of the potential for serious injury to the area. CyberKnife treatment is also indicated for intra-abdominal lesions because of the concern for radiation injury to the surrounding organs such as the bowel and the liver. Finally, CyberKnife is of particular interest in radiating intrathoracic lesions in patients with limited lung capacity (patients with COPD, emphysema, or with previous radiation injury to the lungs) who would not tolerate further damage to their lungs.

EUS-guided placement of fiducials should be considered in patients with a radiosensitive tumor located within the scanning field of the EUS probe, i.e., within 5 cm of the GI tract. Contraindications to EUS-guided fiducial placement include the inability of the patient to tolerate sedation for the procedure, coagulopathy (INR > 1.5 or platelet count < 50,000/cmm), and pregnancy.

12.2.2 Equipment and Procedure

The procedure is performed on an outpatient basis, in the endoscopy suite in a room where fluoroscopy is available. The patient is kept NPO after midnight the day before the procedure. For the procedure, the patient receives intravenous sedation, typically midazolam and fentanyl, or propofol. It is also recommended that patients receive prophylactic antibiotics, such as ciprofloxacin, on the day of the procedure and for three days afterward. A linear-array echoendoscope (Pentax, Orangeburg, NY) is introduced into the patient's mouth and advanced into the upper GI tract under direct endoscopic visualization. Using the ultrasound function of the echoendoscope, the intestinal or extraintestinal tumor is localized. The Doppler function is then used to verify that no vessel is present between the needle and the target. The tip of a 19-gauge needle (MEDI-Globe, Achenmuhle, Germany, or Sonotip II, Wilson-Cook, Winston-Salem, NC) is inserted into the lesion under EUS guidance (Fig. 12.1). The stylet inside the needle channel is removed and a fiducial is manually inserted into the needle lumen. The stylet is then reintroduced in the needle channel to push the fiducial through the channel until it enters the target tissue. The position of the fiducial should be verified by EUS (where it appears as a bright hyperechoic linear structure) and by fluoroscopy (Figs. 12.2 and 12.3).

This should be repeated to place 3 to 6 fiducials around the target area. The optimum angle and distance between the fiducials should also be monitored under real-time ultrasonography and fluoroscopy. The goal is to keep a minimum distance of 2 cm and an angle of at least 15 degrees between two fiducials in order to get accurate fiducial tracking by the CyberKnife system [15]. The size of the fiducials needs to fulfill two requirements: the fiducial should fit in the needle channel and it should be detectable by the CyberKnife system. We find that fiducials from Best Medical International (Springfield, VA) with a length of 3 or 5 mm and a diameter of 0.8 mm best fulfill these criteria (Fig. 12.4). An initial attempt to

Fig. 12.1 Linear-array echoendoscope with 19-gauge needle.

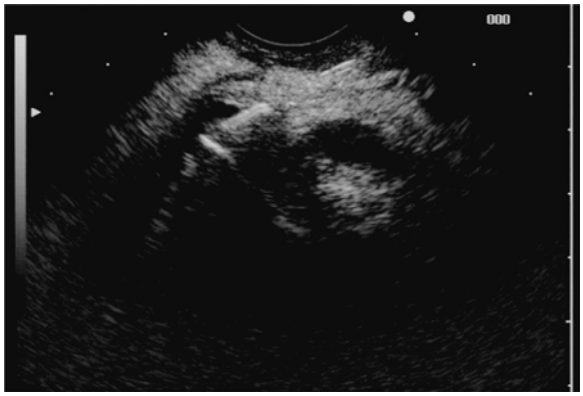

Fig. 12.2 EUS image with placement of gold fiducial.

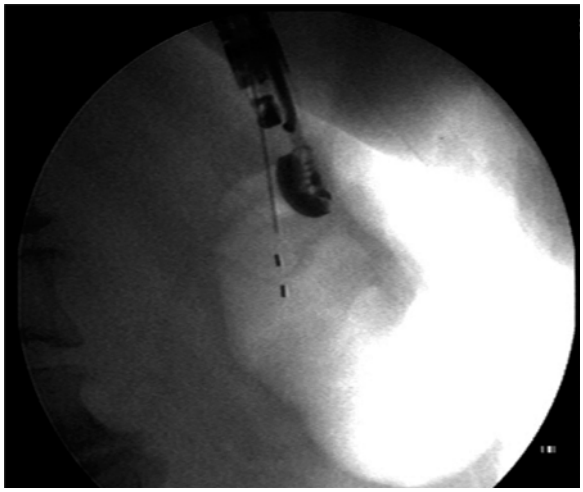

Fig. 12.3 Appearance of fiducials as seen with fluoroscopy.

place 5 mm fiducials should be made because this is the size approved for use with the CyberKnife system. However, in instances where the 5 mm fiducial cannot be passed into the needle for technical reasons, then a 3-mm fiducial can be used. For example, the tip of the EUS scope may be acutely bent in order to visualize a tumor, making the insertion of a long 5 mm fiducial beyond the bending point difficult to do. A smaller, 3-mm-long fiducial can be easier to use in these cases.

12.2.3 Technical Issues

Every attempt should be made to keep the EUS scope straight, to facilitate the passage of 5 mm fiducials;

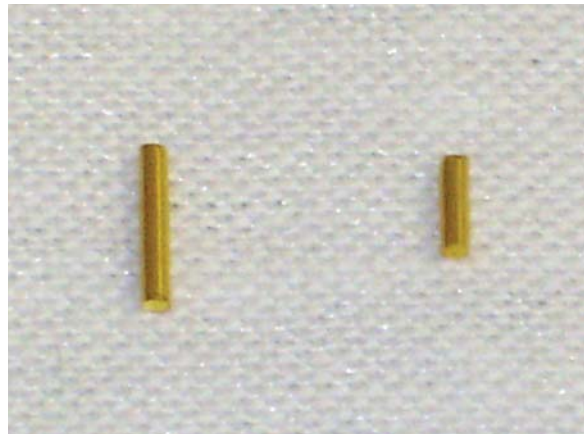

Fig. 12.4 A 5-mm and 3-mm gold fiducial.

as mentioned above, if necessary a 3-mm fiducial may be used. Another potential difficulty is the use of a 19-gauge needle. This is a large needle that can be difficult to penetrate hard tissue, such as pancreatic tumors. Finally, when marking lesions in the mediastinum, it can be difficult to achieve the optimal angle and distance between fiducials because of the nature of the mediastinal space.

12.3 Results

Pishvaian et al. reported that fiducials were successfully implanted near tumors throughout the abdomen and mediastinum in 11 of 13 patients. The procedure failed in 2 patients, in one because the progress and alignment of the endoscope was impeded by a pancreatic tumor obstructing the gastric outlet, and in the other because the aorta was in the path of the needle. The authors reported one infectious complication out of the 13 patients in the study [9]. The infection resolved with antibiotic treatment. Potential complications of the procedure not observed by Pishvaian et al. include the risks of sedation on the cardiovascular and respiratory systems, and the risk of infection, bleeding, and perforation of the GI tract.

12.4 Conclusion

Endoscopic ultrasound allows the visualization of lesions and structures within and around the GI tract. Compared to surgical and the percutaneous approaches, EUS-guided placement of fiducials is a minimally invasive and safe technique to mark tumors. Real-time imaging and the Doppler function minimize the risks of bleeding and perforation during fiducial placement. EUS has the great advantage of accessing lesions located deep in the posterior mediastinum and in the abdomen that would otherwise be difficult to reach. Hence, EUS-guided fiducial placement gives patients the possibility of undergoing CyberKnife treatment when conventional radiation therapy is not a good option.

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