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REVIEW

Computed Tomography-guided Puncture: Preprocedural Preparation, Technical Tips, and Radioprotection

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Abstract:
Computed tomography-guided puncture is a useful technique for various interventional radiology procedures. Puncture from various locations and angles becomes possible using this technique. Moreover, bone and air do not interfere with the computed tomography image. Therefore, computed tomography-guided puncture is feasible even in difficult cases of ultrasonography-guided procedures. However, a computed tomography-guided procedure can cause radiation exposure to patient and operator. Therefore, utmost attention should be given to minimizing radiation exposure.
This study aimed to provide a brief review of pre-procedural preparation and the technical tips for the computed tomography-guided puncture and introduce recent topics related to the radioprotection of computed tomography-guided puncture.

Keywords:
CT-guided puncture, CT fluoroscopy, biopsy, ablation

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Introduction

In interventional radiology (IR), CT-guided puncture is a vital procedure, with related techniques used for various IR procedures such as biopsy, ablation, and drainage [1-6]. Moreover, bone and air do not interfere with the CT image. Therefore, CT-guided puncture is feasible even in difficult cases of US-guided procedures [3]. Careful preparation and precise technique are required to succeed in those procedures and to avoid unnecessary complications.

This study aims to present various tips for pre-procedural preparation and for techniques of CT-guided puncture and introduce recent topics related to radioprotection and CT-guided puncture.

Preprocedural Preparation

Proper preprocedural preparation, such as checking the patient's general condition and preprocedural imaging, is necessary for performing CT-guided punctures safely and reliably.

When a CT-guided puncture procedure is requested, the related medical records and images must be checked carefully to elucidate the patient's general condition. Furthermore, the IR doctor should always examine the patient independently in advance. During the examination, the IR doctor must verify whether the patient can follow the IR doctor's instructions, whether the patient can change and maintain a certain body position, and the degree to which the patient can hold their breath, among others. Furthermore, the patient's medical history, allergy history, and the presence or absence of antiplatelet and anticoagulant drugs must be reviewed carefully. In particular, the management of bleeding risk is important. The criteria for safe CT-guided puncture procedures are as follows: prothrombin time-international normalized ratio (PT-INR) <1.5, activated partial throm-

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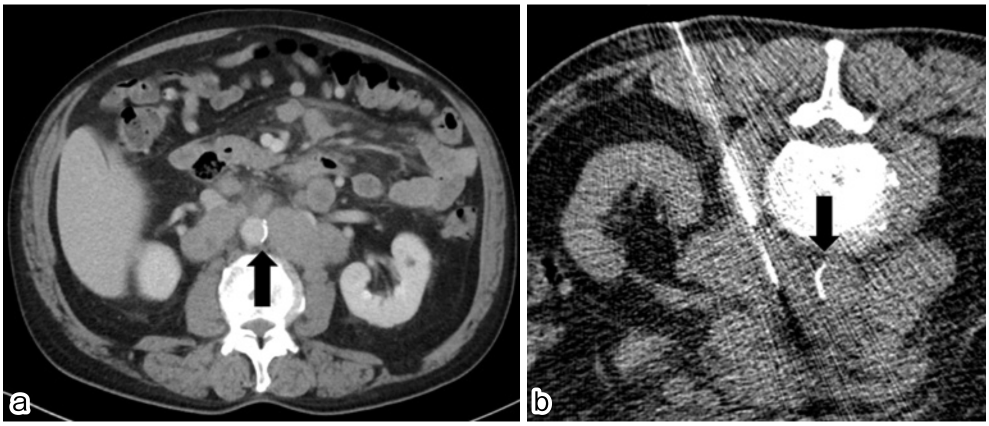

Figure 1. A man in his 70s with paraaortic lymph nodes swelling. (a) Axial contrast-enhanced CT image shows the paraaortic lymph nodes swelling. Calcification of the adjacent aortic wall was observed (arrow). (b) A CT-guided biopsy of the paraaortic lymph node was performed using the calcification of the aortic wall as an anatomical landmark. The result of the biopsy indicated lymph node metastases from malignant mesothelioma.

boplastin time (APTT) ≤1.5 times, and a platelet count of 50,000/uL or more [7].

The indication of a CT-guided puncture procedure is determined based on preoperative images and medical records. In evaluating that indication, operators must thoroughly consider whether CT-guided puncture is suitable. Indeed, even when a CT-guided puncture is requested, there are actually a few cases wherein ultrasound-guided puncture is more suitable, such as cases wherein lesions are located superficially or when lesions are invisible on plain CT imaging. The readily apparent shortcoming of CT-guided puncture is radiation exposure. Therefore, operators must always consider whether the CT-guided puncture is truly the best option for the patient.

The location of critical organs such as blood vessels, nerve system, and gastrointestinal tract should be carefully assessed by the preprocedural CT or MR in order to avoid complications [1, 2, 6]. In particular, contrast-enhanced CT or MR imaging must be included as preoperative imaging whenever possible. There are times when blood vessels are running in an unexpected site. Therefore, preoperative contrast-enhanced CT or MR imaging is extremely useful to avoid unnecessary hemorrhagic complications. In addition, it is also crucial for operators to recognize that the position of the anatomical structures on imaging can change based on the actual position of the patient during the CT-guided percutaneous procedure.

Technical Tips for CT-guided Puncture

To perform CT-guided puncture safely and reliably, the target lesion must be clearly visible on CT imaging. Moreover, even if the target lesion can be clearly seen, it is still necessary to consider carefully whether a safe puncture route can be found to reach the target lesion. When visually recognizing the target lesion is difficult, or when ensuring a safe puncture route is difficult, the following tips can be used.

Increase the visibility of poorly visualized lesions

Even if the target lesion is visible on contrast-enhanced CT, MRI, or PET-CT, it is sometimes difficult to identify the lesion on plain CT. In such cases, anatomical landmarks near the target lesion can facilitate precise targeting. Anatomical landmarks include areas of calcification, cysts, vessels, bones, and the distinctive shapes of organs (**Fig. 1**). To find such anatomical landmarks, a detailed evaluation of preprocedural CT imaging must be done.

If anatomical landmarks are not available, then the injection of contrast material before CT-guided puncture is useful to improve the visibility of target lesion. The type of contrast material (i.e., water-soluble or oil-based) and the route of the contrast administration (i.e., transvenous or transarterial) can be chosen depending on the target tumor or organ. For example, intra-arterial injection of iodized oil increases the visibility of hepatocellular and renal cell carcinoma before CT-guided IR procedures (**Fig. 2**, and **3**) [3, 8]. Accumulation of iodized oil into the target tumor is also useful for the precise evaluation of the ablative margin after ablation therapy (**Fig. 2c**).

Ensure the safe puncture route

Even if the target lesion is clearly visible on plain CT, critical organs such as blood vessels, intestines, and lungs are in some cases located on the pass on the puncture route from the body surface to the target lesion. In such cases, changing the patient's position is sometimes helpful [9]. For example, changing the body position might change the position of the intestinal tract to ensure a safe puncture route. Moreover, when performing a CT-guided puncture for retroperitoneal targets in the upper abdomen, as well as renal and adrenal, if the procedure is performed in the prone position, then the lungs might be positioned on the puncture path, resulting in a transpulmonary puncture. In such cases, changing the patient's body position to the ipsilateral decubitus position (disease side down) can avoid transpulmonary

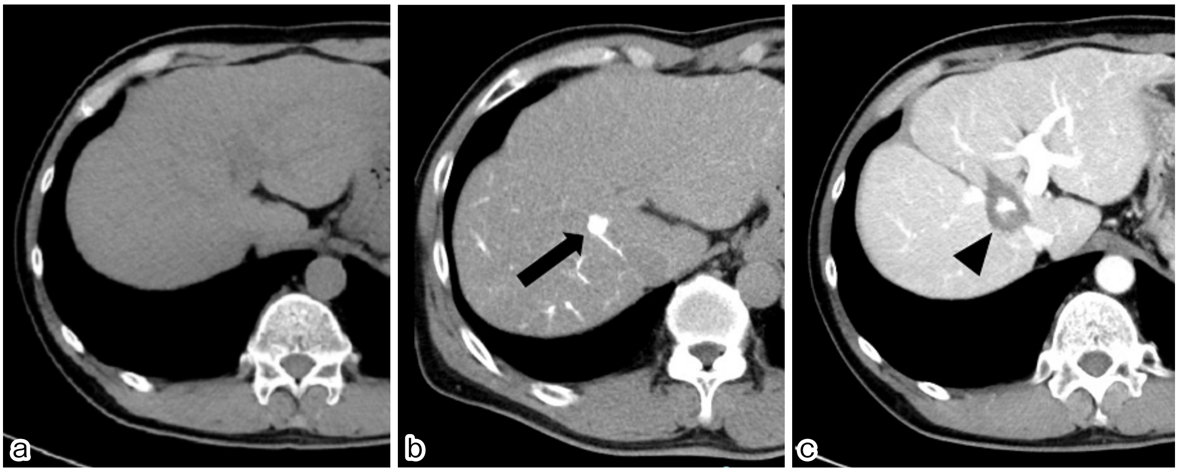

Figure 2. A man in his 60s with hepatocellular carcinoma (HCC). (a) Target HCC was not visible on plain CT. (b) Intra-arterial injection of iodized oil enhanced the visibility of HCC (black arrow). Radiofrequency (RF) ablation was then successfully performed. (c) Contrast-enhanced CT image acquired 3 days after RF ablation showed a non-enhancing area surrounding the index tumor (black arrowhead).

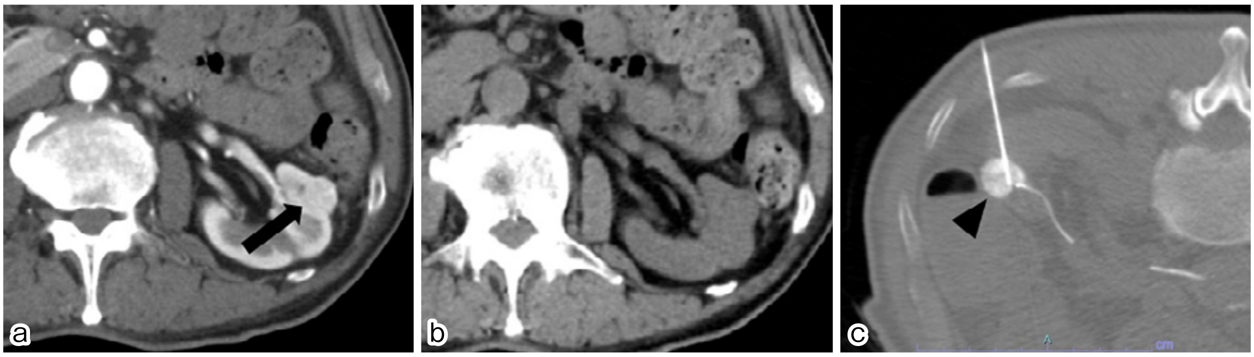

Figure 3. A man in his 70s with a renal tumor. (a) Contrast-enhanced CT image shows a hypervascular tumor in the left kidney (black arrow). (b) Target renal tumor was less visible on plain CT. (c) Intra-arterial injection of iodized oil enhanced the visibility of the renal tumor. Percutaneous biopsy and ablation were successfully performed (black arrowhead).

Figure 4. Reprinted by permission of the Japanese Journal of Interventional Radiology [6].
A woman in her 80s with a right adrenal tumor. (a) Axial contrast-enhanced CT image shows the right adrenal tumor (black arrow). (b) CT in the prone position. In this position, lung parenchyma intervened in the access root; there was a risk of a transpulmonary approach (white arrowhead). (c) CT in the ipsilateral decubitus position allowed the ipsilateral lung to be compressed to avoid the transpulmonary approach. The biopsy was successfully performed from the right adrenal gland (black arrow). The biopsy result indicated adrenal metastasis from primary lung cancer.

puncture (**Fig. 4**).

If there will be a case wherein no safe puncture route can be ensured even after the changes in the patient's body position, then injecting fluid between the target lesion and the

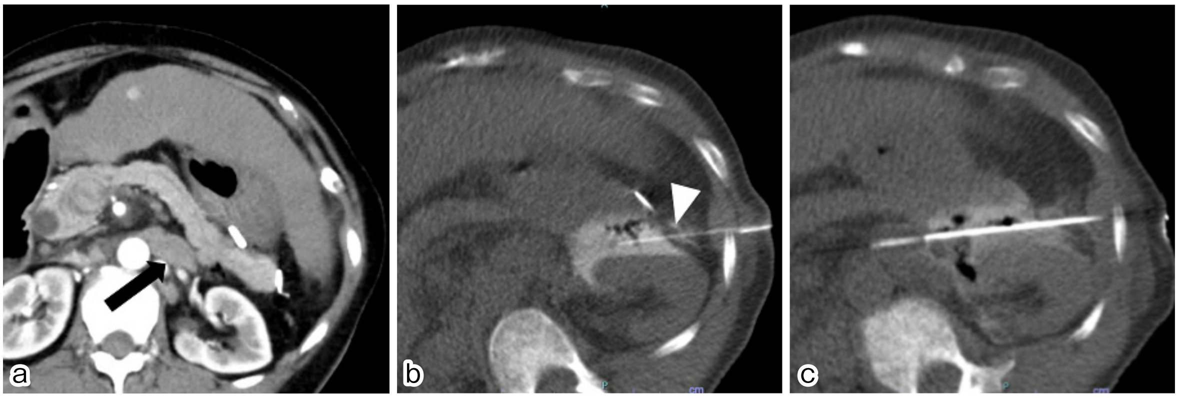

Figure 5. A woman in her 70s with a paraaortic tumor. (a) Axial CT image shows a paraaortic tumor (black arrow). A CT-guided biopsy was requested for histopathological diagnosis. (b) To ensure a safe puncture route, saline with contrast medium was injected at the left perirenal space by a 22-G Cathelin needle (white arrowhead). (c) A CT-guided biopsy was successfully performed without injuring adjacent organs. The biopsy result indicated follicular lymphoma.

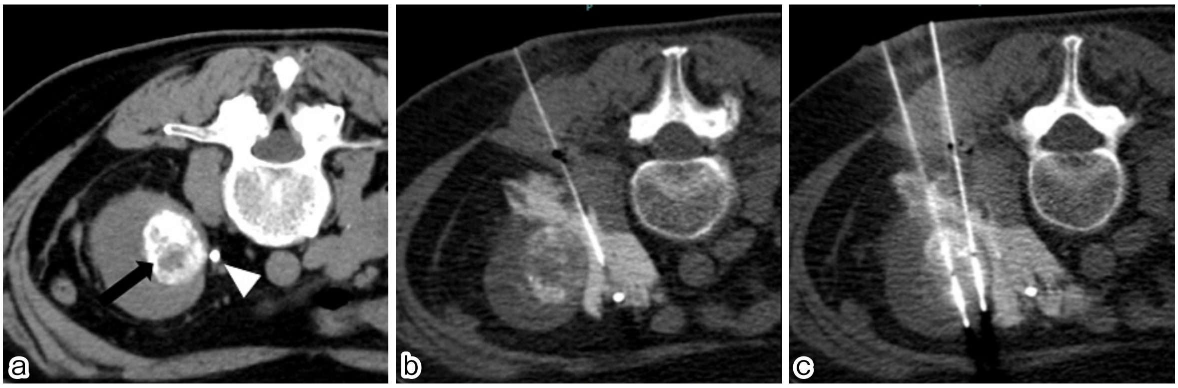

Figure 6. A woman in her 70s with renal cell carcinoma (RCC). (a) Axial CT image shows a left RCC with lipiodol accumulation (black arrow). The left ureter with the ureteral catheter was adjacent to the RCC (white arrowhead). (b) To avoid ureteral damage, saline with contrast medium was injected at the left perirenal space using an 18-G PTC needle. After hydrodissection, the ureter was separated from the RCC. (c) Cryoablation was successfully performed without injuring the ureter.

critical organ (hydrodissection) can be useful (**Fig. 5**) [10]. Saline and 5% dextrose in water are commonly used fluids at the time of hydrodissection. This method prevents damage to organs adjacent to the target lesions during ablation therapy (**Fig. 6**). Pneumodissection using air or carbon dioxide gas also ensures a safe puncture route and avoids collateral damage to the adjacent organ at the time of ablation therapy [11]. Furthermore, when performing CT-guided puncture for lung or anterior mediastinal lesions, it might be possible to avoid the puncture of normal lung parenchyma by accumulating local anesthesia immediately below the parietal pleura (**Fig. 7**).

A transorgan approach is another technique to reach the target lesion at a difficult location. Transorgan approaches through the scapula, rib, iliac bone, sacral bone, and liver have been reported (**Fig. 8**) [12-14].

Radiation Exposure and Protection

The methods of CT-guided puncture are classified into two types: conventional and CT fluoroscopy-guided. The conventional method is performed by repeating conventional CT imaging and by advancing and adjusting the angle of the puncture needle to reach the target lesion. In CT fluoroscopy-guided methods, the puncture needle is advanced to the target lesion using real-time CT fluoroscopy imaging. In general, CT fluoroscopy-guided method enables more precise targeting and reading to a low complication rate. Indeed, it has been reported that the frequency of pneumothorax after CT fluoroscopy-guided lung biopsy was lower than the use of the conventional method [15, 16].

The greatest shortcoming of CT fluoroscopy is its inherent radiation exposure to the operator and the patient. Kim et al. compared the respective degrees of the patients' and the operators' radiation exposure during conventional and CT fluoroscopy-guided lung biopsy [15]. Their findings showed that the patients' and the operators' radiation exposure were significantly greater during the CT fluoroscopy-guided lung biopsy (p < 0.001) [15]. Froelich et al. used the CT dose index to compare patients' radiation doses received

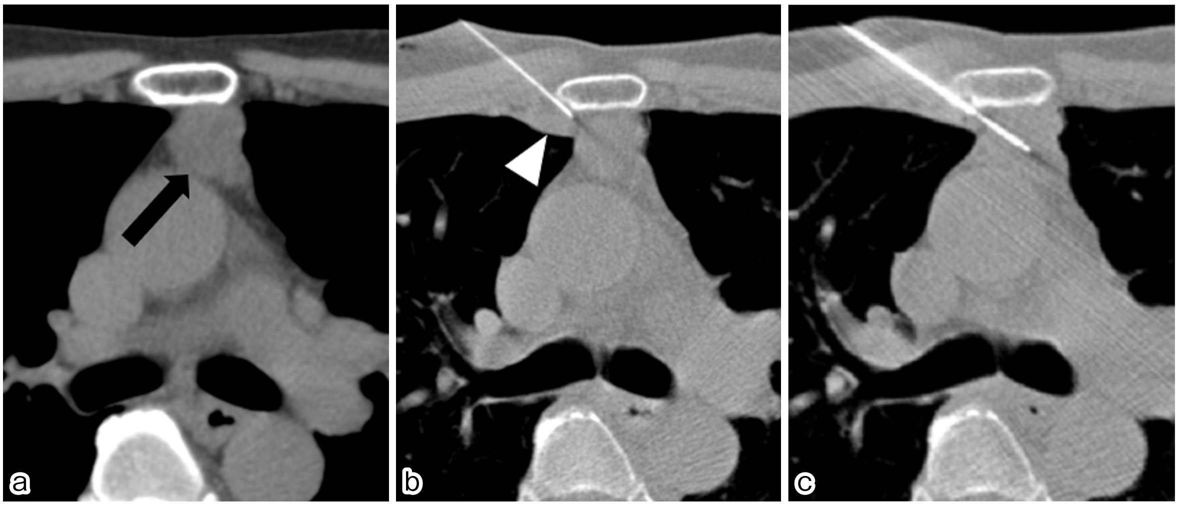

Figure 7. Reprinted by permission of the Japanese Journal of Interventional Radiology [6]. A man in his 60s with an anterior mediastinal tumor. (a) Axial CT image shows an anterior mediastinal tumor (black arrow). A CT-guided biopsy was requested for histopathological diagnosis. (b) To avoid transpulmonary puncture, 0.5% lidocaine was injected into the parasternal region (white arrowhead). (c) A CT-guided biopsy was successfully performed without penetrating the lung parenchyma. The biopsy result indicated primary lung cancer.

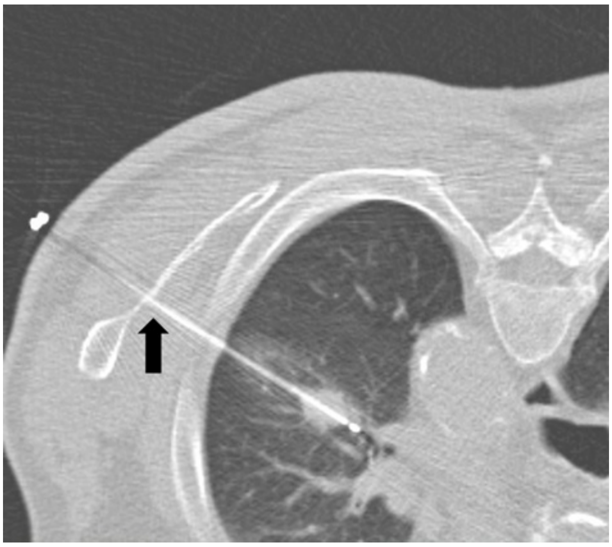

Figure 8. A man in his 60s with a metastatic lung tumor from rectal cancer. For the treatment of the lung tumor, CT-guided radiofrequency ablation was performed. In this case, the lung tumor was surrounded by pulmonary vessels. To avoid the pulmonary vessels, the electrode was inserted via transscapular approach (arrow).

during conventional and CT fluoroscopy-guided lung biopsy [17]. Their results indicated that although there was no significant difference, there was a tendency by which the patients' radiation dose was greater in the CT fluoroscopy-guided biopsy group (451 mGy) than in the conventional biopsy group (374 mGy, p = 0.36) [17].

Operators must wear radioprotective devices such as lead glass, aprons, and gloves to reduce radiation exposure. Moreover, recently, the usefulness of angular beam modulation (ABM) as a technique used to reduce radiation exposure for CT fluoroscopy-guided IR procedures has been reported. ABM is a function that blocks X-ray generation completely over a range of approximately 100° centering on a certain angle (10 o'clock, 12 o'clock, 2 o'clock direction) of a rotating X-ray tube. Moreover, it has been reported that ABM reduces scattered radiation to the operator by approximately 20% and reduces direct radiation by approximately 70% [18]. However, in our study, the operator's exposure dose during the CT fluoroscopy-guided procedure reached a maximum of 1,013 μSv/case, even with ABM. Therefore, further radioprotective measures for operators are necessary [19]. Recently, a semicircular X-ray shielding device specialized for CT fluoroscopy-guided IR procedures (Kamakura®; Sankyo Medical Instruments Co., Ltd., Japan) was introduced (**Fig. 9**). Results obtained from our experimentation indicated that the use of this X-ray shielding device can reduce the operator's radiation exposure by approximately 80%-90%. In this way, even for CT fluoroscopy-guided IR procedures, the amount of radiation exposure can be significantly reduced using the radioprotective function of the CT machine together with radiation protection devices.

Conclusion

CT-guided puncture is a useful technique for various IR procedures. This technique sometimes becomes decisive for diagnosis and treatment in difficult cases. Therefore, interventional radiologists should be proficient in using this technique.

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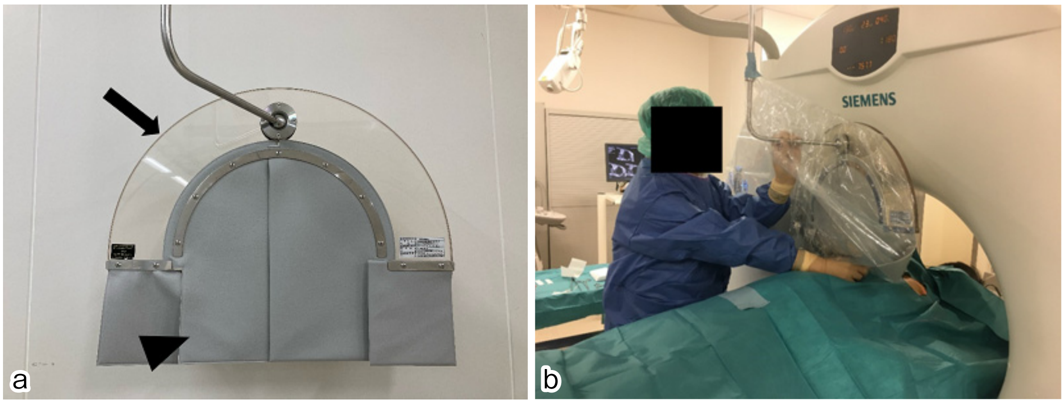

Figure 9. Semicircular X-ray shielding device. (a) Semicircular X-ray shielding device comprises a semicircular Pb acrylic board (arrow) and Pb drapes (arrowhead). (b) Operators can perform the IR procedure by inserting their hands through the slit of the Pb drapes or below the drapes.

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