ACTA RADIOLÓGICA PORTUGUESA
January-April 2024 | Vol 36 nº 1 | 20-24
https://doi.org/10.25748/arp.34838

State-of-the-art Interventional Radiology - Selected Cases/ Vanguarda da Radiologia de Intervenção: Casos seleccionados

Microwave Ablation of Lung Nodule

Termoablação por Micro-Ondas de Nódulo Pulmonar

Tiago Paulino Torres[1], João Praia[1], Rui Ramos[1], Catarina Oliveira[1]

[1]Departamento de Radiologia, Unidade Local de Saúde de Trás-os-Montes e Alto Douro (ULSTMAD), Vila Real, Portugal

Address

Tiago Paulino Torres
Departamento de Radiologia
Unidade Local de Saúde de Trás-os-Montes e Alto Douro (ULSTMAD)
Av. da Noruega – Lordelo
5000-508 Vila Real, Portugal
e-mail: tiagoptorres@gmail.com

Received: 11/03/2024
Accepted: 12/04/2024
Published: 30/04/2024

Abstract

We present a clinical case of a 71-year-old man with history of rectal adenocarcinoma cT3N1M0, previously treated with neoadjuvant chemotherapy/radiotherapy and anterior resection of the rectum. During imaging follow-up, a new growing pulmonary nodule was identified in the left upper lobe. After two biopsies of this nodule yielded insufficient material, the patient refused a third attempt. This nodule is intensely hypermetabolic on PET-CT, suggestive of metastasis. The decision by a multidisciplinary team was to treat the pulmonary nodule with microwave ablation. Image-guided thermal ablation is a technique in the field of Interventional Radiology that has emerged as a minimally invasive option for treating tumors in multiple organs, with various indications and excellent results. A good understanding of the (un)expected imaging characteristics after thermal ablation, also presented in this article, is crucial for effective patient surveillance and management.

Keywords

Thermal ablation; Microwave; Lung; Interventional radiology.

Resumo

Apresentamos o caso clínico de um homem de 71 anos, com antecedentes de adenocarcinoma do reto cT3N1M0, previamente tratado com quimioterapia/radioterapia neoadjuvante e resseção anterior do reto. No seguimento imagiológico, identificou-se um novo nódulo pulmonar em crescimento no lobo superior esquerdo. Após duas biópsias deste nódulo com material insuficiente, o paciente recusa a terceira tentativa. Este nódulo é intensamente hipermetabólico na PET-TC, sugestivo de metástase. A decisão em equipa multidisciplinar foi de tratamento com termoablação por micro-ondas do nódulo pulmonar. A termoablação guiada por imagem é uma técnica no campo da Radiologia de Intervenção, que tem surgido como opção minimamente invasiva para tratamento de tumores em múltiplos órgãos, com diversas indicações e ótimos resultados. Uma boa compreensão das características imagiológicas (in)esperadas após termoablação, também apresentadas neste artigo, é crucial para uma vigilância eficaz destes doentes.

Palavras-chave

Termoablação; Micro-ondas; Pulmão; Radiologia de intervenção.

Introduction

Image-guided percutaneous thermal ablation techniques are established in the local treatment of liver, kidney, bone tumors, thyroid nodules, among other organs.[1] These Interventional Radiology techniques include radiofrequency, microwave (MW), cryoablation and laser-induced thermotherapy (LITT).[1]

In the context of lung lesions, the growing population of patients with comorbidities or surgical contraindications has given popularity to less invasive therapeutic options, such as stereotactic radiotherapy and thermal ablation, in selected patients. Thermal ablation may be indicated in some patients with stage IA non-small cell lung cancer (NSCLC) (limited to T1a and T1b) and in patients with oligometastatic colorectal carcinoma with up to 3 pulmonary nodules (≤ 2 cm each), with surgical contraindications.

Clinical Case

In this article, we present the clinical case of a 71-year-old man, with a history of cT3N1M0 rectal adenocarcinoma, previously treated with neoadjuvant chemotherapy/radiotherapy and anterior rectal resection. During imaging follow-up, a new growing pulmonary nodule was identified in the left upper lobe (Figure 1). After two biopsies of this nodule with insufficient material, the patient refused a third attempt. This nodule was intensely hypermetabolic on PET-CT, suggesting metastasis (Figure 1). The decision made by a multidisciplinary team was to treat the pulmonary nodule with microwave (MW) thermal ablation.

On the day of the procedure, the patient was admitted to the hospital and informed consent was previously obtained. A review of previous exams, blood tests and medication was carried out in accordance with CIRSE standards of practice.[2] After reviewing recent thoracic tomodensitometric images for pre-procedural planning, it was decided to perform thermal ablation with a posterior percutaneous approach – the anterior approach, with a possible shorter intra-parenchymal route, would not be possible due to interposition of some anterior anatomical structures (subclavian artery and vein, clavicle, sternoclavicular joint, brachial plexus). A tomodensitometric acquisition immediately prior to the procedure allowed the correct positioning of the patient and selection of the best axial slice to perform the procedure guided by CT fluoroscopy.

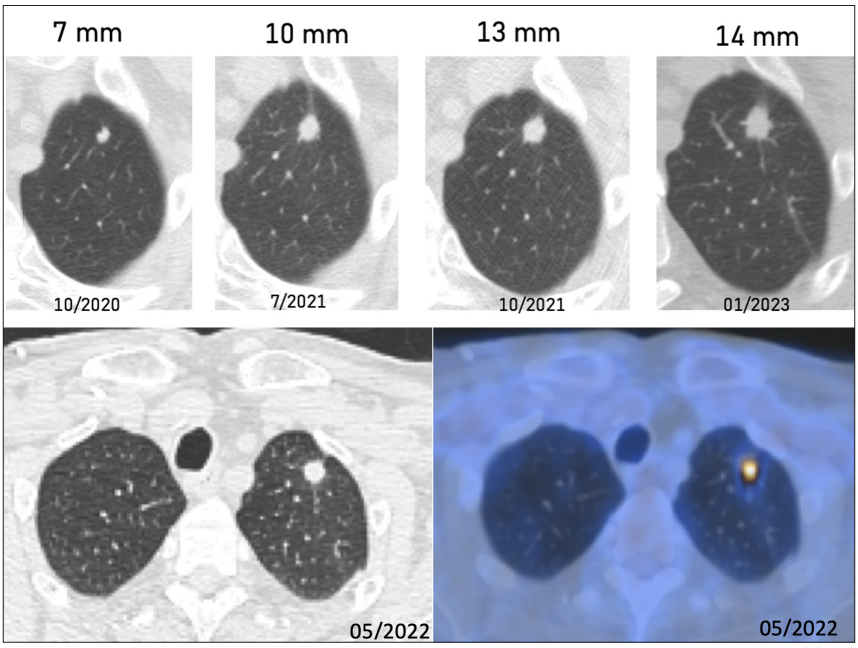

Figure 1 – Growing pulmonary nodule in the left upper lobe, intensely hypermetabolic on PET-CT, suggesting metastasis.

Figure 2 shows the necessary material to perform thermal ablation.

The preparation and organization of the team, the intervention room itself, the material and ensuring the proper functioning of the microwave generator are essential initial steps. With the patient correctly positioned in relation with the gantry, the skin was sterilized and a sterile surgical field was placed in the region of interest – at that point, it was possible to confirm the most appropriate skin entry point and administer lidocaine locally (Fig. 3A), already planning the correct orientation of the needle (and subsequently, of the antenna).

Then, a small incision was made in the skin with the scalpel. The following step involves percutaneous puncture with the microwave antenna (Fig. 3B), positioning it in the correct entry angle toward the target lesion.

With the necessary adjustments, the antenna was progressively advanced, under image guidance (fluoro-CT), until reaching the target lesion (Fig. 3C and 3D). In this process, it is

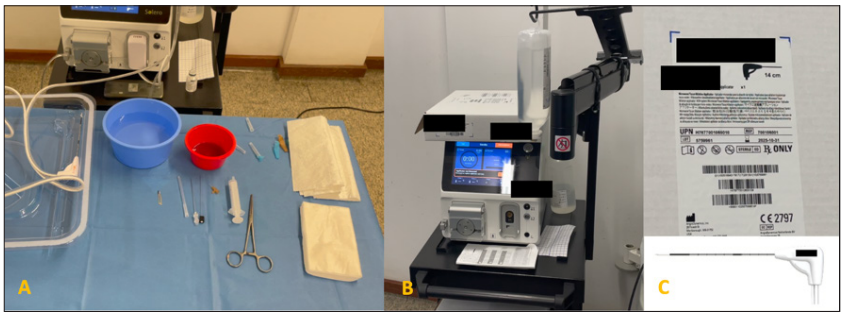

Figure 2 – Equipment and material. A) Hypodermic needles (23G x 25 mm; 25G x 16 mm), 22G x 15 cm needle, 20 mL syringe, scalpel, lidocaine (1%, 10mg/mL), 0.9% saline solution, antiseptic skin solution. B) Microwave generating system (MW). C) 15G x 14 cm MW antenna.

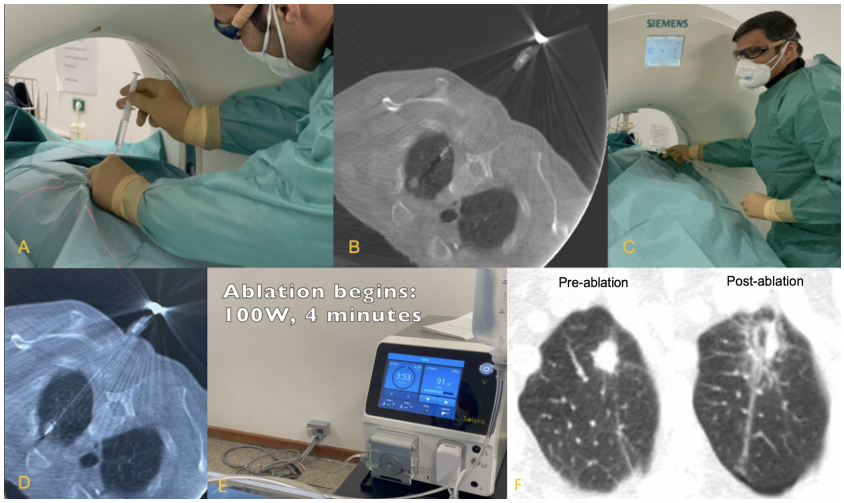

Figure 3 – Thermal ablation procedure. A) Lidocaine injection. B) Percutaneous path of the microwave (MW) antenna. C) Adjustment of the antenna orientation and progressive advancement towards the lung lesion. D) Final confirmation of the correct positioning of the antenna in the target lesion. E) Beginning of thermal ablation, with anesthetic support. F) Tomodensitometric acquisition before and immediately after ablation.

important to pierce the pleura and parenchyma with a single deliberate movement.

With a last tomodensitometric acquisition (Fig. 3D), the position of the antenna was confirmed before starting the ablation. The anesthesiology team confirmed adequate sedo-analgesia at this stage. The correct ablation power and time were chosen according to the table provided by the equipment, to ensure treatment of the target lesion with an adequate margin, thus starting thermal ablation (Fig. 3E). During the procedure, it is important to keep the antenna in the correct position. At the end of the ablation, the antenna was safely removed, without performing ablation of the path (not recommended in pulmonary ablations, due to the risk of bronchopleural fistula[1]).

To confirm the final result, a chest CT was performed immediately after ablation. In this case, it was possible to appreciate the ablation zone (AZ), with a halo of ground-glass opacity with a margin of approximately one centimeter, also observing the trajectory of the antenna and a small post-procedure pneumothorax (Fig. 3F, Fig. 4).

A chest x-ray should be performed 1 to 4 hours after the procedure to exclude pneumothorax or other complications.

The patient remained hospitalized and monitored for only 1 day. Control radiographs showed no relevant changes, the patient remained apyretic, without dyspnea or other respiratory symptoms, with controlled pain (paracetamol 1000 mg, per os, every 8 hours). The patient was discharged the morning after the procedure and follow-up appointments and protocol surveillance imaging exams were scheduled (Fig 5). On the follow-up CT 3 months after ablation (Fig. 5C), a nodular area with an elongated morphology and larger dimensions was evident in the thermal ablation site, prompting a re-evaluation by PET-CT to exclude local recurrence of disease. In this PET-CT examination carried out 8 months after ablation (Fig. 5D and 5E), a dimensional reduction of the previous nodular area was observed, now assuming a linear cicatricial densification morphology, without FDG-F18 uptake, and no hypermetabolic changes suggestive of active, loco-regional or distant, disease. This lung thermal ablation procedure was a technical and clinical success, and the patient remains asymptomatic and under surveillance.

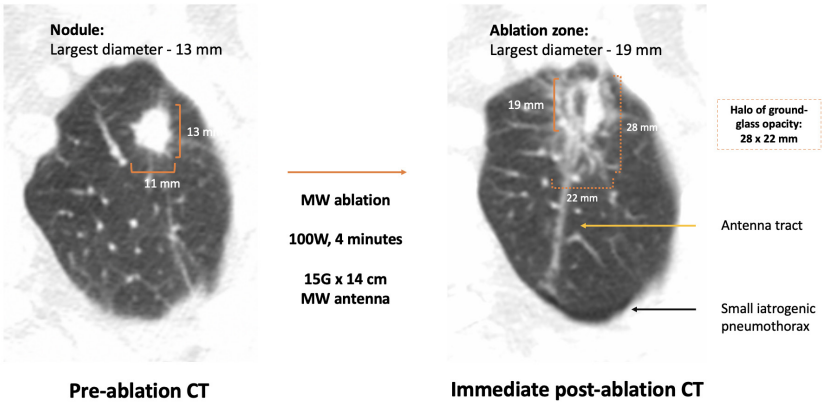

Figure 4 – CT immediately after thermal ablation.

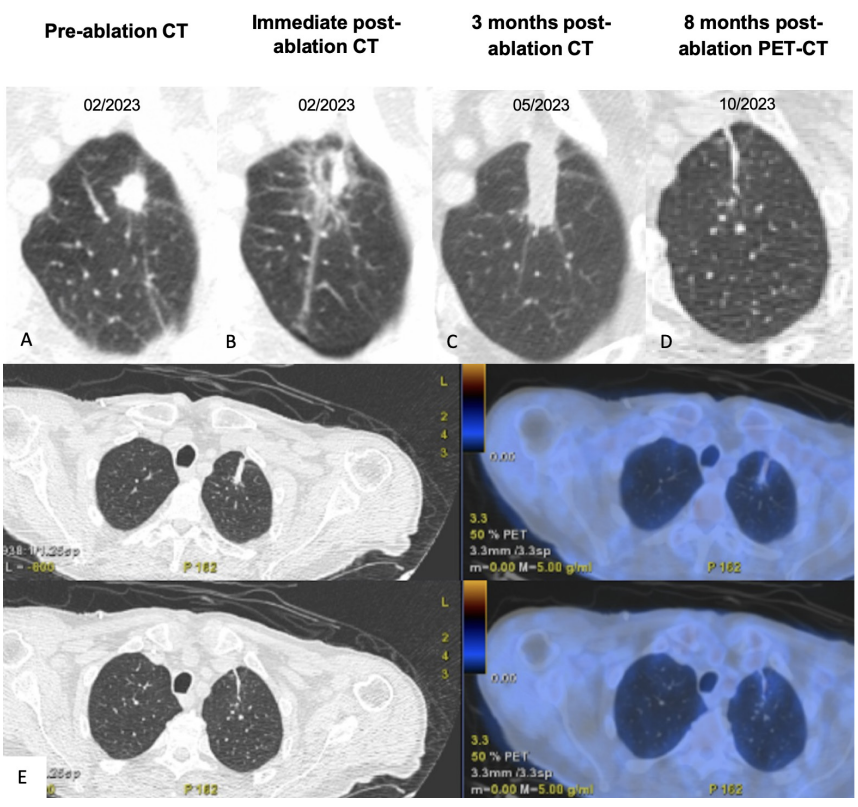

Figure 5 – Imaging surveillance. Pre-ablation tomodensitometric examinations (Fig. 5A), immediately after ablation (Fig. 5B) and post-ablation imaging follow-up (Fig. 5C-E). PET-CT examination performed 8 months after ablation (Fig. 5D and 5E) without findings suggestive of active, loco-regional or distant, disease.

Discussion

Microwave (MW) thermal ablation is a technique that, through an antenna, uses electromagnetic energy to oscillate water molecules and produce heat through friction, culminating in cell death. Compared to other thermal ablation technologies (e.g. radiofrequency (RFA)), MW technology has some advantages: less heat sink effect (efficient ablation close to vessels); propagation into fat and calcifications (homogeneous coagulation necrosis); higher (intra-tumoral) temperatures (greater and faster necrosis); faster ablation time; larger ablation volume; no need for grounding pads.[1]

In patients with non-small cell lung carcinoma (NSCLC), although surgical resection is the first therapeutic option in stages I to IIIA, percutaneous thermal ablation may be indicated in patients with stage IA NSCLC (limited to T1a and T1b) who have contraindications for surgery or stereotactic radiotherapy (due to cardiorespiratory comorbidities or insufficient lung vital capacity).[1,3,4]

In cases of pulmonary metastasis, lung thermal ablation is indicated in patients with oligometastatic colorectal carcinoma with up to 3 pulmonary nodules (≤ 2 cm each) and who have a contraindication for surgery.[1,3]

An example of a recommended protocol[1] for imaging surveillance after lung thermal ablation, similar to that adopted by our institution, includes: contrast-enhanced computed tomography (CT) performed at 1, 3, 6, 9, 12, 18 and 24 months, and then annually; PET/CT scan with FDG performed at 3 and 12 months, and whenever there is suspicion of disease recurrence at any time during the protocol CT assessment.

For effective surveillance, it is crucial to recognize the imaging features expected after ablation and the features suggestive of residual or recurrent tumor.

The tomodensitometric characteristics after thermal ablation vary in time[5] and can be framed and described as follows (adapted from Torres et al, educational poster "CT imaging features of microwave ablation of lung malignant nodules" presented at the Portuguese National Congress of Interventional Radiology in 2021) (Figure 6 and Figure 7):

- Early stage (immediately after ablation until 1 week afterwards)
  Immediate post-ablation CT demonstrates a central area of consolidation (representing the ablated tumor and necrotic lung parenchyma) surrounded by a halo of ground glass opacity (GGO) that may be composed of two layers: an inner circle of GGO around the lesion and an outer circle of denser GGO. This described area, considered as the ablation zone (AZ), is generally oval and larger than the initial tumor (continuing to increase in size in the first 24 hours), with comparatively reduced enhancement (however, at this stage, a benign peripheral border of enhancement, concentric, smooth and < 5mm thick can be identified). Sometimes, dissection of the central tissue is identified along the path of the antenna.
- Intermediate stage (1 week to 2 months)
  The AZ margin becomes denser and the surrounding GGO involutes in up to 3 months. Cavitation is common and can be considered a positive response to treatment. The AZ remains larger than the pre-ablation tumor but may be smaller compared to the immediate post-ablation acquisition. AZ enhancement is inferior compared to pre-ablation, although the aforementioned benign peri-ablation enhancement may persist.
- Late stage (> 2 months)
  The AZ continues to regress and after 6 months it is expected to be smaller than the pre-ablation tumor, resulting in a scar (as in our clinical case) or a thin-walled

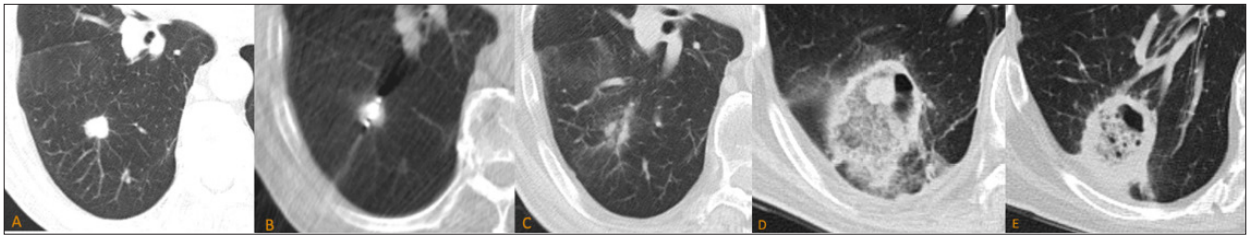

Figure 6 – Imaging characteristics after thermal ablation - early phase (immediately post-ablation to 1 week) and intermediate phase (1 week to 2 months). Companion case: 78-year-old male, invasive primary rectal adenocarcinoma. A) 15 mm lung metastasis in the upper segment of the right lower lobe (RLL). B) Microwave thermal ablation (MWA), 100 W for 2 minutes. C) Immediately post-thermal ablation: ground glass opacity (GGO) involving the treated lesion, with dissection of the parenchyma along the path of the antenna. D) 4 days post-thermal ablation: cavitation in the ablation zone (AZ), Central area of consolidation surrounded by a halo of GGO: internal area of GGO around the lesion and an external circle of denser GGO. E) 1-month post-thermal ablation: decreased size of the AZ, denser peripheral margin, involution of the surrounding GGO, persistent internal cavitary changes.

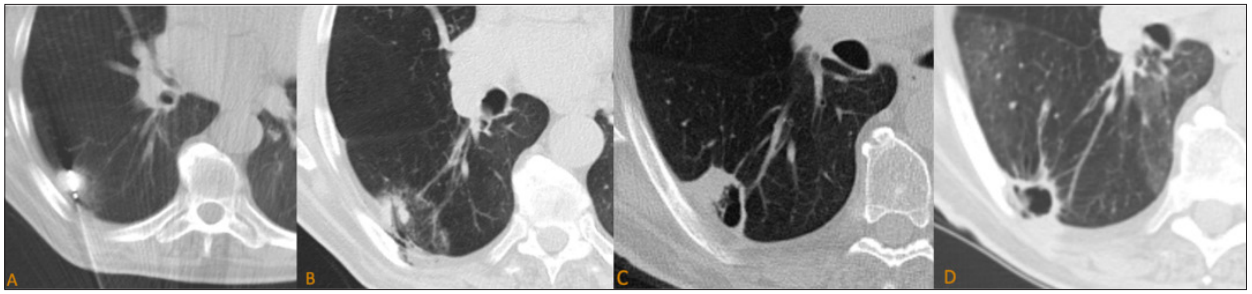

Figure 7 – Imaging characteristics after thermal ablation - late phase (> 2 months). Companion case: 71 years old, male, invasive primary rectal adenocarcinoma. A) Single metastatic pulmonary nodule measuring 14 mm in the right lower lobe, submitted to microwave thermal ablation (MWA), 140 W for 4 minutes. B) Immediately post-thermal ablation: ground glass opacity (GGO) involving the treated lesion, with dissection of the parenchyma along the path of the antenna. C) 4 months post-ablation: cavitation, resolution of the surrounding GGO, with a remaining solid nodular component smaller than the initial lesion. D) 12 months post-ablation: involution of the solid nodular component, regression of the lesion to a well-defined cavitation.

cavity. The presence of new nodules, particularly after 6 months, is highly suggestive of tumor recurrence. After this period, contrast enhancement should not be greater than that of the initial tumor. Some parenchymal features such as cavitation and pleural changes (thickening, effusion, local pneumothorax) may resolve during this period.

The criteria proposed in the CIRSE Standards of Practice on Thermal Ablation of Primary and Secondary Lung Tumors[1] document for evaluating response after thermal ablation include:

Complete response:

- ≥ 30% reduction in the largest tumor diameter (compared to the tumor diameter assessed in the 1st month post ablation)
- And no evidence of post-contrast enhancement.

Incomplete ablation (features suggestive of residual tumor):

- Intratumoral enhancement after contrast, or
- Tumor growth on the periphery of the ablation site, or
- Increase of ≥ 20% in the largest tumor diameter.

The imaging characteristics suggestive of residual or recurrent tumor after MW thermal ablation are relatively overlapping with the characteristics after RFA ablation, described in the literature.[1,5]

Practical and theoretical knowledge of the specificities of each thermal ablation equipment and antenna, as well as the characteristics of the generated ablation site, are essential for a controlled and effective intervention.

This clinical case reports the use of microwave thermal ablation in the treatment of a lung lesion, with technical and clinical success, illustrating the step-by-step procedure, with an explanation of the surveillance protocol, the imaging characteristics expected after ablation and the features suggestive of residual or recurrent tumor.

Conclusion

Image-guided thermal ablation is a technique in the field of Interventional Radiology that has emerged as a minimally invasive option for treating tumors in multiple organs, with diverse indications and excellent results.

A good understanding of the (un)expected imaging features after thermal ablation is crucial for an effective surveillance of these patients.

Ethical Disclosures / Divulgações Éticas

Conflicts of interest: The authors have no conflicts of interest to declare.

Conflitos de interesse: Os autores declaram não possuir conflitos de interesse.

Financing Support: This work has not received any contribution, grant or scholarship.

Suporte financeiro: O presente trabalho não foi suportado por nenhum subsídio ou bolsa.

Confidentiality of data: The authors declare that they have followed the protocols of their work center on the publication of data from patients.

Confidencialidade dos dados: Os autores declaram ter seguido os protocolos do seu centro de trabalho acerca da publicação dos dados de doentes.

Protection of human and animal subjects: The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Protecção de pessoas e animais: Os autores declaram que os procedimentos seguidos estavam de acordo com os regulamentos estabelecidos pelos responsáveis da Comissão de Investigação Clínica e Ética e de acordo com a Declaração de Helsínquia da Associação Médica Mundial.

References

1. Venturini M, Cariati M, Marra P, Masala S, Pereira PL, Carrafiello G. CIRSE standards of practice on thermal ablation of primary and secondary lung tumours. Cardiovasc Intervent Radiol. 2020;43:667-83.

2. Hadi M, Walker C, Desborough M, Basile A, Tsetis D, Hunt B, et al. CIRSE standards of practice on peri-operative anticoagulation management during interventional radiology procedures. Cardiovasc Intervent Radiol. 2021;44:523-36.

3. Postmus PE, Kerr KM, Oudkerk M, Senan S, Waller DA, Vansteenkiste J, et al. Early and locally advanced non-small-cell lung cancer (NSCLC): ESMO clinical practice guidelines for diagnosis, treatment and follow-up. Ann Oncol Off J Eur Soc Med Oncol. 2017;28:iv1-21.

4. Remon J, Soria J-C, Peters S. Early and locally advanced non-small-cell lung cancer: an update of the ESMO clinical practice guidelines focusing on diagnosis, staging, systemic and local therapy. Annals of Oncology. 2021;32:1637-42.

5. Abtin FG, Eradat J, Gutierrez AJ, Lee C, Fishbein MC, Suh RD. Radiofrequency ablation of lung tumors: imaging features of the postablation zone. Radiographics. 2012;32:947-69.