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Pulmonary Ablation: A Primer

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Abstract

Percutaneous image-guided thermal ablation is safe and efficacious in achieving local control and improving outcome in the treatment of both early stage non−small-cell lung cancer and pulmonary metastatic disease, in which surgical treatment is precluded by comorbidity, poor cardiorespiratory reserve, or unfavorable disease distribution. Radiofrequency ablation is the most established technology, but new thermal ablation technologies such as microwave ablation and cryoablation may offer some advantages. The use of advanced techniques, such as induced pneumothorax and the popsicle stick technique, or combining thermal ablation with radiotherapy, widens the treatment options available to the multidisciplinary team. The intent of this article is to provide the reader with a practical knowledge base of pulmonary ablation by concentrating on indications, techniques, and follow-up.

Résumé

Technique sécuritaire et efficace pour la maîtrise de la maladie à l'échelle locale et l'amélioration des résultats, la thermoablation guidée par imagerie peut être utilisée dans le traitement d'un cancer du poumon non à petites cellules à un stade précoce ou d'une affection pulmonaire métastatique chez les patients qui ne se prêtent pas à un traitement chirurgical en raison d'une comorbidité, d'une faible réserve cardiorespiratoire ou d'une dissémination défavorable de la maladie. L'ablation par radiofréquence est la technique la plus acceptée. Or, les nouvelles technologies d'ablation thermique comme l'ablation par micro-ondes ou la cryo-ablation offrent toutefois certains avantages. Le recours à des techniques de pointe, comme l'induction d'un pneumothorax et la technique du bâton de sucette glacée, ou le recours simultané à l'ablation thermique et à la radiothérapie, fait en sorte d'accroître les options thérapeutiques qui s'offrent à l'équipe multidisciplinaire. Cet article a pour objet de fournir des notions élémentaires pratiques sur l'ablation pulmonaire, qui portent principalement sur les indications, les techniques et les mesures de suivi.

Key Words: Pulmonary; Lung; Ablation; Locoregional; Radiofrequency; Cryoablation; Microwave; Laser

Primary lung cancer is the leading cause of cancer deaths in men and women, and accounts for approximately 29% of all cancer deaths [1]. Despite significant advances in medical and surgical treatment, the prognosis of primary lung cancer remains poor; the strong association with other smoking-related comorbidities means that many patients are not candidates for surgical resection. This has resulted in new chemoradiation regimens (including stereotactic beam radiotherapy) and has fuelled the search for novel, minimally invasive therapies, including thermal ablation.

Image-guided ablation involves the percutaneous insertion of an ablation needle (electrode, antenna, or probe) directly into a tumour under image guidance (most commonly

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computer tomography [CT]) and subsequent manipulation of the thermal environment within and immediately surrounding the tumour, which results in cell lysis, apoptosis, or desiccation. In addition to nonsurgically resectable primary lung neoplasia, this technique has also expanded the treatment options for patients with pulmonary metastases, particularly for those who are poor surgical candidates [2]. The intent of this article is to provide the reader with a practical knowledge base of pulmonary ablation, concentrating on indications, techniques, and follow-up. The reader is encouraged to explore more-detailed aspects of comparative outcomes to better understand the context in which these techniques exist within the spectrum of care.

Background

The prognosis of primary lung cancer remains poor, with a 5-year survival of just 15% [1]. The prognosis and treatment depend on the histologic type of tumour (small-cell lung cancer [SCLC] vs non−small-cell lung cancer [NSCLC]), the clinical stage at presentation, and the patient's cardiorespiratory function [3].

Surgical resection remains the standard of care for early stage NSCLC and offers the most favorable outcome [3]. When possible, lobectomy is preferred to smaller wedge resections, which have been shown to result in a higher incidence of local recurrence and reduced long-term survival [4,5]. The 5-year survival rates of resected stage I and II disease are reasonable (75% and 60%, respectively), but, unfortunately, only approximately 5% of patients present with both early stage disease and meet the pulmonary physiologic guidelines to undergo resection [5]. The great majority of patients with SCLC are treated with chemotherapy; surgical intervention is reserved for those few individuals with localized stage I disease.

Minimally invasive surgical techniques, for example, video-assisted thoracoscopic surgery have revolutionized the ability to perform curative surgery on historically nonsurgical candidates. Complementary interventional radiologic techniques, for example, fuzzy wire localization, have contributed to the safety and efficacy of these procedures [6]. However, many patients remain poor surgical candidates due to compromised lung function or other comorbidities [7]. External-beam radiotherapy, with or without chemotherapy, may be considered when poor pulmonary function precludes resection, but published outcomes are inferior to surgery [8]. Significant adverse effects may also be encountered with external-beam radiotherapy, which may result in morbidity (including radiation pneumonitis, esophagitis, skin burns, and oropharyngeal mucosal sloughing) or even mortality [2].

Within the context of nonlung primary neoplasia, the lung represents the second most common organ location of metastatic disease; unfortunately, many patients with lung metastases also present with extrapulmonary disease and may, therefore, not be candidates for treatment with curative intent, although cytoreductive and/or palliative therapy may be indicated. Pulmonary metastases are typically peripheral and have a predilection for the lung bases, and, therefore, are often easily targeted for image-guided localization, biopsy, and percutaneous ablation. A peripheral location also means that many metastases are amenable to video-assisted thoracoscopic surgery resection or open metastasectomy, although segmentectomy or lobectomy may be indicated, depending on the distribution of the disease. Disease distributed within multiple lobes may be difficult or impossible to resect but may be amenable to thermal ablation [9]; therefore, all potential surgical or ablation targets (primary and secondary tumours) should ideally be reviewed and discussed in the setting of a multidisciplinary team. When poor pulmonary function or disease distribution preclude resection, or when chemotherapy or radiotherapy have failed, percutaneous thermal ablation can offer an alternative approach [2].

Technology and Techniques

Radiofrequency Ablation

The term radiofrequency (RF) describes all electromagnetic energy sources with frequencies lower than 30 MHz, but most probes in current use operate around the order of 3-500 kHz. RF ablation (RFA) is well established in the treatment of solid organ tumours, and, since the turn of the century, this technology has shown promise as a minimally invasive and efficacious treatment platform within the lung. Pulmonary RFA was first described in a rabbit lung model in 1995 [10], and the first treatment in human lungs was reported by Dupuy et al [11] in 2000.

There are 2 varieties of RF electrodes available, those with tines and those without [12]. Tines are small wires deployed from within the electrode, once a suitable electrode position is achieved within the lesion under image guidance; the deployed tines either point forward (RITA System; RITA Medical Systems, Fremont, CA) or curve back towards the hub (LeVeen Electrode; Boston Scientific Corp, Marlborough, MA). The nontine systems (eg, Covidien Cool-tip; Covidien, Mansfield, MA) consist of forward-oriented electrodes, deployed singularly or as a cluster array (Figure 1). The electrodes are cooled internally, often by an ice-cold saline solution pump, which prevents charring at the needle tip, which would otherwise impede the circuit and reduce the ablation zone.

Once inserted under image guidance (typically CT), the electrode is attached to a generator and the electrical circuit is completed through the patient by using grounding pads, usually placed on the thighs. The generator produces an alternating current that passes through the patient; the oscillating current causes collisions of electrons within molecules close to the electrode, which produces friction and heat [13]. The tissue is heated to temperatures higher than 60°C, which results in cell death [14]; the ablation zone aims to encompass the entire lesion with a safety rim of normal parenchyma (ideally of up to 10 mm).