

Review

Laser interstitial thermotherapy application for breast surgery: Current situation and new trends



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ARTICLE INFO

Article history:

Received 12 November 2016

Received in revised form

24 March 2017

Accepted 29 March 2017

Keywords:

Breast cancer

Thermotherapy

Laser

Interstitial

Minimally invasive

ABSTRACT

While breast specialists debate on therapeutic de-escalation in breast cancer, the treatment of benign lesions is also discussed in relation to new percutaneous ablation techniques. The purpose of these innovations is to minimize potential morbidity. Laser Interstitial ThermoTherapy (LITT) is an option for the ablation of targeted nodules. This review evaluated the scientific publications investigating the LITT approach in malignant and benign breast disease. Three preclinical studies and eight clinical studies (2 studies including fibroadenomas and 6 studies including breast cancers) were reviewed. Although the feasibility and safety of LITT have been confirmed in a phase I trial, heterogeneous inclusion criteria and methods seem to be the main reason for LITT not being yet an extensively used treatment option. In conclusion, further development is necessary before this technique can be used in daily practice.

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1. Introduction

1.1. Breast diseases and laser interstitial thermotherapy

1.1.1. Fibroadenomas

Tumoral breast diseases mainly include cancer and fibroadenomas. Fibroadenomas are well-defined benign tumors. Their frequency in the general population has not been clearly determined. One study reported a frequency of 13% [1] in patients who underwent a systematic clinical breast examination while another study reported fibroadenomas in 9% of patients who underwent mastectomy [2]. Those tumors are mainly asymptomatic and are discovered by breast self-exam or systematic breast examination. Pain is the main revealing symptom. A majority of those tumors requires basic follow-up, while surgery is currently the only treatment for painful fibroadenomas with increased size and for those causing significant esthetic deformation of the breast [3].

1.1.2. Breast cancer

There are numerous types of breast cancer with different prognoses and treatment strategies. Size and lymph node involvement are the main elements that determine the treatment. An increasing number of early-stage cancers are being diagnosed thanks to progress in imaging techniques and to systematic screening programs. Early-stage cancers are mainly ductal invasive carcinoma with a good prognosis and a five-year survival rate of 88% [4]. At present surgery performed under general anesthesia is the standard treatment of these carcinoma. This invasive treatment results in two main delayed complications: chronic breast pain and unattractive scarring. The incidence of chronic pain after breast surgery is about 30% (5–10% of patients with severe chronic pain) [5]. Cosmetic sequelae are quite common with an incidence of 15–30% following conservative treatment (3–5% with severe scarring) [6]. Nonetheless, a recent report showed that rates around 7% could be achieved at 2 years with the incorporation of oncoplastic breast surgery techniques in an expert center [7]. Surgery is the gold standard but due to comorbidities, patient's age and also patient's preferences, exclusive hormone therapy can be proposed. Thus, percutaneous treatments have been developed to reduce morbidity and improve esthetic results. Laser Interstitial ThermoTherapy (LITT) has been tested in other organs with various outcomes [8–11]. Although several preclinical and clinical studies were conducted (with a first implementation in breast disease in 1992) [12], this is not yet a routine technique. Although numerous studies [13–19] evaluating percutaneous techniques to treat breast cancer have been published, there are no studies specifically analyzing the technical and practical aspects of the technique. The aim of this review was to identify the optimal indications, technical settings and follow-up protocols for this procedure.

1.2. LITT mechanisms

Thermal damages obtained with LITT are due to laser electromagnetic radiations (EMR). In the history of laser, surface treatment was first developed, in particular in dermatology and in the digestive tract. Then, interstitial therapy permitted to treat tumor tissues by delivering the energy directly while minimizing side effects on the surrounding healthy tissues. But the main limitation was the lack of real-time imaging control as well as the absence of treatment planning system. LITT is defined as the thermal destruction of tissue by laser. A photothermal effect is the main expected action. At the interface of laser radiation and biological tissue, laser light photons are absorbed by surrounding tissue molecules, causing excitation and release of thermal energy [20]. Heat redistribution is not always the same and is determined by

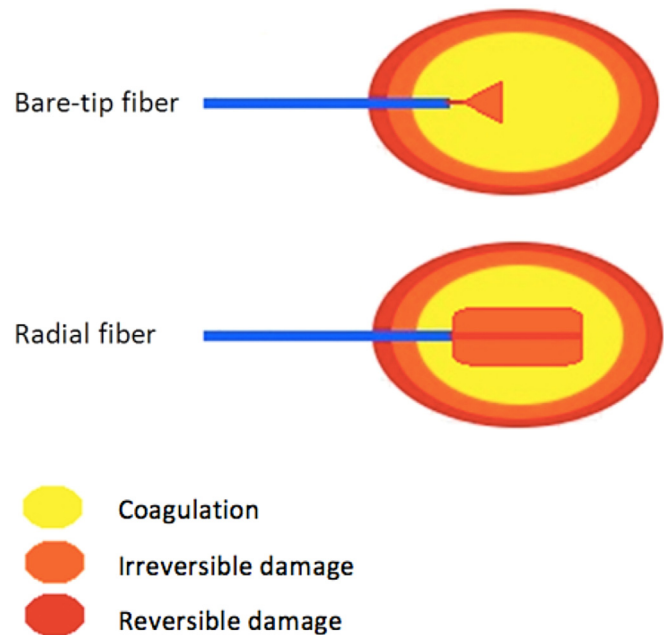


Fig. 1. Diagram of bare-tip and radial fiber emitting profile and damages. Tissues near the fibers are the first to be coagulated, and then surrounding areas are damaged reversibly or irreversibly depending on temperature exposure. Shape of damages is ellipsoidal and damage distribution depends on the type of fibers used for the treatment.

tissues' properties and the laser parameters [21]. This leads to a rapid increase in tissue temperature and irreversible damage to cell and tissue architecture. The redistribution of heat also takes place through convection and conduction via blood flow. The amount of heat energy and the depth of light penetration determine the thermal effect [22]. The damage extent depends on the temperature, the optical and thermal properties of the tissue and the duration of heating. Apoptosis and cell necrosis occur when critical proteins undergo denaturation, which occurs at a temperature of about 60 °C [23]. Tissue exposed to that temperature rapidly coagulates while heat diffusion causes surrounding tissue to reach supraphysiological hyperthermia (42°–60 °C) inducing delayed thermal damage (24–72 h) [24,25] (Fig. 1). Delayed thermal damage is explained by several mechanisms like enzyme induction, protein denaturation, melting of membrane lipids, vessel sclerosis, and coagulation necrosis. Rapid increases in temperature can cause tissue carbonization, which subsequently changes the tissue optical properties and limits laser penetration [26]. Overheating can also lead to tissue vaporization [27]. There is also a secondary effect to the endothelial cells of the tumor vasculature caused by thermal damage. To sum up, the goal of LITT is to achieve selective treatment of pathological tissue while not affecting the normal tissue.

1.3. Type of laser used for LITT

Due to low absorption by water or hemoglobin, wavelengths between 590 and 1064 nm are usually used to obtain deep tissue penetration. Currently, the two main types of laser used for LITT are diode lasers with wavelengths between 800 and 980 nm, the continuous-wave laser and the Nd:YAG laser, with a wavelength of 1064 nm that operates at a wide range of power [37,38,45]. Nd:YAG lasers achieve the highest degree of tissue penetration at wavelengths between 1000 and 1100 nm, within the near infrared spectrum where scattering of light is greater than its absorption, thus resulting in greater tissue penetration [26,28]. They are

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