CT-Guided Laser Probe for Ablation of Brain Tumors

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ABSTRACT

In this study, 22 patients (15-75 years old) were selected and transferred to CT scan for tumor ablation. For ablations, after prep and drep under the local anesthesia and mild sedation in proper position, small incision made and special needle inserted and guided by proper direction to the core of the tumor. Then, laser probe inserted through the needle and laser energy delivered. Although we have not a good prognosis in metastatic tumors but post-operative follow up and brain CT scan established the effect of laser on resection and evaporation and diminution of mass effect in tumor lesions.

1. Introduction

Tumor ablation has begun in USA for several years. CT-guided laser probe has been used for deep brain lesions in many patients with Parkinson's disease. Its safety, facility and ability to sampling are agreeable procedure. Its probable complications are similar to stereotactic surgery. The tiny local effect, linear direction without pripheral tissue extension and probe guiding ability and most important features, controllable tissue destruction, is a causative clue for using laser in stereotactic surgery.

2. Methods

2.1. Patients and Methods

In this study, 21 patients aged 15-72 years old at the time of study presented with multiple brain lesions and one 75 years old male with single capsulated tumor were selected from all brain tumors within 3 years. They had lesions with significant mass effect and all of them have been inoperable and referred to us by radiotherapy Department and other surgeons except one of them who suffered from sever ischemic heart disease and COPD and had significant problems for general anesthesia.

2.2. Procedure

Patient transferred to CT scan room and placed in CT table and made a brain CT scan with contrast. Then, after prep and drep under the local anesthesia and mild sedation in proper position, small incision made, one burr hole (skull perforator) (Figure 1) placed and dura matter exposed and about 2-3 ml of lidocaine dribble on the dura, then open it by knife (no 15) and special needle inserted and guided in proper direction to the core of tumor and controlled by serial scans (Figure 2). Sampling was performed and laser probe inserted through the needle, then laser energy was delivered (1,2). Each 1500 j energy evaporated about 1cm^3 of the soft tissue. During the lasering, residual of tumor and extent of destruction was controlled by serial scans. When we worked

on eloquent area can evaluate the patient by neurological examination .In case of multiple lesions the ablation should be performed at multiple stages (Figure 6).

3. Results and Discussion

Only 4 patients lived more than 6 months. Cause of death was significant systemic organ involvement, pneumonia and sepsis (Table 1).

Laser technology has been used in medical applications for over 20 years; it is one of the most important new technologies applied to medical applications in decades. Lasers are widely used in ablation, surgery and measurement. Laser stands for Light Amplification by Stimulated Emission of Radiation. Lasers are very special lights. They are different from ordinary lights in many ways. Lasers are monochromatic. All photons in a laser beam are at the same frequency. Energy of a laser beam is concentrated in a very narrow wavelength

Table 1.

Tumor Origin	Pathoogy	Age	Sex	Survival	Cause of Death
Right Femur	Melanoma	39 y	f	4 weeks	New Brain Metastasis
Lt Kidney	Adenoma	46 y	m	5 weeks	Lung Involvement
Breast	Adenocarcinom	60 y	m	8 weeks	Sepsis
Thyroid	Adenocarcinom	63 y	m	12 weeks	Metastasis
Colon	Adenocarcinom	70 y	m	8 weeks	Hemorrhage
Stomach	Adenocarcinoma	68 y	m	9 weeks	Lung Metastasis
Colon	Adenocarcinoma	66 y	m	10 weeks	Rectorhagy
Lung	Small Cell Carcinorma	61 y	m	4 weeks	Hemoptesis
Colon	Adenocarcinoma	68 y	m	12 weeks	Brain Edema
Lung	Small Cell Carcinorma	63 y	f	20 weeks	New Metastasis
Brain	Meningioma	75 y	f	16 weeks	Pneumonias
Kidney	Adenocarcinoma	60 y	f	4 weeks	Invasion to Abdominal Organ
Lung	Adenocarcinoma	63 y	m	50 weeks	Alive
Prostate	Adenocarcinoma	68 y	m	5 weeks	Invasion to Abdominal Organ
Esophagus	Adenocarcinoma	62 y	f	6 weeks	Involvement
Thyroid	Adenocarcinoma	55 y	m	2 weeks	GI Bleeding
Thyroid	Scc	64 y	m	6 weeks	New Metastasis
Gastric Ulcer	Adenocarcinoma	58 y	m	12 weeks	GI Bleeding
Lung	Scc	65 y	m	12 weeks	Lung Metastasis
Lung	Adenocarcinoma	62 y	f	13 weeks	Bleeding
Colon	Scc	69 y	f	12 weeks	Metastasis

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Table 2. Photothermal effects (Dorschel et al., 1991)

Effects	Temperature Range	Explanation
Photo Hyperthermia	37-43 °C 44-60 °C	No irreversible damage of normal tissues cell membranes damage, enzymes denaturation
Photocoagulation	61-100 °C	Coagulation, necrosis
Photocarbonisation	101- 300 °C	Drying out, vaporizing of water, tissue carbonization
Photovapoisation	>300 °C	Pyrolysis, vaporization of solid tissue matrix

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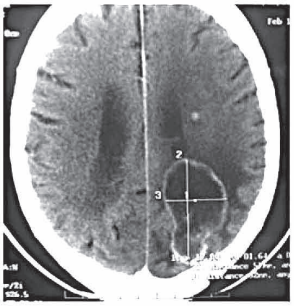
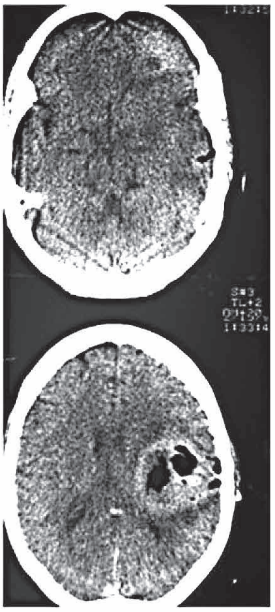
Figure 3

Figure 4



A B

Figure 5. A: just after operation. B: pseudo cyst without any mass effect and with probable relation with CSF circulation 6 months after laser ablations



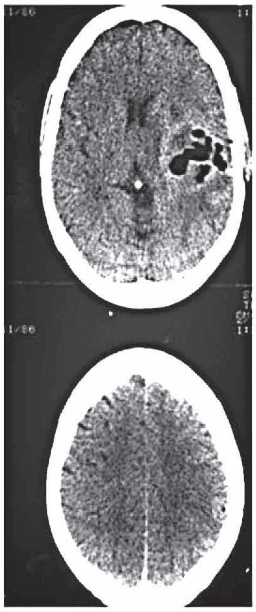


Figure 6. A 63 y female wiyh two metastatic lesion at frontal and parieto-frontal lobes, first stage of laser ablation

Table 3. Laser ablation advantages

Advantages	Explanation
High precision, low collateral tissue damage	This is one of the most important advantages of laser ablations. it makes lasers the best choice for high precision procedures such as ocular ablations.
Laser probes & optical fiber cables are MRI compatible	Laser ablations are compatible with most guidance devices, including MRI, ultrasonic, etc.
Fast procedure	Laser ablations procedures are usually fast as comparing to RF, microwave and ultrasonic ablations.
Multiple probes	Multiple laser probes can be used si,ultaneously to ablate multiple tumors. probes do not interference one another.
Shorter hospital stay, and faster recovery	Patients recover faster than regular surgery.
Less operative and postoperative pain	Patients get feel less pain during and after the laser ablations as compared to regular surgery and other ablation techniques.
Less bleeding during ablation, sterilization of wound	By comparing to regular surgery. patients bleed much less with laser ablations. ablation wounds are automatically sterilized.
For both soft and hard tissue	Laser ablation techniques can be used for both soft and hard tissues.
Selective ablation	Selective ablations is a unique advantage of laser ablations. By using the absorption coefficient difference between different substaces in the tissues, laser ablation can target on only the malignant tissues without damaging healthy tissues.
Compatible with other medical electronic devices	Laser ablations are compatible with other medical devices, such as pacemakers, x-ray device, etc.
Ultrahigh temperature hyperthermal procedure	High power density lasers can cause extremely high temperature on the target tissue, the temperature can be high enough to physically modify or vaporize hard tissues.

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Table 3. Laser ablation disadvantages

Disadvantages	Explanation
Not for large volume tissue ablation	Since lasers do not penetrate deepy into tissues and heat does not conduct very well in tissues, laser ablations are usually not a good choice for ablating large volumes of tissue such az large or multiple liver tumors. RF and microwave ablation techniques are better suited for such applications.
Not for deep tissue ablation	Lasers do not penetrate deeply into tissues and they can only ablate tissues on the surface. ultrasonic ablation is a better choice for deep tissue ablation.
Higher system cost, bigger and more complex system	Laser systems are usually large and costly, such az CO2 lasers and excimer lasers. this is not always the case; some lasers are quite small and inexpensive, such as diode lasers.
Need special safety procedures	See texts

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band. Lasers are coherent. All photons in a laser beam are exactly in the same phase (3).

Lasers are always directional, not divergent. The direction of a laser beam is exactly parallel to the axis of the laser generator cavity. Unique properties of lasers are important for laser medical applications. Since lasers are directional and coherent, they can precisely target very small optical zones on tissues to minimize lesion size and collateral tissue damage. Since tissues interact differently with lasers of different wavelengths and lasers are monochromatic. Lasers of different wavelengths can be used for different clinical effects. Lasers at certain frequencies can be used to selectively ablate only malignant tissues without damaging healthy tissues. Lasers are among the best choice and often the only choice for many medical applications, especially the high precision ones. Lasers have these properties because of the way lasers are generated (4-5). The absorbed laser energy is converted to heat or chemical energy and induces laser tissue interaction effects. The photothermal effect which is caused by heating is one of the most important effects. When lasers are absorbed by tissues, they excite the movement of tissue molecules and electrons as the laser energy is converted to heat. Heat causes tissue coagulation, dehydration, carbonization, pyrolysis, and vaporization. Results of the photothermal effect are coagulation of the tissue, ablative removal of the tissue, or both (See Table 6.4 for more details). The laser treatment of kidney stones is one example. Laser beam is applied directly to the kidney stone. It vaporizes water inside the kidney stone causing expansion and acoustic effects to disintegrate the kidney stone (6).

There are many factors affecting the photothermal effects. Factors include the wavelengths of lasers, absorbance and scattering properties of exposed tissues, power densities of applied lasers, laser pulse lengths and pulse frequencies, total exposure time, etc. Tissues are ablated through tissue coagulation, water vaporization, tissue dehydration, tissue carbonization, and pyrolysis (Table 2). Ablated tissue can be directly removed through vaporization and explosive mechanical ruptures (8).

First case was a 39 years old woman with malignant melanoma and multiple brain lesions that was resistant to radiotherapy and chemotherapy .this patient had sever headache and was on dexamethasone and narcotic agents. The largest lesion (Figure) evaporated then she had acceptable pain with lower dose of dexamethasone and narcotic agents until 6 weeks .she developed sudden loss of consciousness and had a large new hemorrhagic metastasis in direction of left MCA and dead after 2 days.

One of patients was a 75 years old male who were suffered from sever ischemic heart disease and COPD and had significant problems for general anesthesia. He developed progressive right side weakness, seizure and were not ok for general anesthesia. He had large meningioma on left temporofrontal convexity. Other patients died due to extensive metastatic involvement of other organs. Although we have not a good prognosis in metastatic tumors but post operative follow up and brain CT scan established the effect of laser on resection and evaporation and diminution of mass effect in tumor lesions. This diminution of mass effect is important for radiotherapic effect and decreasing high ICP. Lasers work in either pulse mode or continuous mode. Some lasers can work in either mode.

Other lasers work in pulse mode only. Continuous laser beams can be chopped by mechanical means to become pulsed laser beams.

There are many important parameters to be considered for laser ablation procedures. The optical and thermal properties of tissues as well as the mechanical parameters of the laser beam such as wavelength , pulse duration, pulse frequency, energy density, power density total irradiation time, etc. are all important parameters for laser ablations. Pulsed mode lasers are used the most because ablation procedures can be easily controlled by controlling laser beam parameters. Pulse duration, Pulse frequency, and laser pulse peak energy power density are the most important parameters they are used to control the magnitude of laser tissue interaction effects so as to control the laser ablation procedure. Eye and skin are two of the most vulnerable body parts. Unprotected skin can be easily injured or severely burn by direct or indirect laser exposures. Eyes must be protected with appropriate eye wear. Lasers can easily cause ocular hazards to unprotected human eyes. With direct exposures, lasers can cause cornea photokeratitis, lens photochemical cataract and corneal burn, and photochemical and photo thermal retinal injuries. Ocular hazards caused by lasers depend on the wavelength of the laser (9).

3.1. Advantages and Disadvantages of The Laser Ablation

Laser ablations have many advantages over other ablation techniques for many medical applications. High precision is one of the most important advantages. Nevertheless, laser ablation techniques are not for all medical ablation applications. They have disadvantages

for certain applications and under certain situations. Advantages and disadvantages of laser ablations are summarized in Tables 3 and 4 .The summary did not cover all aspects, even though many different aspects are covered.

Optical fibers are flexible, reliable, inexpensive, and easy to couple with laser output probes. They are the most convenient mechanism to deliver the laser beam from the laser generator to the target tissue or to the laser probe used to treat the target tissue. CT Guided laser probe for ablation of brain tumors is safe, low risk, micro invasive and effective procedure for metastatic lesions and some tumors with significant medical problems (10).

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