Medical Applications of EM waves

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***Abstract* — We present ultrasound, Laser, Radiation as medical applications of EM waves. Ultrasound can be used as the cure of fractures, Diode-pumped fiber laser as a new clinic tool at otolaryngology, cardiobasular healing and etc, Radiation as a therapy of cancer.**

I. INTRODUCTION

It's getting widely recognized that it could be quite useful to use EM waves in practice. Among a variety of EM uses, we found that there are lots of possible uses of EM waves in the medical area such as Laser, X-ray, CT, MRI , eletromicroscope and etc.

We are going to focus not on the introduction of these equipments in this paper. But, we will present several practical uses of EM waves which are being used in the hospital. Ultrasound as a cure of fractures, Diode-Pumped Fiber laser, Radiation therapy. Ultrasound, a form of mechanical energy that can be transmitted in organisms as high frequency acoustical pressure waves, has been used widely in medicine as a therapeutic and diagnostic tool. And Diode-Pumped Fiber laser is a tool that has high surgical and medical applications. Lastly, we're going to look into Radiation therapy which is a very important tool in the fight against cancer and is used in the treatment of as many as 50% of all cancer patients.

II. ULTRA SOUND

Brief (20 min per day) ultrasound exposure of the nonunion site resulted in a healed nonunion in 70% of the cases without any harmful effects observed. These brief periods of low intensity pulsed ultrasound were capable of accelerating the recovery of mechanical strength in the fractured bones.

A subsequent evaluation of the signal parameters demonstrated that low intensity pulsed ultrasound (200 ms burst of 1.5 MHz sine waves repeated at 1 kHz), with an intensity of 30 mW/cm^2 for 20 min per day, actually increased bone strength over that of intact controls. Investigators showed that by day 21 the average maximum torque of a treated fracture was 22% greater than that measured from the contralateral unstimulated control femora. The selectivity of the response to specific waveform parameters also was apparent, because the stiffness of ultrasound treated fractures in the 0.5 MHz group failed to reach the strength of that in the untreated controls.

On passing through the tissue, the ultrasonic energy is absorbed at a rate proportional to the density of the tissue. As bone is much more dense than fat, muscle, or hematoma, this differential absorption plays a critical role in targeting the ultrasound to the fracture gap. Absorption also results in energy conversion to heat. Although this heating effect is small (<18℃), some enzymes (collagenase) are exquisitely sensitive to small variations in temperature. Thus the ultrasound facilitates enzymatic processes. Ultimately, the ultrasonic signal must be translated from a physical alteration of the cell's mechanical response to a molecular and biochemical response in the cell, thereby modulating cell function.

Ultrasonic stimulation at the signal parameter of 500 mW/cm^2, 1.5 MHz, and 15 min/day can induce significant thermal effect around the local region of treatment. The promotion of bone healing after ultrasonic stimulation can be induced by the thermal effect accompanied with ultrasonic treatment.

The bone healing after ultrasound stimulation was faster than that of the contralateral sham-treated limb (Fig. 1-2). The new bone formation after ultrasound stimulation was 23.1-35.8% faster than that of the contralateral sham treated limb during 3-week experimental period(Table 1-1). After microwave hyperthermia treatment, the new bone formation in the experimental limbs was higher than that of the sham operated limb, but the differences did not attain a statistical significance. On comparing new bone formation at the microwave hyperthermia treated limb with that of the right limb of the control group (osteotomy only), we found that the new bone formation of microwave hyperthermia treated groups was significantly increased (Table 2). As a corollary to fracture studies, a series of experiments examining the effects of low intensity ultrasound on bone growth into porous coated dog femoral implants found that ultrasound treatment stimulated more bone ingrowth than that observed in untreated contralateral controls. These results suggest that the ultrasound stimulation at this specific parameter is osteogenic and have clinical potential.

Ultrasound also has been shown to have a direct and persistent effect on blood flow. Low intensity ultrasound treatment over a 10 day period stimulates an increased degree of vascularity at the osteotomy site. This increased blood flow was paralleled by greater callus formation and a markedly improved blood flow distribution around the fracture. Although preliminary, these data imply that greater blood flow serves as a principal factor facilitating the acceleration of fracture healing by ultrasound. This effect may seem inherently obvious as maximizing the delivery of nutrients, metabolites, growth factors, and even cells to the site of injury. It had been reported that low pulsed ultrasound treatment increased bone mineral content and density, peak torque and stiffness, and accelerated the overall endochondral ossification process. In this study, torsional stiffness after ultrasound stimulation in the experimental limbs was statistically higher than that of the sham-treated limb (Fig. 1-2). Torsional stiffness of the specimen after of ultrasound stimulation was 44.4-80.0% higher than that of the sham-treated site during the 3-week period.

III. Diode-Pumped Fiber Laser

Fiber lasers' basic principle is described in Figure 2-1. It shows a schematic diagram. The basic elements of a high power fiber laser(the pump source, the doped core, the pump cladding, and the outer cladding). Light from a pump source is launched into the pump cladding of the fiber and becomes absorbed in the core(Fig 2-2). After a number of bounces within the pump cladding, the pump light from the source is absorbed essentially in total. The outer cladding of the fiber provides the lossless confinement of the pump light in the fiber. In the normal way, the ions in the core become excited and eventually emit fluorescence which can be fed back by the placement of mirror which are butted to each end of the fiber. The required stimulation of the fluorescence, laser action is then free to take place.

Features of the fiber laser are its small transverse cross section, the large surface area to volume ratio and, the overall long(1-20m) length. These special properties lead to very low threshold pump powers, high slope efficiencies and very good thermal management properties. Fiber lasers are considered efficient providers of high average power output in either a continuous wave(CW) or a high repetition rate low energy pulsed form. fiber systems are very easy to use and very compact because even though the fiber laser cavity can extend to 10s of meters, the fiber can be tightly coiled resulting in a physically small system. The qualities of fiber lasers make them a very practical tool for a large number of medical applications.

In Otolaryngology, Fiber lasers have application in the reduction of hyperplastic inferior turbinates, secondary to rhynitis. The standard lasers currently used in the clinical practice for turbinectomy are the Nd:YAG and CO_2 lasers. Such lasers have been used with post surgery complications in CW mode at an output power ranging from 7-1W. Fiber lasers emitting at $\lambda = 1$ ㎛, $\lambda = 1.55$ ㎛ and $\lambda = 2$ ㎛ are appropriate for precise coagulation during the reduction of the turbinates, as the beam penetration in water varies from 2.4cm at $\lambda = 1$ ㎛ to 14 ㎛ at $\lambda = 2$ ㎛. Fiber lasers are compact and they couple very well with the operative microscope,which is often used in turbinectomy procedures. The flexible fiber of these lasers also allows the treatment of the posterior turbinates, which cannot be reached by the bulky delivery system used for the CO_2 beam.

Let's look at other case. In Cardivoscular procedures, Transmyocardial revascularisation is another procedure that is receiving strong interest in the field. At present, these procedures mainly rely on either pulsed Ho:YAG or pulsed CO_2 lasers to create transmural channels in the ischaemic myocardium. As a result of the strong absorption in muscular tissue of radiation at wavelengths ~3 ㎛, high power(>10W) fiber lasers operating at these wavelengths may offer a practical alternative to CO_2 lasers. In addition, since these lasers have their output delivered by way of approximately 1-mm diameter fiber, the significantly small core of the fiber laser and hence focussability(down to about 50 ㎛) of the diode-pumped fiber laser allows for the production of smaller and narrower channels, if desired. This may allow the surgeon greater flexibility during the operation.

IV. RADIOTHERAPY

Radiotherapy involves the exposure of parts of the body to radiation, beams of high-energy X-rays, gamma rays or particles. Radiotherapy, also called radiation therapy, is the treatment of cancer and other diseases with ionizing radiation. Ionizing radiation deposits energy that injures or destroys cells in the area being treated (the "target tissue") by damaging their genetic material, making it impossible for these cells to continue to grow. Although radiation damages both cancer cells and normal cells, the latter are able to repair themselves and function properly. Radiotherapy may be used to treat localized solid tumors, such as cancers of the skin, tongue, larynx, brain, breast, or uterine cervix. It can also be used to treat leukemia and lymphoma (cancers of the blood-forming cells and lymphatic system, respectively).

It can be used alone as a complete treatment for cancers such as some skin cancers, cancer of the thyroid and some brain tumours in conjunction with surgery, either before surgery to reduce the size of a tumour or after surgery to make sure all the cancer cells are destroyed, and to treat local spread of the cancer (such as in the treatment of breast cancer); it can also be performed in conjunction with chemotherapy (cancer-killing drugs), in the emergency treatment of a cancer pressing on the spinal cord to reduce the size of the cancer and prevent damage to the nerves, , as a palliative measure in advanced cases of cancer to treat symptoms, such as the pain caused by spread of cancer to the bones.

The type of procedure that is performed depends on the type of cancer and where it is in the body. Different machines are used to produce narrow beams of X-rays, gamma rays and particles such as electrons. These beams have different energies and properties which determine the depth that the beam penetrates into the body. The equipments of cancer therapy by using radiation are Low-energy X-rays, Cobalt-60, Cesium-137, linear accelation, Betaron, Microtron, Cyclotron, Synclotron, AVF cyclotron, Synchrotron, Van de Graaff generator, Stereotactic radiosurgery system etc.

We explain the main equipment using Gamma rays by cobalt 60 of many radiotherapy equipments (Fig. 3-1). EM waves with a wavelength shorter than X-rays are called gamma rays or gamma radiation . Gamma rays may be emitted from radioactive materials Ra, Cs, Co, etc. Low intensity gamma radiation can damage living cells and cause cancer. High intensity gamma radiation will kill cells. It is used in a technique called radiotherapy to treat cancer by targeting the cancer cells with a beam of radiation and then rotating the source of the beam (Fig. 3-2) The normal cells receive a lower dose of gamma radiation than the cancer cells, where all the rays meet. Radiotherapy aims to kill the cancer cells while doing as little damage as possible to healthy normal cells. Gamma radiation is used to kill microorganisms, which is called sterilizing. It is used to sterilize food and hospital equipment such as surgical instruments.

V. CONCLUSION

We have seen how EM wave in the medical field is being used in practice. Firstly, we presented Ultrasound as a Fracture healing method. It is a specialized type of wound repair that involves a complex replay of development which leads to the restoration of the bony structure. And Diode-Pumped Fiber laser was presented as a laser clinic tool. Lastly, we knew that Radiation therapy is a very important tool in the fight against cancer.

In short, we have come to our conclusion that the more we understand how EM waves can be applied in practice , the more technicalities can be taken cared of nowadays in the easier manner. So we need to keep studying and investigating in this medical area so that we can get ourselves ready to deal with many expected problems in the future

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	Control	U.S. (−)	M.W. (−)	Control	U.S. (+)	M.W. (+)
1st week	L	L	L	R	R	R
Mean (μm)	14.9	27.0	27.6	17.1	35.9	34.0
SD	1.7	4.7	3.0	5.6	5.2	6.8
P		0.0003	<0.0001		0.0003	0.0032
2nd week						
Mean (μm)	35.8	60.1	54.7	41.9	81.6	66.1
SD	6.4	8.6	3.5	12.0	10.6	15.6
P		0.0005	0.0002		0.0003	0.0124
3rd week						
Mean (μm)	61.0	99.7	82.0	69.9	122.7	88.2
SD	4.2	22.7	7.6	23.2	28.1	22.3
P		0.0066	0.0010		0.0059	0.1196

Table 1-1. Comparison in New Bone Formation of Ultrasound Stimulated and Microwave Hyperthermia Treated Limb With That of the Ipsilateral Limb of the Control Group

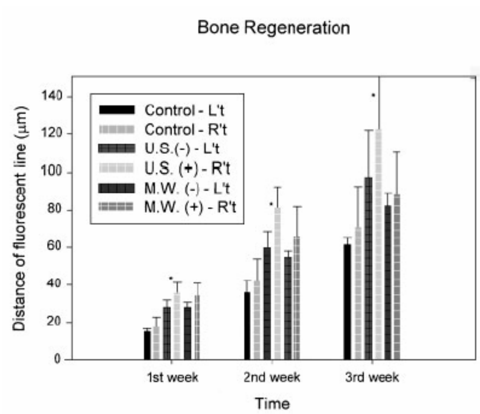

Fig. 1-1. Measurement of new bone formation after ultrasound stimulation and microwave hyperthermia treatment. In the rabbits of control group, there is no statistically significant difference existed in the amount of new bone formation between both hind limbs. After ultrasound stimulation, new bone formation of the experiment hind limb was faster than that of the contralateral sham operated limb. In the group of microwave hyperthermia treatment the new bone formation after osteotomy in the experimental limbs were higher than that of the sham-treated limb, but the difference did not attain a statistical significance

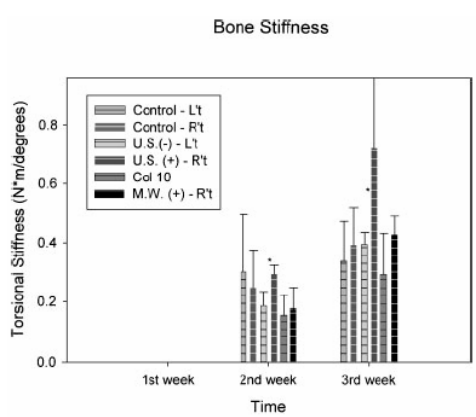

Fig. 1-2. Measurement of torsional stiffness after ultrasound stimulation and microwave hyperthermia treatment. After ultrasound stimulation, torsional stiffness of the experiment hind limb was higher than that of the contral ateralshamtreated limb. In the group of microwave hyperthermia treatment, the torsional stiffness in the experimental limbs and the sham-treated limb showed only borderline statistical significance

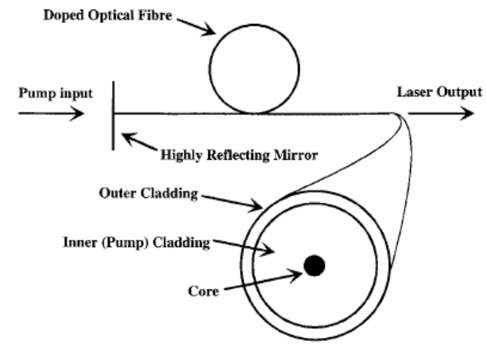

Fig. 2-1. Schematic diagram of a fiber laser showing the pump source, the doped optical fiber and the highly reflecting mirror which directs the laser output in one direction. Also shown is a transverse cross section of the double clad fiber showing the three main parts of the fiber namely the core, the pump cladding and the low index outer cladding.

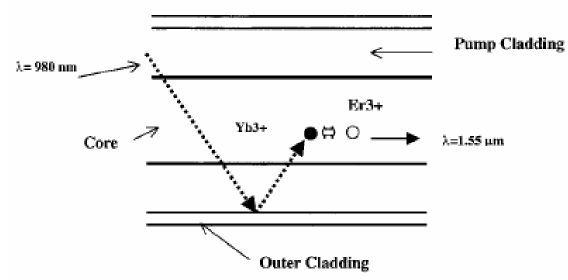

Fig. 2-2. Schematic diagram of the longitudinal section of a double-clad optical fiber, showing the diode laser pump beam(λ=980 ㎚) being absorbed by Yb3+ sensitizer ions in the core of the optical fiber. The Yb3+ sensitizer ion then transfers this absorbed energy to the Er3+ laser ions(which are also doped into the core), which fluoresces at an emission wavelength of 1.55 ㎛

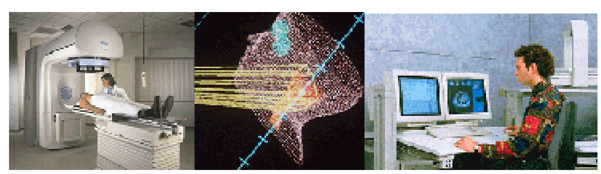

Fig. 3-1. Radiotherapy equipment by using gamma rays of Cobalt 60

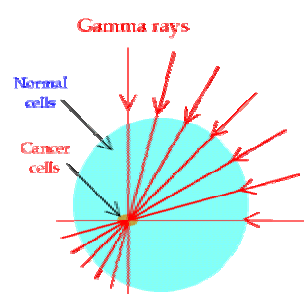

Fig. 3-2. Radiotherapy to treat cancer by targeting the cancer cells with a beam of radiation and then rotating the source of the beam