Experimental Estimation of Thermal Damage in Tissues Subjected to Continues Wave CO_2 Laser

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Abstract- In This work, the water content is determined in muscle, liver, heart, brain and lung. In addition, this work estimate the damage depth in different types of tissues subjected to continuous wave CO_2 laser. In this paper, three types of tissues have been used (muscle, lung and brain) which are subjected to different power level of CO_2 laser intensity for 20 s. Some conclusions are obtained; as laser power increased the damage depth decreased; In addition, it is found that as water content increased the damage depth decreased, because of the water content of brain tissue is more than lung and muscle tissue, so that brain has damage depth less than muscle and lung tissues. The results of this research are of great interest in the medical field when using CO_2 laser as cutting tool in surgery, which helps surgeons to know the damage that occurs when tissue is cut using CO_2 laser.

Index Terms- CO_2 laser, Damage depth, water content, tissue.

I. INTRODUCTION

Patel first introduced the CO_2 laser in 1964; it is emission in the middle of the infrared wavelength of 10.6 μm [1]. After that, CO_2 laser has largely used in the next decades as incision instrument .It is widely applied in different areas of medical science such as dermatology, neurosurgery, and otorhinolaryngology, plastic surgery, gynecology, ophthalmology, and general surgery [2]. Presently, the CO_2 laser is considered as a necessary piece of equipment of diagnostic and therapeutic [3].

Tanna N. In 2014, reported that the first pass of the CO_2 laser cause nearly 50-70 μm of ablation. Since the resulting thermal necrosis layer has minimal tissue water than the skin that uninjured, successive pass result in less tissue vaporization[4].Joel N. Bixler, in 2015, presented the importance of tissue water content with regard to the possibility of photothermal damage. In addition, he highlights the importance of hydration when evaluating thermal damage resulting from exposure to laser [5].

When the tissue absorb laser light, the water temperature increases and exceed 100° C. Therefore, the water in the cell turns to steam. In additions, cellular protein affected by the heat and it may destroyed as heat continues to rise, resulting the wrack and smoke that spewed from the tissue. The acute heat produced by the period of incidence light lead to damage adjacent tissue [6] .The degree of thermal damage depends on the temperature that the laser energy warmed the tissue [7].

In this paper, the percentage of the water in three types of tissue, which are muscle, lunge and brain, had been determined by measuring the weight of each fresh sample before and after drying in oven [8],and it was found that the water content in brain tissue is more than lung and muscle tissue. In addition,The samples was subjecting to different power of CO_2 laser for 20 s, after that the tissue was prepared for examination under light microscope by fixation of the tissue on glass slide using (paraffin) embedding section method to determine damage depth using scaled optics [9]. It is found that as laser power and water content increased the damage depth decreased.

II. EXPERIMANTAL WORK

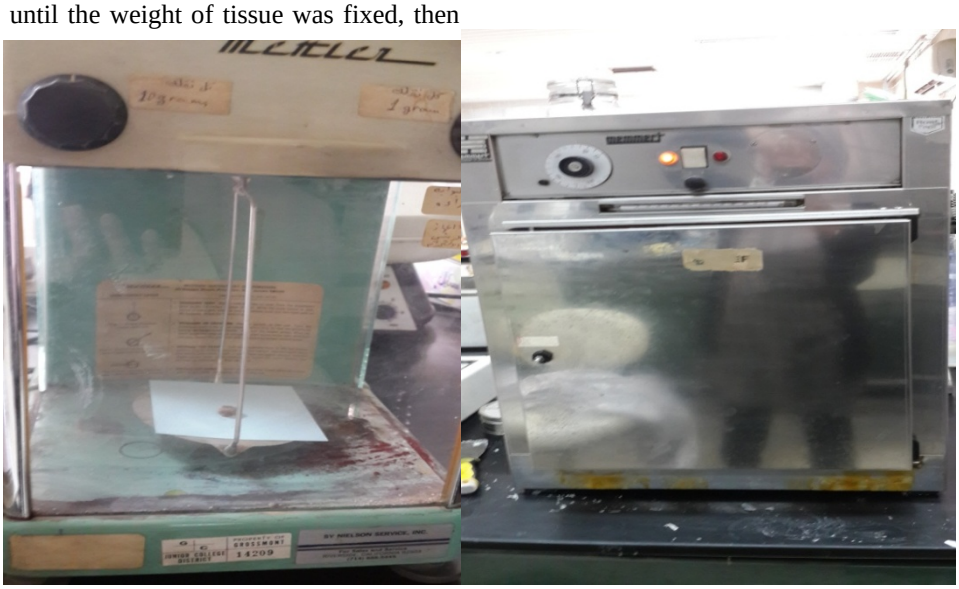
1. Measurement the percentage of water in tissues

The samples were prepared by cutting the sheep tissue samples into a rectangular shape piece with dimensions 1cm long, 0.5cm width and thick**,** as shown in Fig.1.

Figure 1.0 Fresh sheep tissues with dimensions 1cm length, 0.5cm width and thick.

The cutting step followed by calculating the weight of each sample by using electrical sensitive balance (Mettler),as shown in Fig.2a. Then the samples were placed in the oven in temperature 50°C for 10 min., as shown in Fig.2b, then the weight of each sample was calculated to determine the difference in weight that represents the weight of the water. This step was repeated several times until the weight of tissue was fixed, then calculated the percentage of water in each tissue by the following equation [8]:

$$\text{The percentage of water} = \frac{\text{Weight of fresh tissue} - \text{Weight of dray tissue}}{\text{Weight of fresh tissue}} \quad (1)$$



(a) Electrical sensitive balance (Mettler) (b) The oven

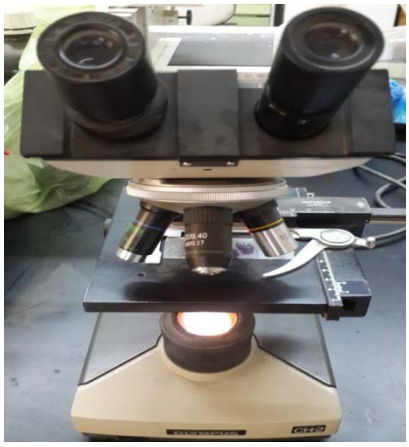
Figure2.0 Devices used to calculate the percentage of water in the tissue

2Measurement of damage depth on tissue

2.1Set up of the work

1- CW CO_2 laser
2- Pieces of tissue from the sheep
3- Holder
4- Power meter, as shown in Fig.3a.
5- Microscope as shown in Fig.3b.
6- scaled optics, as shown in Fig.3c.

(a)



(b) **(c)**

Figure 3.0 The set up of work, a) CW CO2 laser, power meter, holder and tissue,(e) Microscope,(c) Scaled optics.

2.2Experimental work

In this work different sheep organs (age 6 months) was used (Brain ,Lung ,Muscle). The tissues of these organs were prepared by cutting them in to pieces of same dimensions .Each sample has fixed in the holder at a distance of 30 cm from CO_2 laser beam where the spot diameter is 2mm. The tissues were exposed to CO_2 laser for 20 seconds with different laser power level (from 3 to 14 Watt), as shown in Fig.4.

Figure 4.0 Tissue fixed in the holder and shoot with CO_2 laser.

Then each tissue had been cut from the center of the spot into two pieces to see the damage depth, as shown in Fig.5. Then each tissue was prepared for examination under light microscope by fixation of the tissue on glass slide using (paraffin) embedding section method.

Figure5.0Cut the tissue from the center of the spot into two pieces

2.3Sample preparation

The samples are prepare after exposure to CW CO_2 laser by cutting samples into two pieces where the dimension are (1 cm long, 0.5 cm width and thick) the sample were put in a container contain formaldehyde 10% for 24 hr. to fix the sample and prevent autolysis which may affect the results[10]. After formalin, the samples placed in Ethyl alcohol with different Concentration to extract water from the samples. Then the samples were put in xylene 2 hr. this step was repeated twice. Then the samples were put in molten paraffin wax for one day, and then put in the oven at a temperature 65°C. Next, the paraffin blocks are put on ice to harden [11]. After the wax hardens, can make thin slices of the wax using a microtome. This instrument can cut slices just a few microns thick. The slices are carefully placed in a warm water bath to remove crinkles. Then , the wax in the samples are removed and the section is stained[12]. Finally, put the slides under the microscope, looking for thermal damage in tissue and determine it using graduated lens used on the microscope[9]. As shown in Fig.6.

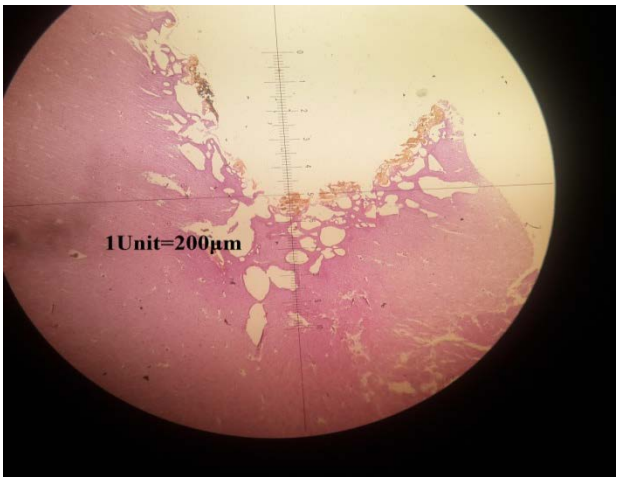


Figure 6.0 Sample of brain tissue with power of 10w and time 20s under the microscope.

III. RESULT AND DISSCUTION

1. Measurements the percentage of water

Different types of tissue are tested muscle, lung, liver, heart, brain and three type of tissues that has noticeable change in the percentage of water; are used in this work muscle, lung, and brain ,as shown in table 1. The procedure used in this work was used in reference [8].

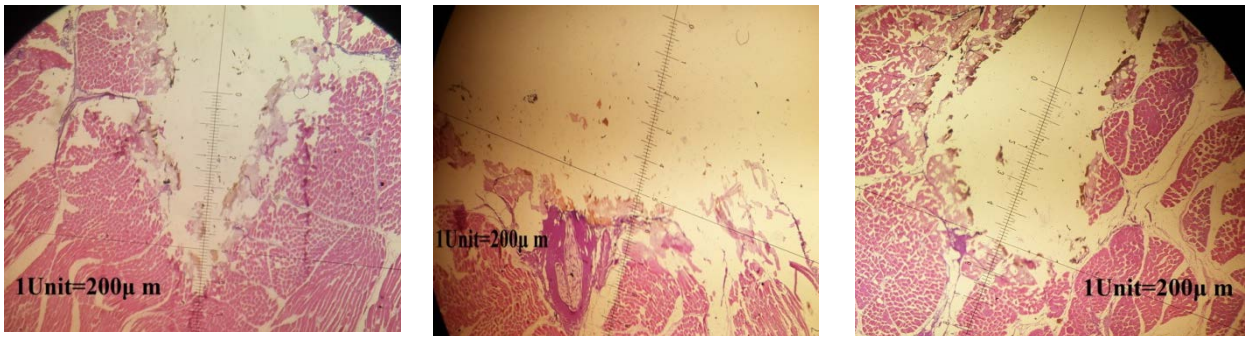
Table 1: The percentage of water in each tissue

Samples	Weight before dehydration	Weight after dehydration	Percentage of water %
Muscle	0.72	0.15	79
Lung	0.77	0.11	85
Liver	1.16	0.22	81
Heart	1.19	0.16	86
Brain	1.29	0.14	89

1.2 measurements of damage depth in tissues

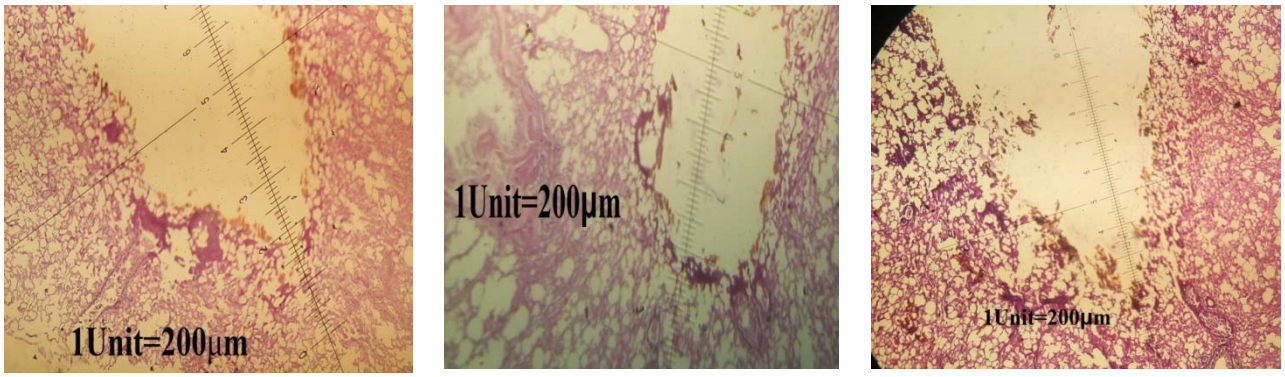
The thermal damage of tissue was seen using a microscope as shown in Figs.4- 6 and the damage depth is measured using scaled optics used on the microscope, the result is as shown in table 2.

From Fig.7 and tables 2, it is found that the damage depth in tissue decrease as the CW CO_2 power (intensity) and tissue water content increase; assume all tissue is subjected to 20s of laser where quasi-steady state is insured [13,14].



(a) (b) (c)

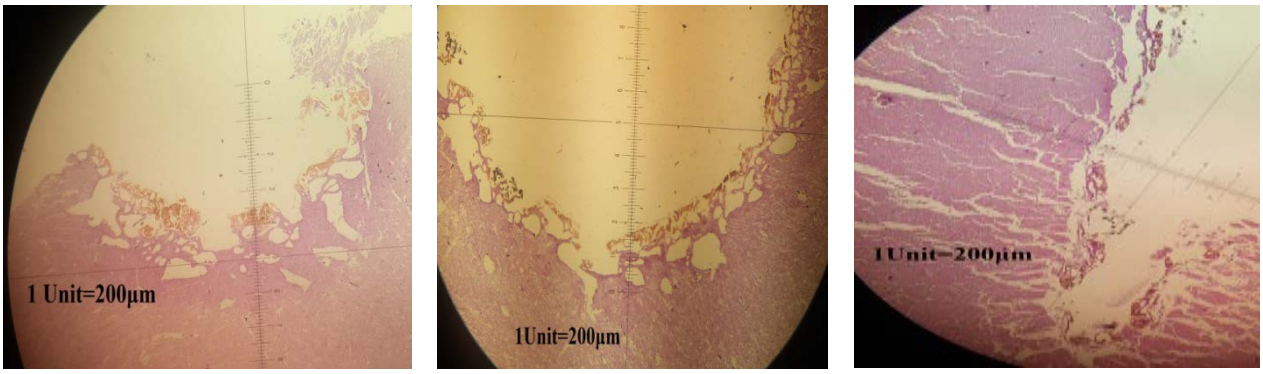
Figure 4.0 Thermal damage in tissue of muscle under the microscope caused by CO_2 laser after20 s with power of :a) 6w, b)9w,c)14w .



(a) (b) (c)

Figure 5.0 Thermal damage in tissue of lung under the microscope caused by CO_2 laser after20 s with power of

:a) 6w, b)9w,c)14w.



(a) (b) (c)

Figure 6.0 Thermal damage in tissue of brain under the microscope caused by CO_2 laser after20 s with power of :a) 6w, b)9w,c)14w.

Table 2: experimental damage depths of tissue subjected to CO_2 laser.

Power(w)	Exp. Damage depth (m) of muscle	Exp. Damage depth (m) of lung	Exp. Damage depth (m)of brain
6	3.4×10^{-4}	3.1×10^{-4}	3.0×10^{-4}
9	2.4×10^{-4}	2.0×10^{-4}	1.9×10^{-4}
14	1.35×10^{-4}	1.20×10^{-4}	9.8×10^{-5}

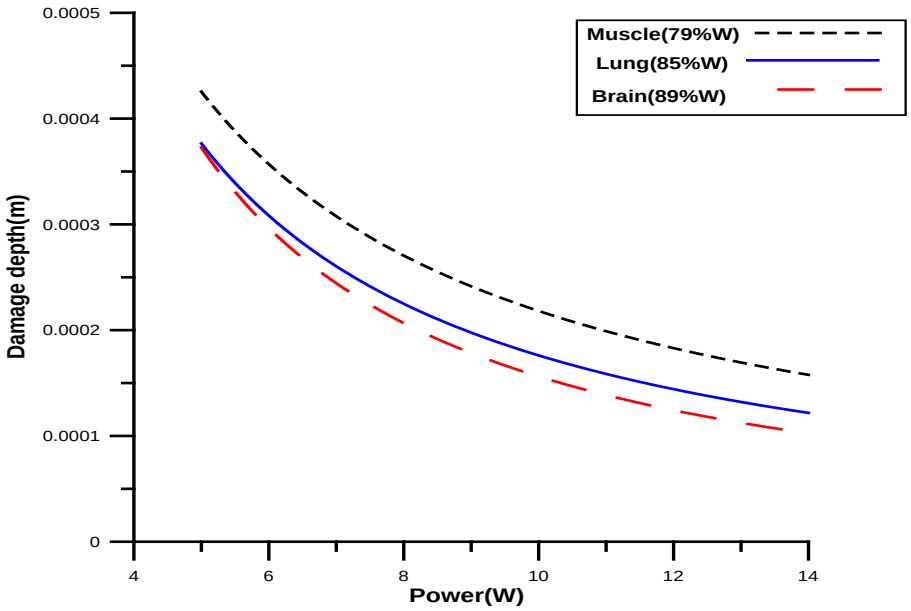


Figure 7.0 The variation of laser power with damage depth at 20 s in the muscle, lung and brain.

Fig. 7, show that the damage depths of tissue having different water content of muscle (79%), lung (85%), brain (89%). It is found that as power increased damage depth is decreased, also it is found that as water content increased damage depth is decreased. This is due to increase in cutting speed where heat is not allowed to accumulate to cause large damage.

The result of this work shows that the damage depth decreased as laser power intensity increased, it is also found that

the damage depth decreased as tissue water content increased, in cutting process where the samples in subjected to20 sec of laser power to insure quasi-steady state condition [13,14].
Lung and muscle tissue have water content less than brain tissue, see table1, so that damage depth in lung is more than brain, while the brain has less damage depth than muscle and lung, as shown in Fig.7.

IV. CONCLUSION

- Water content in tissue has big effect on thermal damage depth, where as water content increases, the damage depth decreases.
- It is found that as power intensity is increased, thermal damage is reduced which is limited by photo disruption phenomenon.
- CW CO_2 laser can be used successfully to cut or ablate bio- tissue, and unfortunately result thermal damage.

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