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Evaluation of thermal effects during vascular lesions treatment by dye laser

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Abstract: The determination of optimum values for laser parameters during laser application on patients' skin to cure several kinds of tissue ailments is of critical importance. In this work, we employed thermal camera to measure the spatial distribution during laser-skin treatment sessions to achieve that purpose, then followed that by measuring the effective time of skin heating. Where we built an image processing stage to analysis the thermal images in the quest to search for the critical safe temperature that can set the limit for better treatment and less side effects. The work is supported by experimental data during actual treatment sessions, namely during vascular lesion treatment.

This research supportsthe possibility of monitoring the temperature changes on skinduring laser treatment in order to avoid any undesired damage,which helps to find the optimum laser treatment parameters.

Keywords: medical laser applications, thermal effects of laser, dye laser, thermal imaging, Port Wine Stain.

Introduction

It is well-known fact that lasers have been used in many medical applications. However, the efficiency of laser treatment is varied in scale of quality for many reasons, which are basically related to the "compatibility" between acting laser parameters and the affected properties of the processed tissue.

Thermal heating is considered to be the major effective mechanism in most of laser treatment cases [1]. Where temporal behavior of heating is of respectable importance [6]. However, heating rise time is normally much faster than acquisition capability of most of the thermal imaging devices, which makes it hard to measure. That is why introducing new temporal parameter to describe heating process would helps in the quantification of the heating process, and in turn helps to set the right laser parameters during treatment to avoid any unwanted damage [2,3].

Heating happens by skin absorption to laser photons. The major players in this absorption are: melanin, hemoglobin, and water. Figure(1) illustrates the absorption curves of those essential players. It illustrates as well the best wavelength range for hemoglobin absorbance, which is of critical importance in vascular lesion treatment.

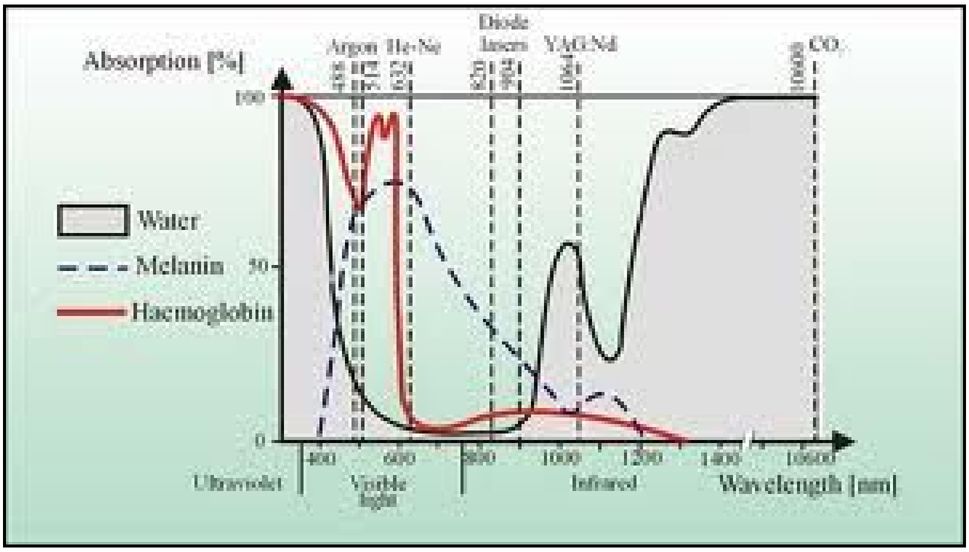

Figure (1) absorption curves of melanin, hemoglobin, and water within skin tissue.

Materials and methods:

The experimental part of this research was done during actual treatment processes of vascular lesions by laser. In all those experiments, we used dye laser at wavelength 595 nm. Temperature changes were captured and observed by using thermal camera (Fluke Ti 55), which has frame rate at 30 fps.

Matlab was used to process the captured images, extract data, and plot the curves of temperature evolution in skin.

We started by optimizing the camera for the imaging process, which can be sketched as bellow:

1. Focusing the lenses for the sharpest possible thermal image of the processed skin. That is of critical importance for the accuracy of temperature readings.
2. Setting the emissivity value of skin, which is 0.98.
3. Setting temperature scale to (-20 to100)C^{o}.
4. Setting the camera readings to gray scaling for more direct processing by Matlab compared to colored scaling.
5. Setting frame rate to the biggest possible.

The adopted laser parameters for all the studied skin treatments are as in the table below:

Energy (J)	**Pulse duration (s)**	**Diameter of laser beam (mm)**
7.1	0.5	7

After setting both the camera and laser parameters, we captured the thermal videos and moved forward to the next steps:

- Prepare the videos for processing in terms of format and time range.
- Applying home-made algorithm to follow laser heating spot during the treatment process and extract the highest temperature within it.
- Calculate and plot the effective time where the temperature stays above 41 C^{o} [7] .

Figure (2) shows the steps of the mentioned algorithm (digital image processing tracking algorithm) in more details.

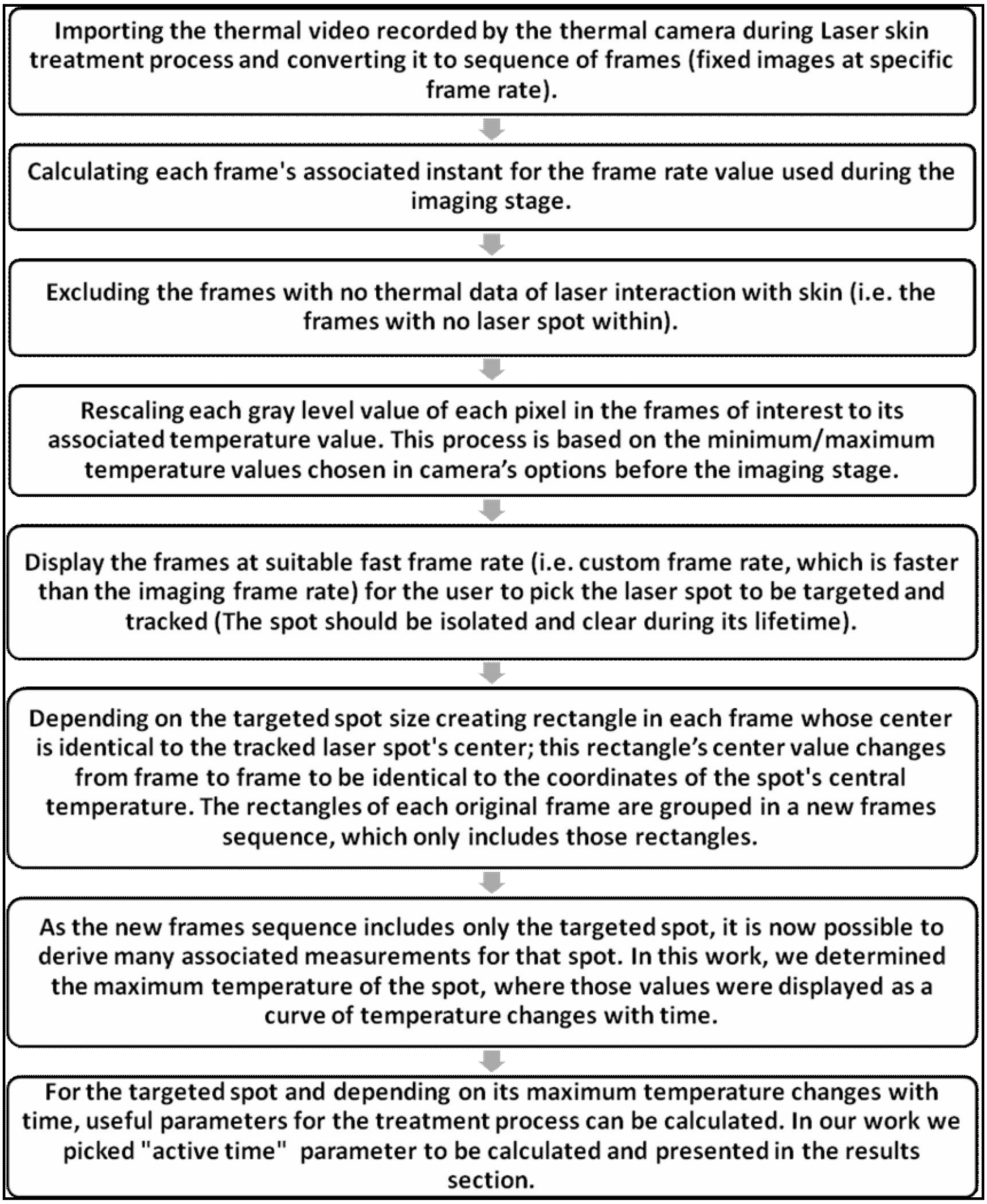

Figure (2)the programming steps for the proposed digital image processing tracking algorithm.

Results:

We show the results of laser heating analysis during laser skin treatment of 8 different patients with variable skin tones. Figure (3) shows the temporal behavior of the maximum temperature during a treatment without cooling. All the treatments without cooling follow the same behavior, with difference only in the scaling of both axis. The skin tone in figure (3) was4 (on scale of 1-6, higher tone = darker skin), and it was without cooling. The corresponding patient number in our table is 8.

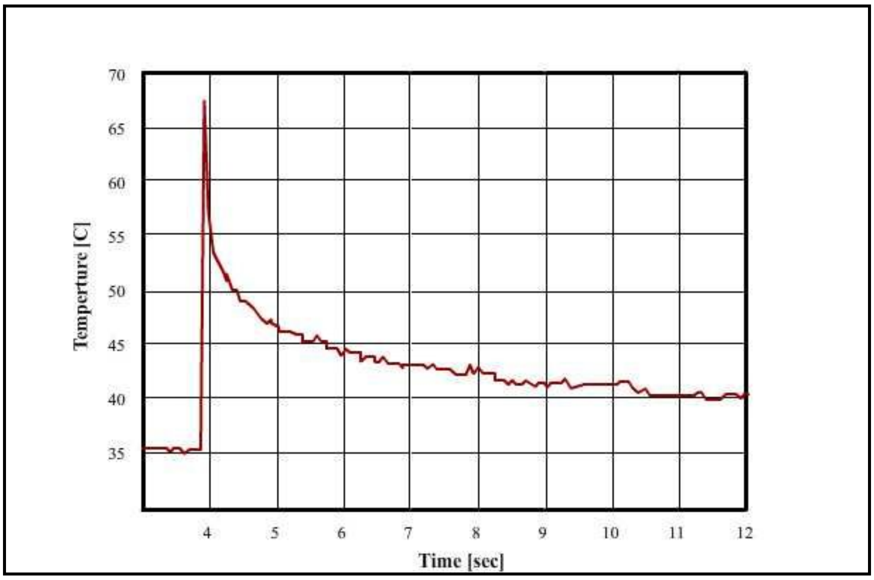

Figure (3) temperature changes with time. The corresponding patient number in our results is 8.

The next table lists the results without cooling:

Patient	Skin tone	Effective time (s)	Average time (s)
1	1	6.995	6.995
2	2	6.452	6.452
3	2-3	6.001	5.999
4	2-3	5.998	
5	3	5.554	5.473
6	3	5.634	
7	3	5.233	
8	4	5.126	5.107
9	4	5.089	

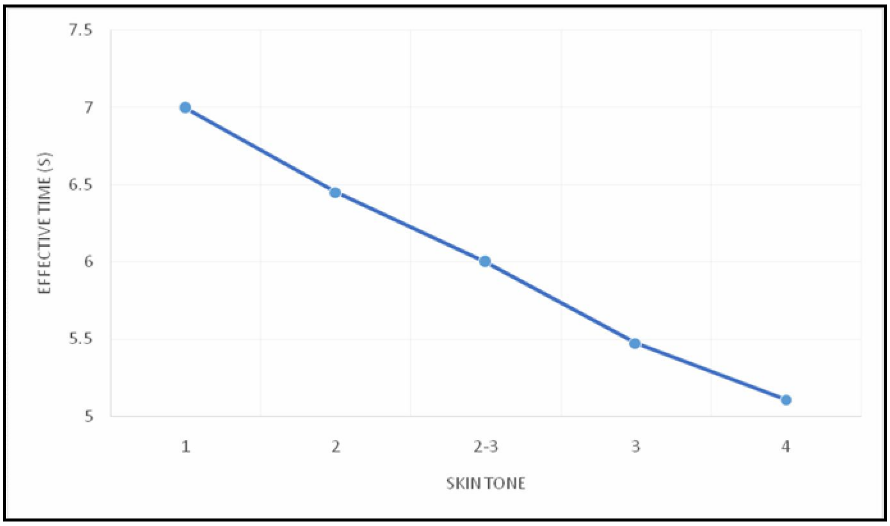

Figure (4) show dependency of the measured effective time on skin tone without cooling.

With cooling. All the treatments with cooling follow the same behavior, with difference only in the scaling of both axis. The skin tone in figure (5) was 4 (on scale of 1-6, higher tone = darker skin).

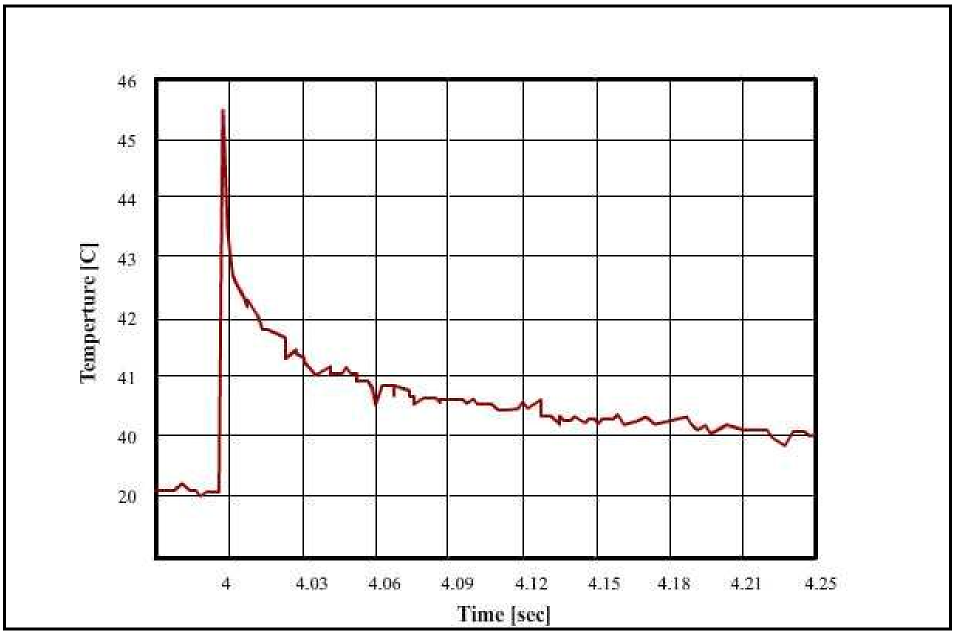

Figure (5) shows the rise of temperature (skin tone 4) after laser pulse with time (with cooling).

The next table lists the results with cooling:

Patient	Skin tone	Time value to reach to 41℃ (s)	Average time (s)
1	1	2.401	2.401
2	2	2.000	2000
3	2-3	1.100	1.120
4	2-3	1.141	
5	3	0.038	0.042
6	3	0.034	
7	3	0.045	
8	4	0.036	0.037
9	4	0.038	

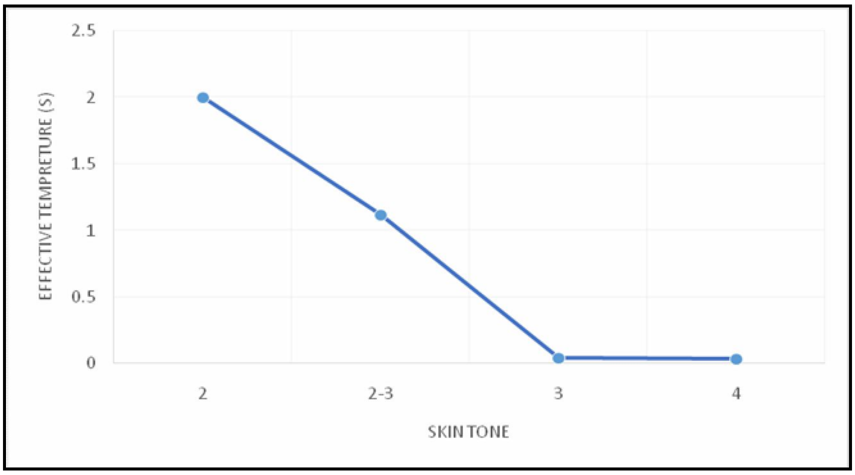

Figure (6) shows dependency of the measured effective time on skin tone with cooling.

We notice that the presence of cooling decreases the effective time. That permits to increase laser energy during treatment without causing much pain to the patient.

And we can conclude from above that the use of thermal camera and Matlab is effective to follow the temporal changes of skin temperature during laser treatment.

Conclusion:

This work offers the results of monitoring the laser heating temporal behavior during treatment of vascular lesions. That can help doctors to research the effect of laser heating and monitor it, then they can use this data to guide the treatment parameters toward the optimum values.

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