Simulation of the Frequency Doubled Nd:YAG Laser Effect on the Retina

T.A. Abdul Nabi, H. H. Mohammed andK.A. Mohammed
Ministry of Education.
Ministry of Sciences and Technology.
Deparement of Physics, College of Education, Ibn Al-Hatham, University of Baghdad.

Abstract

The present study was conducted with a view to determine whether focal laser therapy results in avisual recovery and regression of macular odema in patients with non-proliferative diabetic maculopathy. A Frequency doubled Nd:YAG laser was used for the treatment of diabetic maculopathy. For several has been studied and the treatment results were discussed. The study evaluates 14 eyes of 8 diabetic patients. Mathematical model of the laser interaction with the retinal tissue is demonstrated and analysis results are explained and compared with the recent experimental and mathematical models . It has been shown that the laser treatment of the retinal diabetic macolapathy , a disease that reduces vision significantly , would stop the extension of such adisease in many cases , while it improves the visual acuity for the other cases, mathematical model put forward is shown to be consistent with the recent experimental and theoretical models .Calculation results of the laser retinal energy density as a function of the spot size are studied and compared with the corresponding features of a typical laser damage which is based on athermal damage.

Introduction

Diabatic maculopathy is one of the leading causes of the reduced vision in cases of non-proliferative and proliferative diabatic retinopathy(1,2) .Non -proliferative diabatic retinopathy with maculopathy is generally treated with focal macular teachnique using the frequency – doubled Nd:YAG laser .While in causes of proliferative diabatic retiropathy with maculopathy usually focal technique is combined with scatter therapy (3,4).

The persent study was conducted with a view to determine whether the focal laser therapy results in avisual recovery, a regression of maculopathy and amacular odema in patients with non-proliferative diabetic retinopathy with maculopathy. And inorder to determine whether there is a visual recovery and a regression of risk factor like neovascularization and macular odema in patients with proliferative diabetic retinopathy with maculopathy treated by combined focal laser therapy (pan retinal photocoagulation) . Follow up period ranges from 6-8 months to evaluate the visual recovery , regression of macular odome and occurrence of complication like decrease visual acuity , visual field loss vitreous hemorrhage , and subscquent complication (5).

Materials and Methods

This study evaluate 14 eyes of 8 diabetic patients with Non Insulin Dependant Diabetes Mellitus (NIDDM) having Diabetic Maculopathy treated by focal retinal photocoagulation .Duration of the disease ranges from 4-27 years and their visual acuity ranges from 6/60 to 6/12 .

The patients, age and sex were recorded and a detailed medical history was taken regarding type of diabetes mellitus , duration of the disease , duration of the visual problem , drug history (drugs used to control diabetes mellitus and any other medication the patient is taking) , presence of systemic diseases (hypertension , cardio vascular disease and renal disease) in addition to any history of ocular surgery . Baseline examination included measuring best corrected visual acuity using

snellen's chart , slit –lamp biomicroscopy to examine the anterior segment , fundus examination which was performed by using the slit-lamp biomicroscope with the aid of contact lens and by using indirect ophthalmoscopy . Measurement of intraocular pressure was also performed and retinal photography was taken by fundus camera before and after application of laser treatment.

Focal retinal photocoagulating

A Frequency doubled Nd- YAG laser is used for the treatment of diabatic maculopathy by focal photocoagulation and clinically significant macular oedema. The criteria is for the clinically significant macular oedema (2,7,8).

Indication

Thickening of the retina is closer than 500 microns to the center of the macula.Hard exudates closer than 500 microns to the center of the macula are associated with adjacent areas of retinal thickening.
Retinal thickening areas which are larger than one disc diameter, any part of which is within one disc diameter of the center of the macula .
The wavelength of 532 nm of frequency doubled Nd:YAG laser is preferable for discrete area of vascular leakage since it is obsorbed by blood vessels. .Fundus contact lens minster focal field laser can cause a burn size approximately 1.05 time The spot zise on laser machine .50 micron setting gives 52.5 micron of true spot size.

The laser parameters

The spot size of the laser beam range from 50 to 100 microns , with a duration of 0.05 to 0.1 .The output power starts with a minimal value 100 mw and can be adjusted as necessary to achieve a light to modurate intensity burn to produce a relatively burn without speading of the spot apply 2 or 3 rows burn .The repetition rate was 1 Hz.
The power density was equal to 4.62x103, 6.93x103, 9.24x103 and 11.55x103 w/cm2,for the power 100 ,150 ,200,and 250 mw respectively.
The energy per pulse was equal to 10,15,20 and mj respectively .

Treatment scheme

The treatment scheme is represented by he following steps :

1- Confluent spots and multiple burns are applied over the same site as needed to obliterate focal areas of leakage, (note that the density of burn may be varied depending on the density of leakage which always leaves at least one burn width between spots). The treatment may be extended out in to two disc diameters from the center of the macula if necessary but should not approach closer than 500 micron to the optic disc.

2- Large areas of confluent treatment near the center of the macula shouldn't be applied to avoid development of Para central Scotomata.

3- Focal photocoagulation should be applied to diffuse areas of leakge.

Typical treatment scheme

The treatment scheme is represented by the following steps:-

1- 2500-3000 spots applied over 2 to 3 session. Total number of spots and density of burns varies with clinical response to treatments. Separated sessions would approximately last for3 weeks.

In the first session, a section of retina for treatment is selected by aspot and avarying power which are needed to obtain uniform burn intensity. In subsequent sessions, the treatment of previously untreated region is approximately 600-800 spots per session.

2- Space spots have one burn width from each other.

3- Burns applied in peripheral area of relatively normal retina are tested to obtain baseline power for treatment and the laser power is adjusted to produce a gray-white (not intense white) burn.

Evaluation criteria

We should emphasize that the main aim of our treatment is to preserve the patients current visual acuity:

1. Best corrected visual acuity after treatment.
2. Best corrected visual acuity after treatment.
3. Slit lamp examination.

4.Tonometry examination of intra ocular pressure.

5.Fundoscopic examination: examination of the retina full papillary dilatation (directional indirect ophthalmoscope).

6.Slit lamp biomicroscopy examination.

7.Visual field testing by gold man perimetry.

Theoretical Analysis Of The Laser Retinal Energy Density

In the near field and direct irradiation of the eye, the distance of the laser from the eye should be less than a2/λ, where a is the aperture of the laser and λ is the wavelength (8). The fractional portion of the energy entering the eye is given by:

$$R1=(D/d)2 \qquad [1]$$

Where D is the beam diameter at the entrance pupil of the eye and d is the output laser beam diameter. The diameter of the spot on the retina is given by:

$$Dr=f.\theta \text{ div} \qquad [2]$$

Where f is the effective focal length of the eye, and θdiv is the beam divergent angle of the laser. The laser energy per single shot at the cornea is given by:

$$Ec= Pout.\ t\ .R1.\ R2 \qquad [3]$$

Where Pout is the output power delivered by the laser source ,t is the exposure time ,R2 is the attenuation factor through the transmitter fiber which is equal to 20% (9) .

The image spot area at the retina is:

$$Ar= \pi Dr2/4 \qquad [4]$$

Similarly the corneal area is given by

$$Ac= \pi\ Dc2/4 \qquad [5]$$

The energy density at the retina is given by:

$$Er= Ec\ Ac/Ar \qquad [6]$$

The laser parameter data presented in Table (1) were used for the diabetic retinopathy cases explained in the previous section. The equations (1-6) were used for the retinal energy density calculations. The calculation were first conducted for the successful laser treatments, the cases demonstrated in the fluorescence angiography pictures would be for the DRP. The calculations results for the example of the case number (2) in Table (2) were

Ec= 0.32 J /cm2 and Er= 70 J/ cm 2 .

In order to employ a more useful diagnosis of the mathematical model, the data were extended so as to include different spot sizes other than 100 μm. The spot sizes which are used in our calculations were extended to include different spot size other than 50 or 100 μm .The spot size used in

our calculations were extended from 100 μm to 1000 μm. Calculation results of the laser retinal energy density (J/ cm2) as a function of the spot size were plotted as shown in Fig. (1).The present feature is a typical laser retinal damage which is based on athermal damage. Much interest had been
devoted, for the explanation of the laser retinal damage and then laser safety. The laser effects on abiological system were first reviewed by Ready (8). He mentioned that the significant parameter describes the sensitivity of the eye to the laser radiation which is the amount of energy absorbed by the retina. Birngruber et al. (10)have explained the thermal damage due to the induced disturbances of the genetic of the cells , by inactivation of enzymes , or by denaturation of proteins . Whereas , the nucleic acids seems to be relatively stable with respect to temperature (80°C at times up to an hour), protein denaturation and enzyme inactivation take place at lower temperatures and shorter times (60°C within fraction of second).The temperature at the retina, on the other hand,is dependent on the mean irradiance (11) . Marshall and corner (12) have developed formulae for laser hazard evaluation. They have tried to calculate the eye protection, by evaluation of the laser beam diameter, and the transmitted power through an optical system. . Recently Till et al.(13) have described a new model for laser induced retinal damage and proposed that at threshold laser induced temperature rise melts the membrane of the melanosomes found in the pigmented retinal epithelial cells. Such an effect induces the generation of free radicals by a chain of photochemical reactions.They confirmed that if more than a critical number of radicals are generated then the cell death may occur at a time much later than the return of the retina to body temperature (48 h post exposure as recently reported study).By the comparison of our results presented in Fig.(1) with the data presented in the given cited literature the damage mechanisms in the retina which are represented by image size which depends on the retinal radiant exposure energy density as demonstrated in Fig.(1) They are particularly in a good agreement with the recent experimental and theoretical results given by Till et al. who demonstrated that the observed retinal image size depends on of laser damage thresholds. (13) .For the sake of the current understanding of the

other parameters namely the exposure time and the laser energy density as a function of the spot size, the features of these parameters are shown in Fig.(2) A linear relationship is demonstrated, which facilitates the control of the laser parameters by the surgeons.

Results And Discussion

Varieties of laser treatment associated with the diabetic patients were done. All of the cases concerned patients who suffer from a retinal leaking area.

The laser parameters which were used for the treatments are shown in Table (1). All these cases listed in this Table are for patients suffer from diabetic maculopathy. The results of the laser treatments are very clear. They either stop the deteruration of the vision or obtain an improvement of the treated case.

On the other hand, the figures (3,4) and (5,6,7) represent successful cases for the laser treatments of diabetic patients .The laser parameters used for the treatment are listed in Table (2) .

The numbers of sessions of those patients were three , during each session .The same laser parameters were used .The conditions of those patients were the same since the third laser treatment session .

Case number (1) has a history of diabetic mellitus for the last 20 years. The blood sugar was poorly controlled during this period. The right eye was lost due to advanced diabetic eye disease and became beyond laser treatment. Fundoscopy of the left eye reveals clinically significant exudative and odematous maculapathy involving the center of the macula. Without laser treatment, this maculapathy might progress to cause sever impairment of visual acuity. Focal treatment with Frequency Doubled Nd: YAG laser was carried out immediately and fortunately leads to a significant improvement.

The analyzing of the cases shown in Fig. (3,4) are given below

(i) There is a large amount of exudation (lipoprotein) deposit within the macula, threatening its center (fovea).

(ii) A complete absorption of initial exudation with laser scar treatment was seen at six months later. But other sites of leakage appeared which definitely need more laser treatment in the future.

Case number (2) has circinate maculopathy of the left eye associated with oedema which leads to a decrease in the visual acuity of this eye. Fluorescene angiography was carried out for him to localize the leakage site and then focal laser treatment was done accordingly. After 3 sessions of focal treatment, complete absorption of exudation and oedema occrued .

The medical analysis of the Fig. (5,6,7) mentioned above are given as the following

(i) Circinate maculopathy.

(ii) The site of leakage, which was shown by the fluorescence angiography.

(iii) A Complete absorption of circinate maculopathy and multiple retinal scars of previous laser sessions.

Conclusion

The laser treatments of the retinal diabetic macolapathy, are as follows:

(a) In case of a disease that reduces vision significantly , it should stop the extension of such adisease in many cases , while it would improve the visual acuity for the other cases .

(b) The mathematical model which was put forward in the present work is shown to be consistent with the recent experimental and theoretical results.

References

1. Fredricks, F. I.; Marvin, P. J. and Mathew D.D. (1987) Ophthalmology 94: 754-66
2. Kaniski, J.J.(1990) "Clinical ophthalmology" chap 12: 463-79.
3. Blankenship, G.W. (1988) Ophthalmology 95: 70-76.
4. Dastur, Y.K. (1994) Journal of postgraduate medicine 40: 13-17.
5. Little, H.L. (1985) Ophthalmology 29: 279-83.
6. Peter, S.H.(1988) "Ophthalmic surgical Procedure" Chap.9, pp 385-97.
7. Saeed, M.; Parmer, D. and Mc Hugh, D. (2001) Eye 15: 712-8

8. Ready, J. F. (1971) Effects of high power laser radiation, Academic press
9. Peter, Z. ;Dejan, R. and Simon, R. (2004) Laser in Surgery and Medicine 34: 164-167.
10. Birngrubes, R. ; Hillenkamp, F . and . Gabel, V.P (1985) Health physics 48: 781-788.
11. Hill, R. J. and churnside, J.H. (1987) Health physics, 53: 639-642.
12- Marshall , W. J. and Conner, P.W. (1987) Health physics, 52:27-33.
13- Till, S.J. ;Milsom , P.K. and Rowland, G. (2003) Bul. Math. Biology 65:731-740.

Table No. (1) laser retinal treatment for several patients

Case No.	Power (mW)	Pulse duration (sec)	Spot Size (μm)	No. of Shots
1	550	0.2	210	260
2	450	0.2	100	142
3	60	0.2	200	308
4	300	0.2	90	46
5	400	0.2	70	231
6	200	0.2	100	202
7	400	0.2	200	241
8	650	0.2	200	264
9	410	0.2	200	406
10	600	0.2	200	400
11	400	0.2	70	231
12	200	0.2	100	202

Table (2) Laser retinal treatment for two patients

Case No.	Laser Power (mW)	Pulse duration (sec)	Spot Size (μm)	No. of Shots	Visual Acuity	
					Before treatment	After treatment
1	180	0.1	50	138	6/18	6/12
2	280	0.1	100	250	6/18	6/18

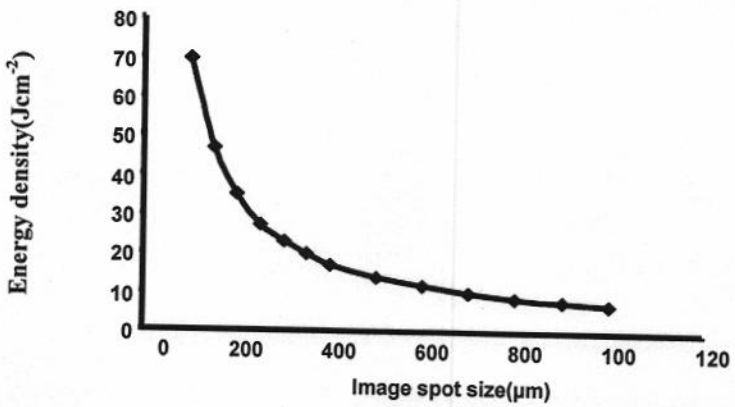


Fig. (1) Laser Energy Density Versus Image Spot Size.

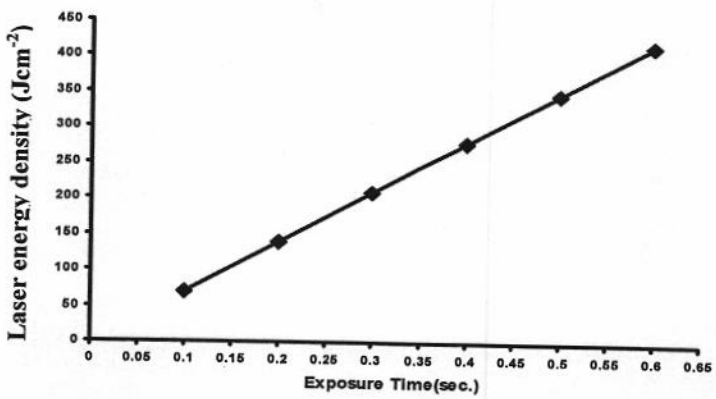


Fig. (2) Laser energy dencity versus Exposure time .

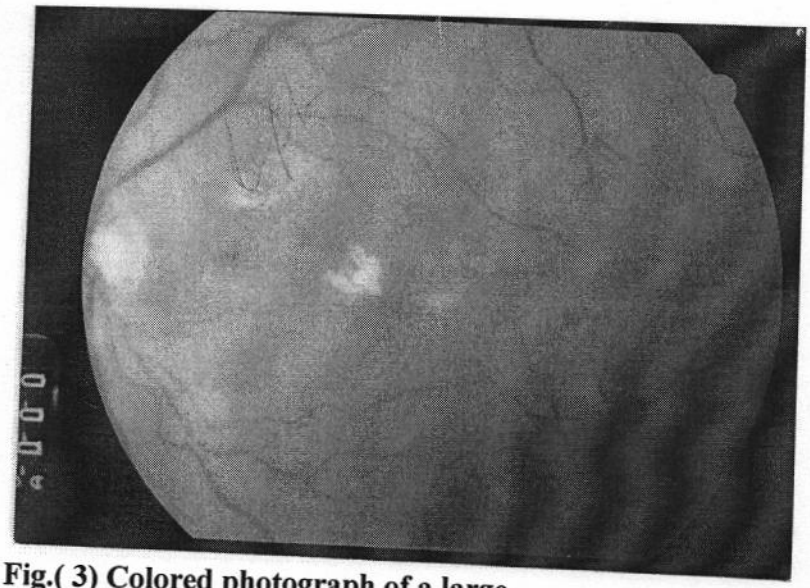
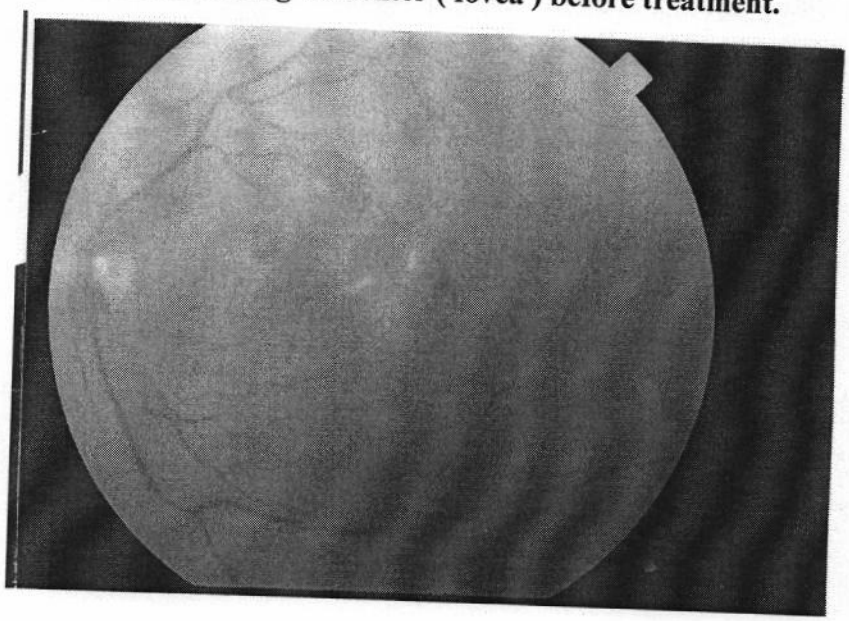
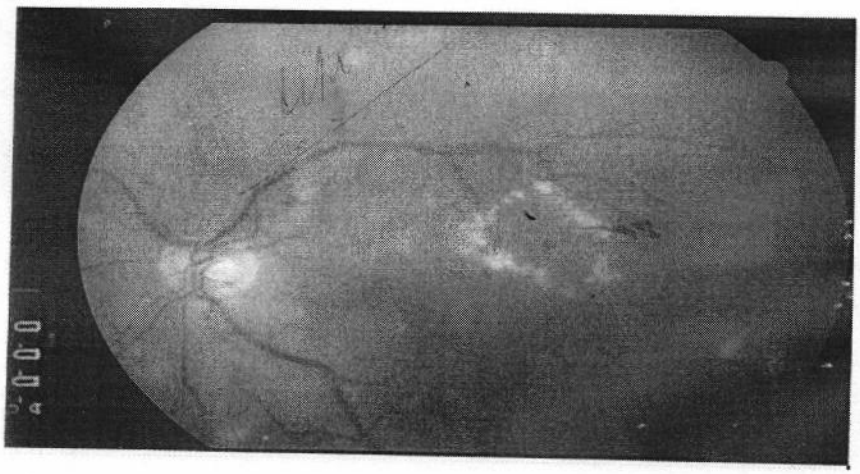


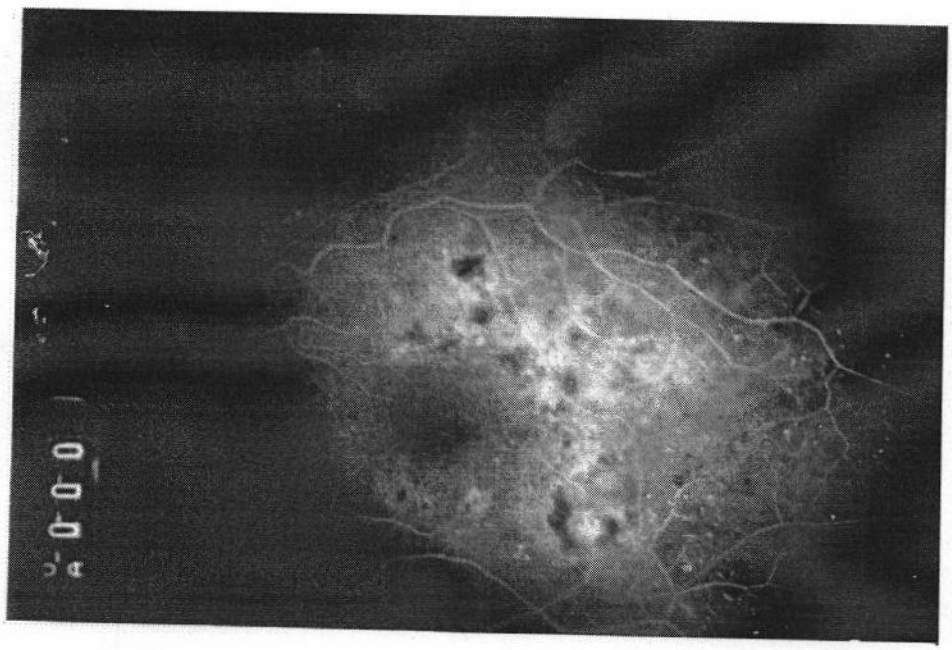
Fig.(3) Colored photograph of a large amount of exudation deposit within the macula threatening its center (fovea) before treatment.



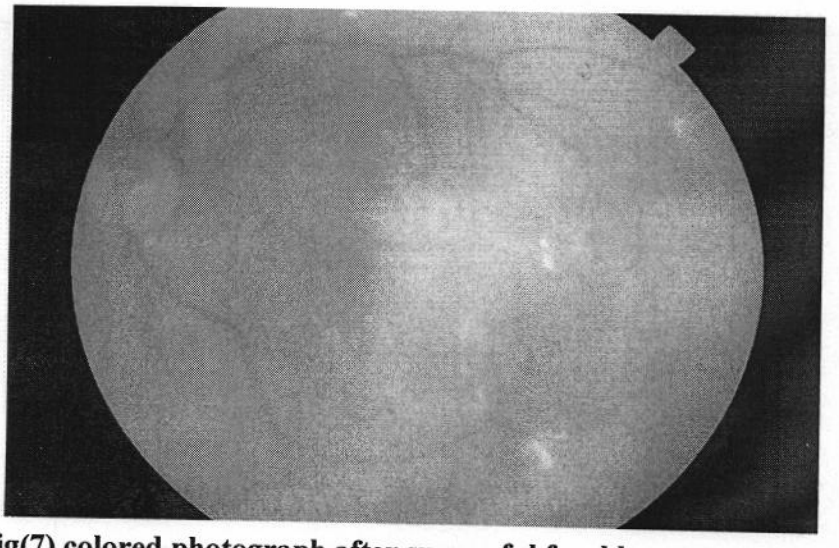
Fig(4) Colored photograph six months later shows a complete obsobtion of initial exudation with laser scar and there are other sites of leakage appeared.



Fig(5) colored photograph before treatment of criminate maculopathy .



Fig(6) fluorescin angiogram which was shown the site of leakage.



Fig(7) colored photograph after successful focal laser treatment..

محاكاة تأثير ليزر Nd: YAG ذي التردد المضاعف فى الشبكية

تغريد عبد الامير عبد النبي الحميري، حسن حمادي محمد و قاسم عزيز محمد
وزارة التربية
وزارة العلوم والتكنلوجيا
قسم الفيزياء ، كلية التربية – ابن الهيثم ،جامعة بغداد

الخلاصة

تناقش الدراسة مدى فعالية وفائدة علاج استحالة الشائبة الصفراء لـداء الـسكري بالليزر. استعمل ليزر Nd^{+3}: YAG ذو التردد المضاعف (λ= 532 nm) لعلاج استحالة الشائبة الصفراء لداء السكري، استعمل العلاج الموضعي للشبكية في السيطره على النـضوح حول الشائبةالصفراء ولتحسن الرؤية وتقليل المضاعفات الناتجة عن المرض. شملت الدراسة 14 عينةلـ 8 مرضى. وقد درست ونوقشت النتائج التي استحصلت من العلاج. ان الانموذج الرياضي لتفاعل الليزر مع نسيج الشبكية قد تم ملاحظته وتفسيره وحللت نتائجه بالمقارنة مع النتائج المختبرية والرياضية الحديثة. كما لوحظ ان الليزر الذي يعالج وذمة الشائبة الصفراء بداء السكري (المرض الذي يقلل من حدة البصر) ،قد أوقف توسع هذا المرض فـي عـدة حالات، بينما قد حسّن من حدة البصر لحالات أخـرى. واتـضح ان الانمـوذج الرياضـي الموضوع يتلائم مع النماذج النظرية والمختبرية الحديثة. النتائج الحسابية لكثافة طاقة الليزر للشبكية دالة لحجم البقعة قد تمت ملاحظتها وقورنت مع دراسـات مماثلـة لـضرر الليـزر الانموذجي الذي اساسه الضرر الحراري.