CHOROIDAL REVASCULARIZATION POSTOPERATIVE MONITORING BY INFRARED RADIOTHERMOMTRY METHODS

UDC 615.849:618.1–089.168.1
Received 19.03.2013

P.I. Orlov, Ophthalmologist[1];
N.M. Shakhova, D.Med.Sc., Leading Research Worker[2];
I.Ya. Orlov, D.Tech.Sc., Professor, the Department of Radioengineering[3]

[1]Clinical Hospital No.50 of Federal Medical and Biological Agency, Bolnichny gorodok, Zernova St., 72, Sarov, Nizhny Novgorod region, Russian Federation, 607190;
[2]Institute of Applied Physics of Russian Academy of Sciences, Ul'yanova St., 46, Nizhny Novgorod, Russian Federation, 603155;
[3]Nizhny Novgorod State University named after N.I. Lobachevsky — National Research University, Gagarin Avenue, 23, Nizhny Novgorod, Russian Federation, 603950

The aim of the investigation was to assess the possibilities of infrared radiothermometry for choroidal revascularization surgery monitoring.

Materials and Methods. A portable microprocessor-based infrared radiothermometer was used to study eyeball surface temperature and eye temperature asymmetry. The patients with central chorioretinal dystrophy after "Alloplant" (Russia) biomaterial transplantation underwent monitoring of revascularization operations.

Results. There were the reduction of the affected eye temperature and the increase of temperature asymmetry before the operation. 5 days after the surgery surface temperature of the operated eyes increased and the asymmetry direction changed due to reactive inflammation. 10 days later the temperature asymmetry decreased and reached its norm by the 40th follow-up day. The patients after alloplant transplantation for retinal revascularization were found to have the change of eye temperature asymmetry in postoperative period.

The possibility of noninvasive real-time monitoring of the eye temperature asymmetry change shows the application perspectiveness of infrared radiothermometry for dynamic control of immediate and long-term results of biomaterial transplantation for retinal blood supply correction in degenerative age-related changes.

Key words: infrared radiothermometry; revascularization; retinal dystrophy; choroidal revascularization operation.

Senile macular degeneration ranks one of the first positions in the structure of irreversible blindness [1]. Medication method in some cases enables to stabilize patients' condition and slow the dystrophic process development, though the recovery of normal retinal condition by a therapeutic method fails. One of surgical management techniques of this pathology — choroidal revascularization operations — partially solves this problem in patients with atrophic senile macular degeneration (SMD) [2]. Optical coherent tomography (OCT) is a monitoring technique of such conditions [3, 4]. However, it can estimate only morphological traits, and cannot be used to assess functional results.

As a rule, transplantation results in aseptic inflammation leading to increased eye-bulb blood supply, and subsequently, the change of temperature factor. Accurate measurement in the area of interest is reasonable for the control of focus evolution against the background of the administered treatment. Temperature measurement techniques currently widely used have a number of characteristics limiting their application: in-touch capabilities, contact quality has an effect on accuracy, the change of thermal transmission conditions [5, 6]. The most promising method is noncontact thermometry using infrared (IR) radiothermometers [7, 8]. These devices noncontact measure their IR emission on an object surface in infrared wavelength band. They record brightness temperature, i.e. the temperature appropriate for human body electromagnetic radiation power. The advantage of IR-radiothermometry is remotability, noncontact character, absolute safety and the possibility of multiple follow-up. It is worth mentioning that recently IR-radiothermometry (pyrometry) is actively used to control the effect in different applications: when estimating temperature effects of laser exposure [9–11], analyzing freezing process in cryosurgery [12], managing venous ulcers [13, 14], and in the rehabilitation of upper limbs [15] etc.

Considering that choroidal revascularization operations result mainly in the process of induced aseptic inflammation, and therefore, local temperature rise, we see it promising to use noncontact IR-radiothermometry to assess the efficiency of the procedure.

The aim of the investigation was to assess the possibilities of infrared radiothermometry for choroidal revascularization surgery monitoring in patients with atrophic senile macular degeneration.

Materials and Methods. A portable microprocessor-

For contacts: Shakhova Nataliya Mikhaylovna, phone: 8(831)436-80-10, +7 951-907-47-49; e-mail: natalia.shakhova@gmail.com

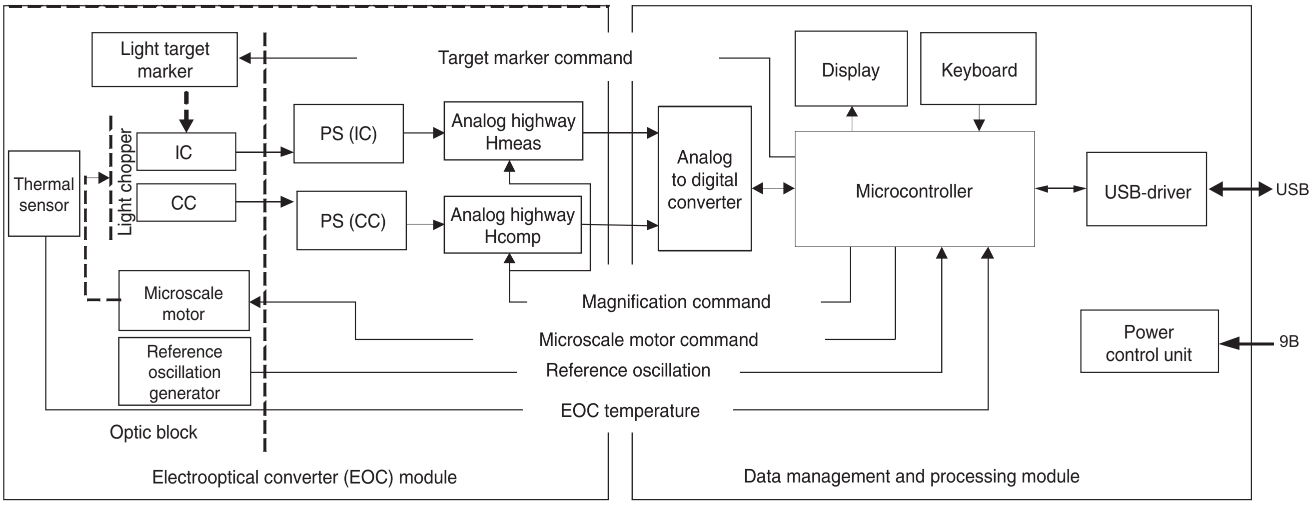

Fig. 1. IR-radiothermometer scheme diagram: PS(IC) — pyrosensor of infrared channel; PS(CC) — pyrosensor of compensation channel

based IR-radiothermometer (Fig. 1) developed by the Radio-Engineering Department, N.I. Lobachevsky State University (Nizhny Novgorod, Russia) [16, 17] was used in biomedical researches.

For computer connection the device provides the use of wireless data transfer channel ISM 868 MHz (Industry Science Medicine) designed for medical facilities. Using a computer one can process the findings (e.g., to calculate dispersion of measurements data, minimum and maximum values), display real time data graphically and in digital values, as well as of research protocol archiving including those in TXT and CSV format for further data processing using such programs as Excel.

To reduce a random error the measurements are made twice and thrice. After every measurement recording, the data are entered a device memory. A radiometer can contain data on 20 measurements in a cycle course. Patient examination time in this technique is 1.0–1.5 min.

We studied the following parameters: eye-bulb surface temperature including various eye areas, and eye temperature asymmetry.

For normal criteria development using IR-radiothermometry we examined volunteers with general diseases and no ophthalmological pathology. A control group included 49 people (21 male, 28 female) aged 16–64, mean age being 35 years.

A treatment group consisted of 9 patients (6 male and 3 female patients) with atrophic SMD aged 46–75, mean age being 61 years, who underwent choroidal revascularization operation using “Alloplant” (Russia) biomaterial transplantation. Radiothermometry was used for monitoring preoperatively (the day before an operation), and in immediate postoperative period (day 5, 10, 40 after the operation).

Results. In control group eyeball surface temperature was within the range of 32–35.5°C. Eyeball surface temperature was found to depend on patients’ age: in young patients (aged 16–35) it was 34.5–35.5°C, that was 2–2.5°C higher than in elderly patients (over 50). It is explained by age-related decrease of general and local circulation level, and therefore, the decrease of heat transfer level, which eye-bulb surface temperature depends on. There was observed a gradual decrease of surface temperature from eyeball periphery to corneal center: temperature difference between them being 0.3–0.4°C. Eye temperature asymmetry changed in corneal centre does not exceed 0.25°C in the norm.

A group of SMD patients was found to have decreased temperature of an affected eye resulting in temperature asymmetry increase up to 0.3–1.15°C (See the Table).

As the table shows, 5 days after the operation there was observed the surface temperature increase of operated eyes by 1.0–2.5°C. Temperature asymmetry changed its “direction” indicating the development of reactive inflammation immediately after allograft transplantation. 10 days later the temperature of an operated eye started decreasing resulting in the reduction of eye temperature asymmetry as well. According to our findings, this index is to reach its norm by day 40 of follow-up.

Fig. 2 demonstrates eye temperature asymmetry changes after alloplant transplantation against the background of anti-inflammatory therapy. The persistence of eye

Monitoring of revascularization operation using IR thermometry

No.	Patient, age, operated eye	Temperature, °C							
		before operation		5 days later		10 days later		40 days later	
		OD	OS	OD	OS	OD	OS	OD	OS
1	B., 68, OS	33.45	32.3	33.4	34.8	33.49	34.77	33.86	34.6
2	T., 40, OS	33.56	33.26	33.98	34.63	33.9	34.85	33.9	34.08
3	T., 58, OD	33.4	33.83	34.27	33.2	34.8	33.6	33.9	33.70

N o t e: OD — right eye, OS — left eye.

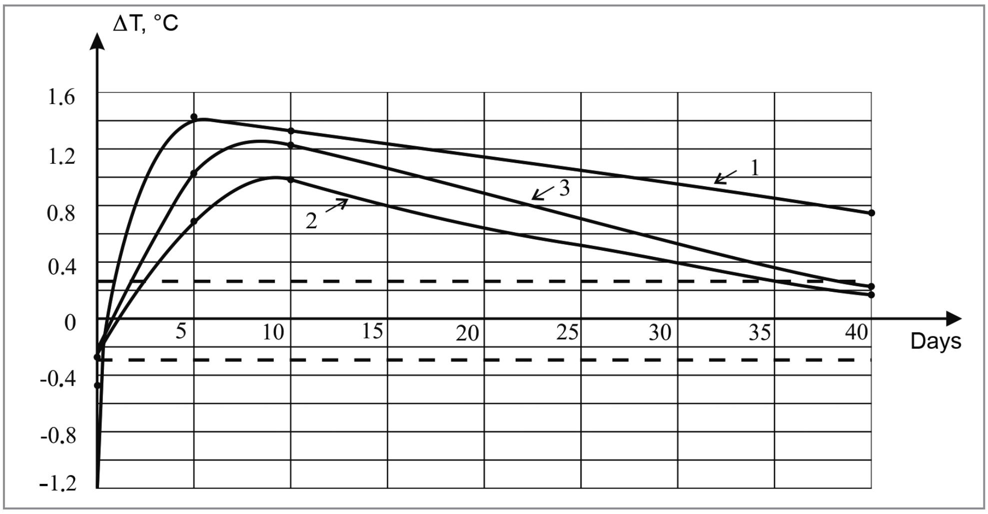

Fig. 2. Temperature asymmetry dynamics of a sound and an affected eye after choroidal revascularization. The range of temperature asymmetry in a norm is shown between the broken lines. The number of graphs correspond to 1, 2, 3 items in the table

temperature asymmetry (Case 1, Patient B.), in our opinion, can indicate continuing postoperative inflammation that can require individual correction.

Discussion. The research carried out strongly indicates the possibility to monitor eye surface temperature with the assessment of temperature asymmetry in patients with atrophic SMD after choroidal revascularization operations. The study of temperature asymmetry dynamics showed postoperative inflammation-related "reverse" temperature asymmetry of a sound and an operated eye compared to preoperative temperature. There was further persistent long decrease of the "reverse" temperature asymmetry up to normal value.

IR-radiothermometry findings demonstrate a number of temperature regularities characteristic of choroidal revascularization operations. The surgery first results in reactive inflammation, then — in the increase in proper choroidal blood supply in a transplant area that is also recorded by surface temperature data, and more objectively — by temperature asymmetry index.

The possibility of real-time monitoring of the eye temperature asymmetry change offers the opportunities of individual monitoring of early and long-term postoperative period when using revascularization technologies.

Conclusion. The results obtained show the application perspectiveness of infrared radiothermometry for dynamic control of immediate and long-term results and recovery time control in biomaterial transplantation for retinal blood supply correction in degenerative age-related changes.

This work was supported by grant 11.G34.31.0066 of Government of the Russian Federation.

References

1. Panova I.E., Prokop'eva M.Yu., Kinzerskiy A.Yu., Ermak E.M. Issledovanie khorioidal'nogo krovotoka u patsientov s nachal'noy stadiey vozrastnoy makulyarnoy distrofii. V kn.: *Trudy Vserossiyskoy konferentsii «Eroshevskie chteniya»* [The study of choroidal blood flow in patients with early age-related macular degeneration. In: Proceedings of Russian conference "Eroshevsky readings"]. Samara; 2007; p. 376–378.

2. Doga A.V., Magaramov D.A., Kachalina G.F., Sergeeva E.S. Lazernoe lechenie nekotorykh zabolevaniy setchatki [Laser treatment of some retinal diseases]. *Vestn Oftal'mol — Ophthalmology Reporter* 2011; 6: 60–64.

3. Stepanov A.V., Lugovkina K.V., Dzhioeva A.V. Novye metody v diagnostike intraokulyarnoy epitelial'noy proliferatsii [New methods in the diagnostics of intraocular epithelial proliferation]. *Rossiyskiy oftal'mologicheskiy zhurnal — Russian Journal of Ophthalmology* 2011; 4(2): 52–55.

4. Neroev V.V., Zaytseva O.V., Kuznetsova I.S. Analiz dannykh opticheskoy kogerentnoy tomografii u patsientov do i posle khirurgii regmatogennoy otsloyki setchatki [Analysis of optical coherence tomography findings in patients before and after the surgery of rhegmatogenous retinal detachment]. *Rossiyskiy oftal'mologicheskiy zhurnal — Russian Journal of Ophthalmology* 2012; 5(4): 57–62.

5. Il'yukhin O.E., Kumar L.A. Termograficheskiy analiz koaksial'noy, mikrokoaksial'noy i bimanual'noy fakoemul'sifikatsii [Thermographic analysis of coaxial, micro-coaxial and bimanual phacoemulsification]. *Rossiyskiy oftal'mologicheskiy zhurnal — Russian Journal of Ophthalmology* 2010; 3(1): 8–12.

6. Afanas'ev A.V., Afanas'eva O.A., Mazunin I.Yu., Orlov P.I. Kontrol' metodami IK i SVCh radiometrii protsessov ustanovleniya termodinamicheskogo ravnovesiya v biologicheskikh tkanyakh [Infrared and microwave radiometry control of the processes of thermodynamic balance in biological tissues]. *Vestnik Nizhegorodskogo gosudarstvennogo universiteta im. N.I. Lobachevskogo — Herald of Nizhny Novgorod State University named after N.I. Lobachevsky* 2005; 2(3).

7. Smetankin I.G. Vozmozhnosti metoda distantsionnoy infrakrasnoy radiopirometrii pri opredelenii temperatury rogovichnoy rany vo vremya fakoemul'sifikatsii katarakty [The possibilities of remote infrared radiopyrometry in corneal wound temperature determination during cataract phacoemulsification]. *Vestn Oftal'mol — Ophthalmology Reporter* 2009; 5: 12–14.

8. Orlov P.I. Infrakrasnaya radiotermometriya v differentsial'noy diagnostike distroficheskikh i vospalitel'nykh zabolevaniy perednego otdela glaza [Infrared radiothermometry in differential diagnosis of dystrophic and inflammatory diseases of the anterior chamber of eye]. *Vestn Oftal'mol — Ophthalmology Reporter* 2008; 2: 19–22.

9. Verkruysse W., Jia W., Franco W., Milner T.E., Nelson J.S. Infrared measurement of human skin temperature to predict the individual maximum safe radiant exposure (IMSRE). *Lasers Surg Med* 2007 Dec; 39(10): 757–766.

10. Plaghki L., Mouraux A. How do we selectively activate skin nociceptors with a high power infrared laser? Physiology and biophysics of laser stimulation. *Clinical Neurophysiology* 2003; 33(6): 269–277.

11. Leandri M., Saturno M., Spadavecchia L., Iannetti G.D., Cruccu G., Truini A. Measurement of skin temperature after infrared laser stimulation. *Neurophysiol Clin* 2006; 36(4): 207–218.

12. Yan J.F., Liu J., Zhou Y.X. Infrared image to evaluate the selective directional freezing due to localized injection of thermally important solutions. *Conf Proc IEEE Eng Med Biol Soc* 2005; 4: 3559–3562.

13. Armstrong D.G., Holtz-Neiderer K., Wendel C., Mohler M.J., Kimbriel H.R., Lavery L.A. Skin temperature monitoring reduces the risk for diabetic foot ulceration in high-risk patients. *Am J Med* 2007 Dec; 120(12): 1042–1046.

14. Sayre E.K., Kelechi T.J., Neal D. Sudden increase in skin temperature predicts venous ulcers: a case study. *J Vasc Nurs* 2007 Sep; 25(3): 46–50.

15. Packham T.L., Fok D., Frederiksen K., Thabane L., Buckley N. Reliability of infrared thermometric measurements of skin temperature in the hand. *J Hand Ther* 2012; 25(4): 358–362.

16. Orlov I.Ya., Afanas'ev A.V., Nikiforov I.A. High-precision radiometer of infrared radiation. *Automation Remote Control* 2011; 72(4): 345–349.

17. Orlov P.I., Afanas'ev A.V., Nikiforov I.A., Orlov I.Ya., Terentiev I.G. *Modulyatsionnyy radiometr infrakrasnogo izlucheniya* [Switched infrared radiometer]. Patent RF No.2.345.333. 2009.