Optica Applicata, Vol. XXXVII, No. 1–2, 2007

Laser transillumination of interphalangeal joints of women suffering from rheumatoid diseases

EWA BOERNER[1], JOANNA BAUER[2], ANNA SZEWCZYK[2], HALINA PODBIELSKA[2]

[1]Faculty of Physiotherapy, University School of Physical Education, ul. Witelona 25a, 51-617 Wrocław, Poland

[2]Bio-Optics Group, Institute of Biomedical Engineering, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland

Experimental set-up consisted of He-Ne laser with optics for collimated illumination, special holder for placing the finger (perpendicular to optical axis, dorsal or ventral site towards camera), and CCD camera was constructed for performing the transillumination examination of proximal interphalangeal joints of 19 healthy female adult volunteers and 21 female patients suffering from joints inflammation. The transillumination images of ill and healthy subjects were compared by histogram analysis. The images were captured from dorsal and ventral side of the fingers. It was found that the mean grey level values in images taken at the dorsal side (laser beam travels from the ventral side) are lower than for the opposite direction. It was also concluded that healthy volunteers have joints more transparent to visible light, so the mean grey level values in captured images were higher. It was possible to observe the changes in images intensity of patients subjected to the anti-inflammation therapy, what may allow for monitoring the efficacy of the therapy.

Keywords: laser transillumination, interphalangeal joints.

1. Introduction

Transillumination, called also diaphanoscopy, is one of the oldest diagnostics methods, based on the qualitative evaluation of the images of organs obtained in transmitted light. Already in 1843, London surgeon T.B. Curling described examination of hydrocele using an ordinary candle as a light source [1]. This kind of diagnostics was used in the past for assessing hydrocephalus in newborns or inflammation in nasal area (the laryngological transillumination was performed, *e.g.*, in Warsaw as early as in 1889 [2]), and again in the last century was proposed for examination of nasal sinusitis [3].

In the past, transillumination was examined as a possible diagnostic method for detection of breast lesions [4–6]. The information on optical features of tissue is

the base for this type of diagnostics, therefore many researchers perform investigations on absorbance, transmittance or light scattering in tissue in various wavelength ranges. One of the first publications on IR transillumination of tissue *in vitro* appeared already in 1930 [7]. Since then, plethora of reports were published around the world. This kind of research had undoubtedly the big impact on theory and practice of optical tomography. In the last years, transillumination gained again an interest as a possible diagnostic tool for evaluation of muscoskeletal system, especially for assessment of interphalangeal joints in early stage of rheumatoid arthritis [8–12].

Arthropathies in finger joints are the cause of discomfort and pain, and decrease patient's mobility. Rheumatoid arthritis is an inflammatory arthropathy, mostly progressive, which significantly decreases the quality of life in 1–2% of the population. Proper diagnosis is essential for proper treatment, especially at early stages. Unfortunately, the existing diagnostic methods are not satisfactory enough. The current diagnosis is mostly subjective and clinical examinations such as X-ray or ultrasound imaging are performed when the pathology is more advanced, thus the joints deformation is further progressing.

Recently, we have compared the transillumination images of finger joints of 9 young healthy volunteers with images of 35 older patients in advanced stages of rheumatoid arthritis. It was demonstrated that transillumination with He-Ne laser light can be used for diagnostic purposes [13]. Here, we report on the results of the transillumination study for diagnosis and therapy monitoring based on assessment of the mean grey level values in transillumination images of interphalangeal joints of female patients. The experimental groups of patients and healthy subjects were carefully chosen to be homogenous in respect of the mean age and gender.

2. Material

The examinations were performed on 19 healthy adult volunteers and 21 patients suffering from interphalangeal joints inflammation, causing the pain and motority discomfort in fingers. All the patients were females (aged 24–62, mean age 45.8). The healthy volunteers were females (aged 24–75, mean age 44.6). The ill persons were females diagnosed as suffering from rheumatoid arthritis, stage II. The administered treatment included the common pharmacotherapy and physiotherapy, including kinesytherapy and lasertherapy.

3. Method

Experimental set-up consisted of He-Ne laser with optics for collimated illumination, special holder for placing the finger (perpendicular to optical axis, dorsal site towards

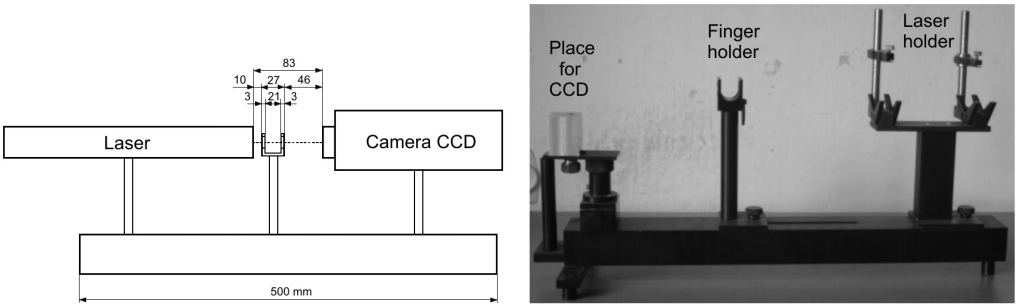

Fig. 1. Schematic representation of experimental setup and its photograph.

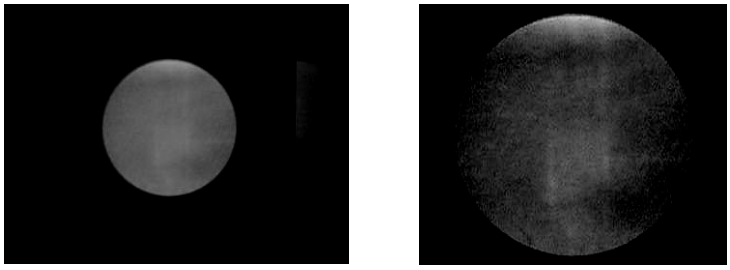

Fig. 2. Initial transillumination picture and processed image.

camera), and CCD camera with memory stick (see Fig. 1). Optionally, the system can be attached directly to the notebook USB port. The captured images were in JPEG format with 1152×864 resolution. For analysis, a 320×240 ROI (region of interest) was selected from the original image (Fig. 2). The person under examination was in sitting position, with the hand comfortably bent in the elbow. The exposure was made in darkness. For each person being examined the transillumination images of proximal interphalangeal joints (PIP) of fingers II, III and IV of the right and left hand were recorded.

The images were recorded in two positions: ventral-dorsal (VD) for the finger placed with dorsal side towards camera (laser beam illuminated the finger from ventral side) and opposite, dorsal-ventral (DV), whilst light illuminated the finger dorsal side and camera was placed at the ventral side. The recorded and processed images were converted into the grey level bitmaps and then analyzed by means of image processing program from OPTIMAS. As a base for evaluation a three dimensional luminance and histogram functions were used. The following data may be obtained from histograms analysis: mean values of grey level (Mean), standard deviation of grey level values – pixel intensity (StdDev), minimal (Min) and maximal (Max) value of grey level, variance (VAR). The intensity of pixels ranges from 0 (black) up to 255 (white).

4. Comparison of transillumination images of healthy and ill persons

As an example, Fig. 3 shows the transillumination images of PIP of ill and healthy person. Their corresponding luminances are depicted in Fig. 4. General observation reveals the fact that the images of healthy joints are lighter than those of ill persons. This is confirmed by histogram analysis (compare the mean grey level values in transillumination images of ill and healthy tissue in Fig. 5).

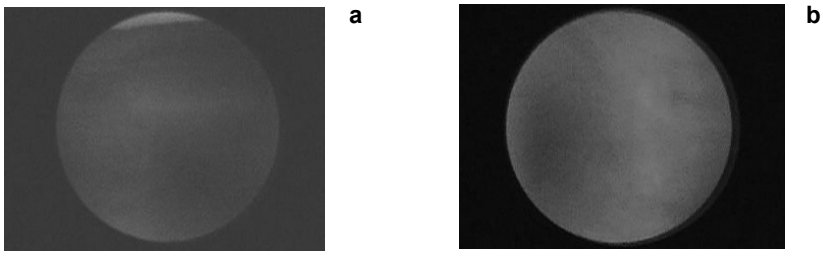

Fig. 3. Transillumination image of interphalangeal joint of ill (**a**) and healthy person (**b**).

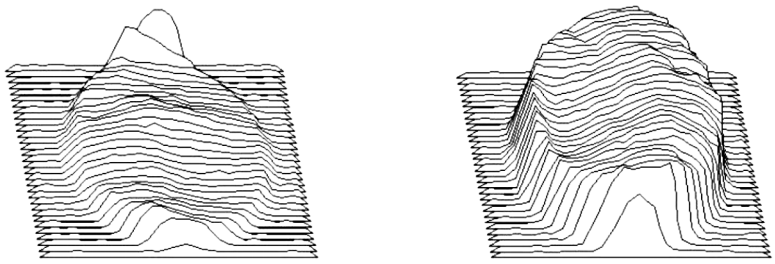

Fig. 4. Three dimensional luminances of the pictures from Fig. 3.

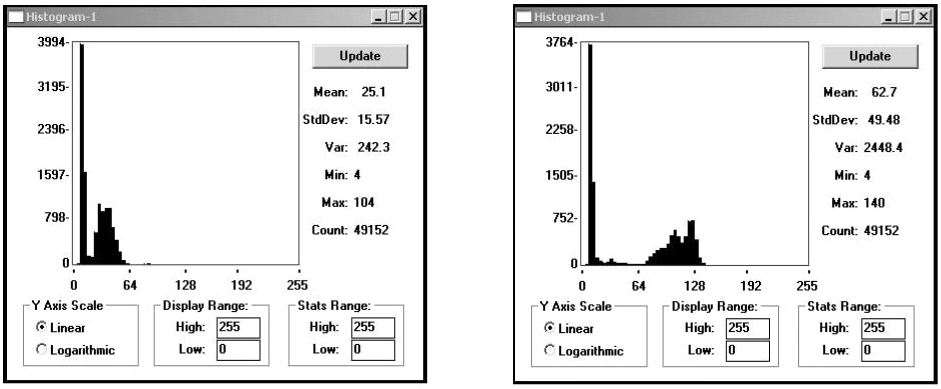

Fig. 5. Histograms of the images from Fig. 3.

T a b l e 1. Mean grey levels in transillumination images of interphalangeal joints of ill persons. Images were recorded in two configurations: ventral-dorsal (VD) and dorsal-ventral (DV).

	Mean grey level			
	Finger II, right		Finger II, left	
Patient No.	VD	DV	VD	DV
1	20.20	24.80	32.20	26.40
2	20.40	27.70	20.30	32.90
3	33.00	37.60	29.90	51.70
4	26.50	40.20	33.50	41.10
5	20.70	40.90	24.30	30.40
6	20.30	36.10	34.00	34.50
7	25.20	40.20	33.90	40.50
8	19.30	19.70	19.00	17.00
9	18.40	25.70	20.60	21.00
10	30.60	53.30	34.40	36.10
11	30.50	33.60	48.00	64.50
12	21.80	32.00	23.80	45.20
13	26.10	37.80	46.10	39.70
14	16.90	23.90	17.60	15.67
15	41.30	48.00	56.60	38.40
16	35.20	53.40	46.60	67.80
17	27.60	24.80	27.00	35.70
18	29.80	46.90	48.80	32.70
19	19.30	21.50	30.80	29.50
20	23.40	39.90	30.50	37.90
21	22.30	22.40	36.30	40.70

Some results of the intensity analysis are listed in Tab. 1. One can see that almost in all the cases the mean grey level values in images taken at the dorsal side (laser beam travels from the ventral side – VD) are lower than for DV recording. This may be explained by the fact that ventral finger side is smoother, so more light is transmitted through the tissue. The skin facture and skin wrinkles on the dorsal side cause the scattering, so less light is transmitted into the camera.

The differences in pixels intensity in transillumination images of healthy and ill persons point out that generally the mean grey level values in images of healthy joints are higher than those of diseased tissue. As an example, Fig. 6 demonstrates the intensities of pixels in images of finger II of the right hand of ill and healthy subjects. Here, the mean value was calculated as an arithmetic mean value of VD and DV parameters.

The summary results for right hands are given in Tab. 2, whereas Tab. 3 presents the results for left hands.

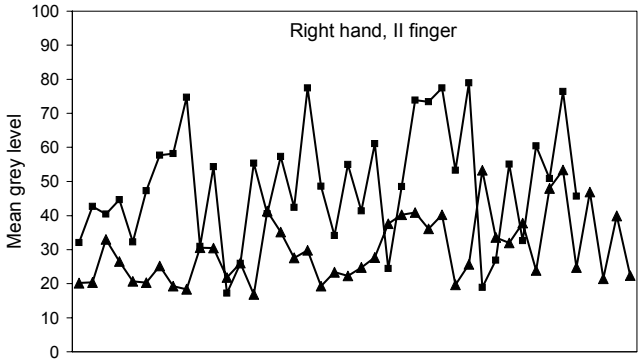

Fig. 6. Exemple of graphic representation of the mean grey level values in transillumination images of interphalangeal joint of finger II: ▲ – ill persons, ■ – healthy volunteers.

T a b l e 2. The summary results for right hands (p = 68.2%).

		Finger II		Finger III		Finger IV	
		Ill	Healthy	Ill	Healthy	Ill	Healthy
Mean grey level value	Minimum	18.40	17.20	14.90	20.50	16.70	24.20
	Maximum	53.40	78.90	50.10	76.70	68.90	81.60
	Mean	**29.98**	**49.16**	**30.02**	**46.36**	**32.97**	**49.88**
StdDev		1.51	2.80	1.36	2.20	2.01	2.42
Confidence intervals	Lower limit	28.47	46.37	28.67	44.17	30.97	47.46
	Upper limit	31.49	51.97	31.39	48.57	34.99	52.30

T a b l e 3. The summary results for left hands (p = 68.2%).

		Finger II		Finger III		Finger IV	
		Ill	Healthy	Ill	Healthy	Ill	Healthy
Mean grey level value	Minimum	15.40	20.90	13.60	20.70	15.67	29.50
	Maximum	63.80	78.60	68.90	77.00	67.80	78.70
	Mean	**33.16**	**52.16**	**31.43**	**48.23**	**35.08**	**54.90**
StdDev			1.71	2.82	1.72	2.59	1.86
Confidence intervals	Lower limit	31.45	49.34	29.71	45.64	33.22	52.37
	Upper limit	34.87	54.98	33.15	50.82	36.94	57.43

Our analysis demonstrated that there are differences in transillumination images of joints of healthy and ill women. Moreover, looking at the differences for separate fingers, we could conclude that theses differences are also finger dependent, which is especially seen for finger II. This may be due to the fact that this finger as the first suffers from the disorder caused by pathologic processes.

5. Therapy monitoring

We have also examined the influence of therapy on the intensity values. The patients underwent a 2 weeks' therapy, whereas pharmacological treatment was combined with physiotherapy, including kinesytherapy and lasertherapy. The transillumination examinations were performed prior to therapy and after two weeks of therapy course.

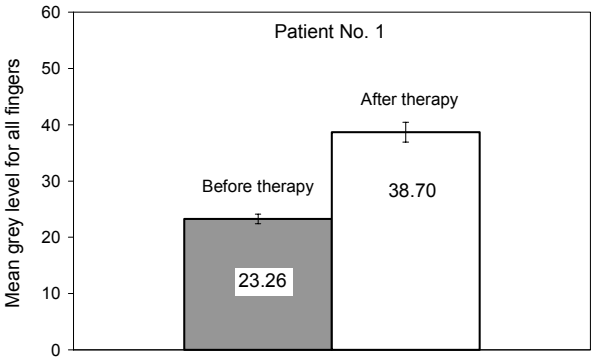

Fig. 7. Mean grey level values for patient No.1 before and after therapy.

We have found out that in 83% of the patients examined the post-therapeutic transillumination images resembled more the images of healthy persons, which means that the higher grey level values were observed. An exemplary diagram is presented in Fig. 7.

6. Conclusions

Transillumination in visible or near infrared light is quite a simple method which may be employed for diagnosis of finger joints. The diagnostic methods used currently for assessment of rheumatoid diseases are mostly subjective. The objective diagnosis is possible when the pathologic process is more advanced. Therefore, the cheap modality as offered by optical methods may be a valuable tool for differentiating between healthy and ill persons, even at early stages. The evaluation of transillumination images by means of computer-aided analysis may also be used for monitoring the therapy results.

References

[1] CURLING T.B., *A Practical Treatise on the Disease of the Testis and of the Spermatic Cord and Scrotum, Simple Hydrocele of the Testis*, London 1849.

[2] HERYNG T., *Die elektrische Durchleuchtung der Highmorshöhle bei Empyem*, Berliner Klinische Wochenschrift **26**, 1889, pp. 774–7.

[3] BEUTHAN J., MINET O., MUELLER G.J., PRAPAVAT V., *Infrared diaphanoscopy in medicine*, [In] *Medical Optical Tomography: Functional Imaging and Monitoring*, [Eds.] Muller G.J., Chance B., Alfano R., *et al.*, SPIE Optical Engineering Press, Vol. IS11, 1993, pp. 263–82.

[4] CUTLER M., *Transillumination as an aid in the diagnosis of breast lesions*, Surgery, Gynecology and Obstetrics **48**(6), 1929, pp. 712–9.

[5] GROS C.M., SIGRIST A., *La radiographie et la transillumination de la mamelle*, Strasbourg Medical **2**, 1951, pp. 451–65.

[6] SICKLES E.A., *Breast cancer detection with transillumination and mammography*, American Journal of Roentgenology **142**(2), 1984, pp. 841–4.

[7] CARTWRIGHT C.H., *Infra-red transmission of the flesh*, Journal of the Optical Society of America **20**(2), 1930, pp. 81–4.

[8] PRAPAVAT V., *Anwendung der experimentellen Systemanalyse zur Informationsgewinnung aus Streulicht im Frühstadium entzündlich-rheumatischer Veränderungen*, ECOMED, Berlin 1998.

[9] YUASA T., TANOSAKI S., TAKAGI M., SASAKI Y., TANIGUCHI H., DEVARAJ B., AKATSUKA T., *Transillumination optical sensing for biomedicine and diagnostics: feasibility of early diagnosis for rheumatoid arthritis*, Analytical Sciences **17**, 2001, pp. 515–8.

[10] BEUTHAN J., CAPPIUS H.-J., HIELSCHER A., HOPF M., KLOSE A., NETZ U., *Erste Untersuchungen zur Anwendung der linearen Signalübertragungstheorie in der Auswertung diaphanoskopischer Untersuchungen am Beispiel der Rheumadiagnostik*, Biomedizinische Technik **46**(11), 2001, pp. 298–303.

[11] BAUER J., BOERNER E., PODBIELSKA H., SUCHWALKO A., *Pattern recognition of transillumination images for diagnosis of rheumatoid arthritis*, Kowalczyk A., [Eds.] Fercher A.F., Tuchin V.V., Proceedings of SPIE: Medical Imaging **5959**, 2005, pp. 15–20.

[12] CYSEWSKA-SOBUSIAK A., WICZYNSKI G., *Preliminary results of using transillumination for optical imaging of hand fingers*, Proceedings of the Symposium on Photonics Technologies for 7th Framework Program, Wroclaw, 12–14 October, 2006, pp. 333–6.

[13] BOERNER E., PODBIELSKA H., BAUER J., DMOCHOWSKA L., DZIEWIĘCKA M., *Laser transillumination for diagnosis of rheumatoid arthritis*, [In] *Lightmetry and Light and Optics in Biomedicine 2004*, [Eds.] Kolacz K., Sochacki J., Proceedings of SPIE, Vol. 6158, 2006, pp. 265–8.

Received November 29, 2006