DIAGNOSTIC VALUE OF THERMAL IMAGING DUE TO WHOLE BODY CRYOTHERAPY

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Abstract:
The whole body cryotherapy takes only 2-3 minutes but triggers of important effects in the organism that can be reflected in temperature, which is sensitive indicator of biological processes. The skin temperature response due to whole body cryotherapy was studied by means of thermovision. Drop of temperature induced by cooling depends on health state of patient. Inflammatory processes lead to the rise of temperature while degeneration states are characterized by decreasing temperature. It follows from our studies that cold impact widens the range of temperature inside the region of interest. The infrared measurements performed after whole body cryotherapy give significant increase of the diagnostic information.

Introduction

Cold treatment is known for ages but the development of new cryotherapy dates back to the end of 19th century when physics learned to condense gases. At the beginning only local cold therapy was used in medicine [1 - 5]. Over the last few decades the whole body therapy has developed quickly.

The first cryogenic chamber was made in Japan in 1978. Over the last few decades many cryogenic chambers have been built in the number of countries all over the world. One of them was built in Poland in 1989 as the second in Europe and the third in the world [7, 8].

In the whole body cryotherapy patient is subjected to low temperature in a special room called the low temperature chamber. Whole body cryotherapy requires the application of a temperature lower than –100°C (usually ~ -120°C) on the body surface for a period of 2-3 minutes in order to cause physiological and biochemical reactions of the organism.

There are a few publications concerning whole body cryotherapy because it is relatively new method of medical treatment [9 - 14].

It is thought that cold treatment can cause increase of blood flow through the internal organs and substantial increase of hormones in the serum. Moreover reduction of pain in the post-operative period after reconstructive surgery of the joints and shortening of the recovery time of the rehabilitation, increase of muscle power and physical relaxation were observed.

The whole body cryotherapy is applied in diseases of motion organs for example: inflammatory states of spinal vertebrae joints, degeneration and inflammatory states of joints (*monoarthritis* and *oligoarthritis*) and *periarthritis* [15 - 22].

Good effects in the cold treatment of rheumatism, low back pain diseases [19, 20, 23] and *sclerosis multiplex* [24 - 26] treatment were observed.

The positive influence of cryotherapy on mental health and *osteoporisis* preventive treatment is also reported [9, 11, 17, 28].

The wide application of cryotherapy is found in sport medicine [28] and biological recovery.

From medical point of view the temperature is very important. It is obvious that the heat transfer between the organism and the external environment takes place through the skin. Therefore the skin temperature can give information of inflammatory and degeneration processes [6, 13, 23].

The purpose of this work was to study the influence of cold impact on change of skin temperature and estimation diagnostic value of thermal imaging before and after cryotherapy.

Materials and Methods

The experimental group consisted of 40 patients with suffering for low back pain, small group of other diseases (inflammatory states of hands and legs) and about 20 healthy people. In this work we present thermograms of the chosen cases: 4 patients (1 female and 3 male) age 35,8 ± 13,9 and one healthy male. Five patients suffered from the *spondyloarthrosis,* 1 male suffered from left tight *endophlebitis* and 1 female suffered from bacterial infection of left hand.

The investigations were carried out at the Provincial Centre of Rheumatologist in Goczałkowice Zdrój (WORR) and Silesian Center of Rehabilitation and Physical Medicine in Ruda Śląska (GCR) where the cryogenic chambers were installed. To get very low temperatures (-120°C) in the cryogenic chambers liquid nitrogen (GCR) and liquid air (WORR) were used.

The physician examined all patients. They were requested not to smoke, drink alcohol or hot drinks for 4 hours before experiment.

The distribution of the skin surface temperature before and after whole body cryotherapy was monitored by using of a Thermovision Camera AGEMA Type 470 made in Germany with the possibility of computing im-

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aging on the basis of software IRVIN 5.3.1. The thermovision camera was calibrated by black body.

Thermal images were recorded in a special measurement room outside the chamber fulfilling established standards. In order to catch the dynamic response of the skin temperature due to cold impact, thermal imaging of the patients was performed immediately after cryotherapy.

Ethical approval was obtained from the Ethical Committee of the Silesian Medical University (No.NN-013-144/I/02). Studies were performed during the normal programme of rehabilitation in the Centre.

Results

Thermograms of the representative objects are presented on Figures 1 - 3.

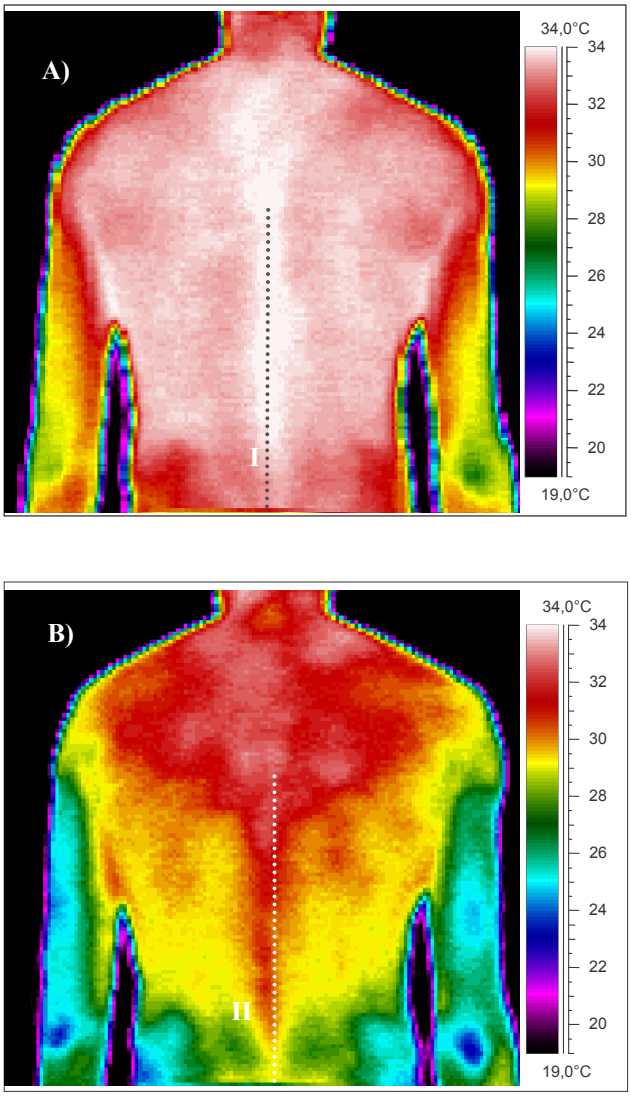

Figure 1: The thermograms of the back of healthy man performed before (A) and after whole body cryotherapy (B).

The thermal imagings marked as **A** were performed before and **B** after whole body cryotherapy. As expected, an essential drop of skin temperature was observed due to cold impact. The mean decrease of temperature decrease of the back was 4,1°C.

In is noteworthy that thermogram of the back of healthy man show that the body skin surface temperature is more diverse after whole body cryotherapy (Figure 1b) than before (Figure 1a). Some areas (*spinal vertebrae* and *musculus trapezius*) reveal higher temperature than other back areas. One can see that more details are visible after cold impact than before one. There are no essential temperature variations along spinal vertebrae.

It is interesting to focus one's attention on the thermograms of patients suffering from *spondyloarthrosis* (Figure 2 and 3). There are some temperature anomalies for patients with spine's diseases, which are better, visible on the thermograms performed after whole body cryotherapy than before one.

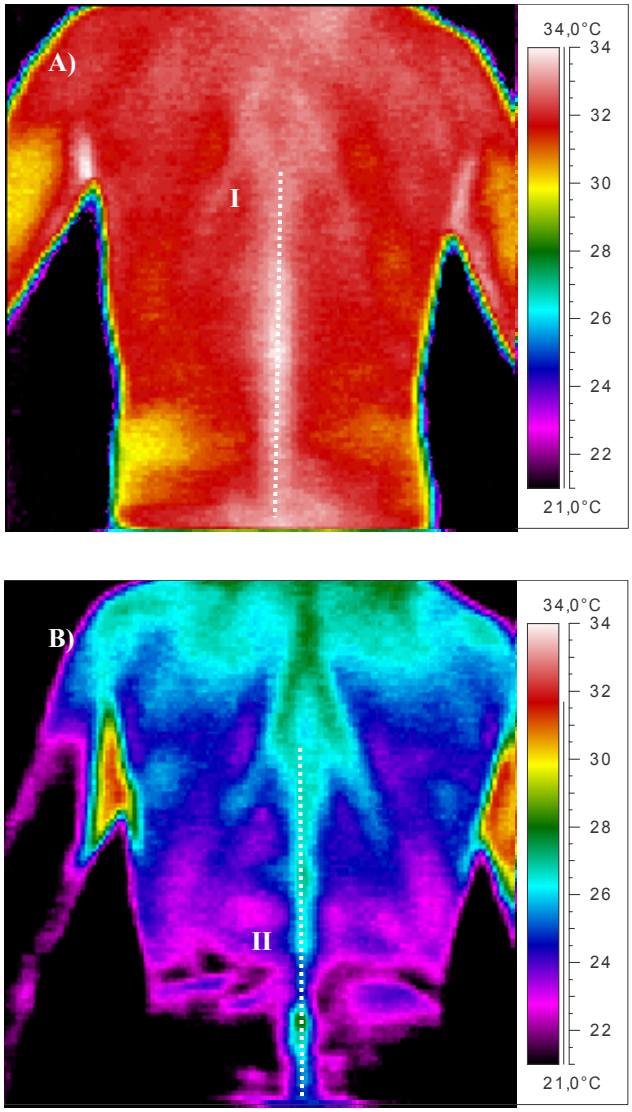

Figure 2: The thermograms of the back of patient 1 performed before (A) and after whole body cryotherapy (B) in man suffering from *spondyloarthrosis*

It should be noted in Figure 2b that along spinal vertebrae are a small area with lower skin temperature on

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the level L1-L2 and then in the vicinity of vertebrae L2-L3 with rising temperature. They reflected degeneration and inflammatory states, respectively. These details were not seen in the thermograms performed before cryotherapy presented on Figure 2A. For patient 2 the main inflammatory state is manifested as a one big area in the lower lumbar region in the vicinity of vertebrae L2-L4 (Figure 3).

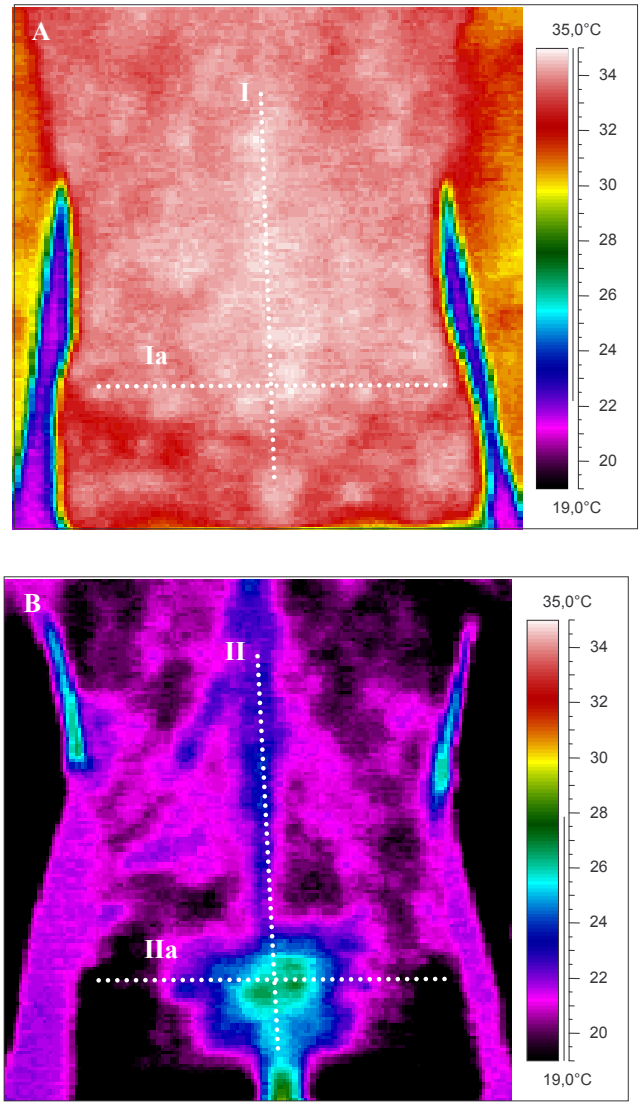

Figure 3: The thermograms of the back of patient 2 performed before (A) and after whole body cryotherapy (B) in man suffering from *spondyloarthrosis*.

To better look inside into the problem the plots of temperature along chosen lines were performed for patients and healthy man. Figures 4 - 6 show the plots of the temperature along vertical line characterizing spinal vertebrae in the range Th5/Th6 to L5/S1 for healthy male (Figure 1) and two males with *spondyloarthrosis* (Figure 2 and 3) preformed before (I) and after (II) whole body cryotherapy, respectively.

Moreover temperature plots along a horizontal line perpendicular to the spinal vertebrae in range L2/L3 for a patient 2 before (Ia) and after (IIa) whole body cryotherapy were done (Figure 7). It is interesting to note that difference $\Delta T = T_{max} - T_{min}$ increasing after whole body cyotherapy what leads to widening of the temperature range of the thermograms.

Monotonic changes of skin temperature and no distinctive places with increased or decreased temperature along the spinal vertebrae were observed along the spine for the healthy subject before (I) as well as after (II) whole body cryotherapy (Figure 4). However the situation has changed for patients with back diseases. Plots after cryotherapy (II) disclose significant variations of temperature while slight changes of the skin temperature were observed before cold impact (Figure 5-7, curves I). Analysis of thermograms and temperature plots along chosen lines recorded after whole body cryotherapy prove that an inflammatory states occurs in the range of L2-L3 (patient 1) and L2-L4 (patient 2) vertebraes (Figure 2 and 3, curves II).

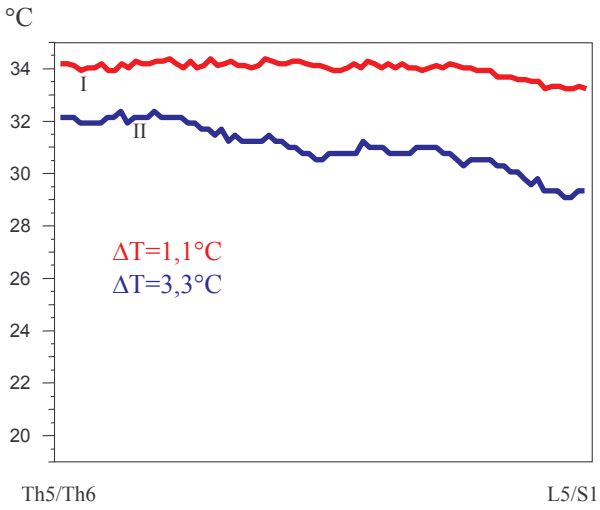

Figure 4: The plots of the temperature along vertical line characterizing spinal vertebrae in the range Th5/Th6 to L5/S1 for healthy male (Figure 1).

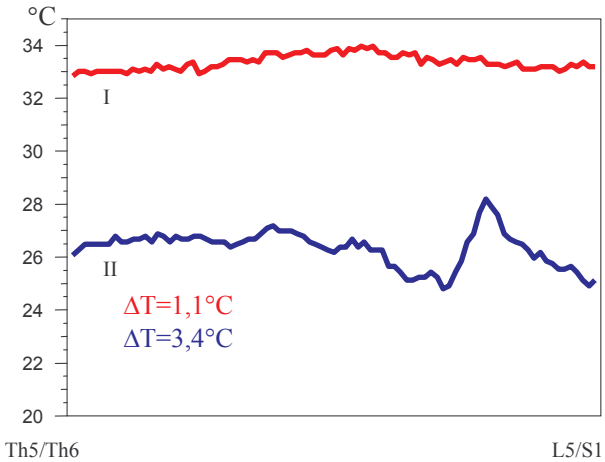

Figure 5: The plots of the temperature along vertical line characterizing spinal vertebrae in the range Th5/Th6 to L5/S1 for patient 1 suffering from *spondyloarthrosis* (Figure 2).

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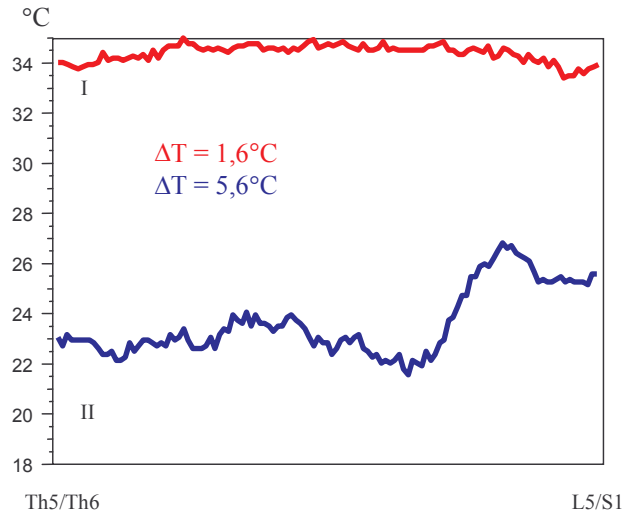


Figure 6: The plots of the temperature along horizontal line perpendicular to spinal vertebrae in the range L2/S3 for patient 2 suffering from *spondyloarthrosis* (Figure 3).

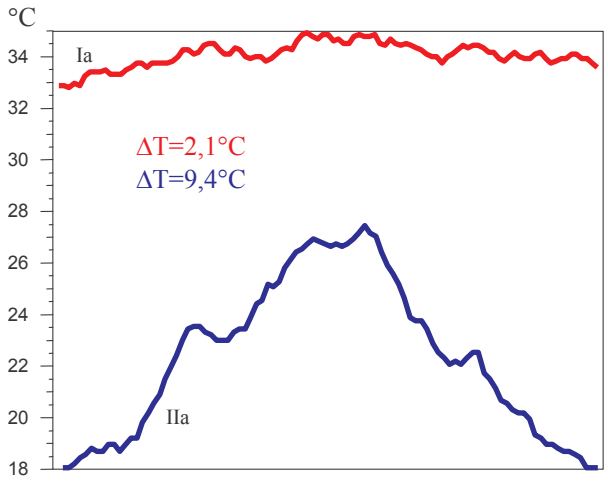
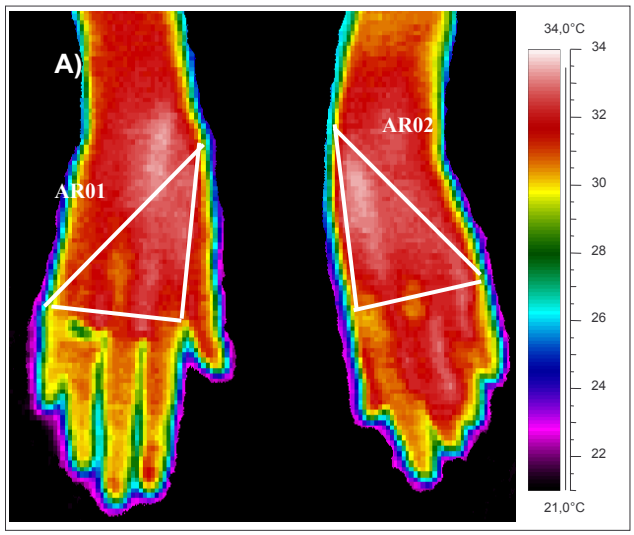


Figure 7: The plots of the temperature along vertical line characterizing spinal vertebrae in the range Th5/Th6 to L5/S1 for patient 2 suffering from *spondyloarthrosis* (Figure 3).

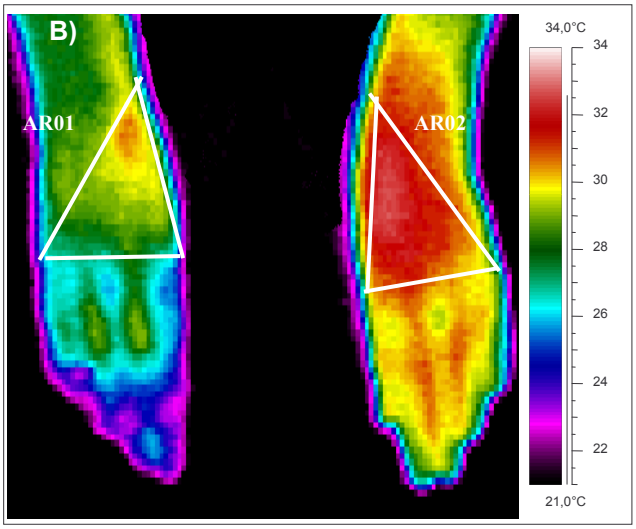
The plot of the temperature performed along horizontal line (IIb) perpendicular to spinal vertebrae in the range L2/L3 for male suffering from *spondyloarthrosis* (Figure 3) showed an extensive area of increased temperature in the vicinity of spinal vertebrae what is not seen in plot Ia (Figure 7). It reveals the inflammatory states of the adjoining tissues.

The next Figures 8 and 9 present the thermograms of the hands and tights, respectively.

It follows from thermograms in Figure 8b that an exposition to very low temperature caused cooling of healthy hand only (AR01).



Area	Temperature°C
AR01 : T_{max}	33,4
AR01 : T_{min}	30,3
AR01 : T_{mean}	**32,0**
AR02 : T_{max}	33,4
AR02 : T_{min}	29,4
AR02 : T_{mean}	**32,2**



Area	Temperature°C
AR01 : T_{max}	30,9
AR01 : T_{min}	24,6
AR01 : T_{mean}	**28,8**
AR02 : T_{max}	32,7
AR02 : T_{min}	28,9
AR02 : T_{mean}	**31,5**

Figure 8: Thermograms of the hands performed before (A) and after whole body cryotherapy (B) in female suffering from bacterial infection of left hand.

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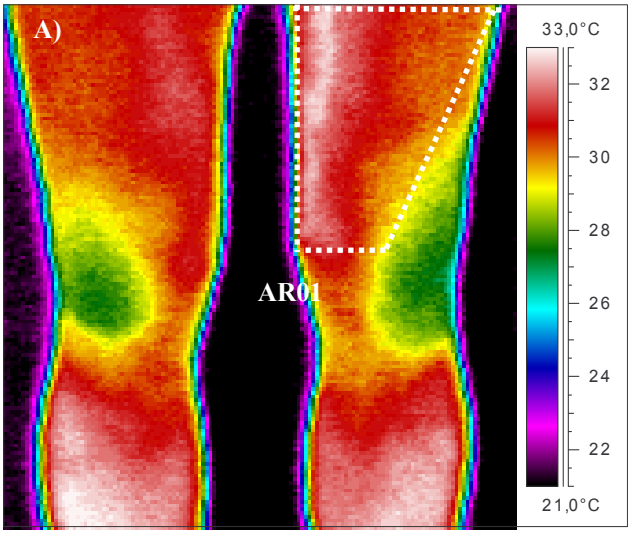
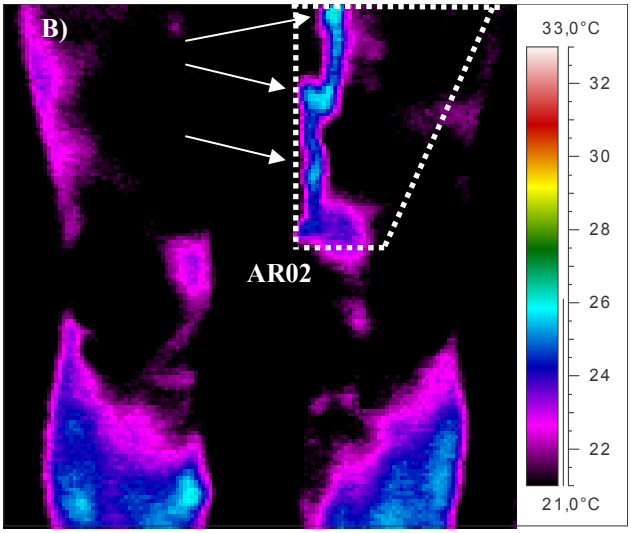


Area	Temperature°C
AR01 : T_{max}	32,9
AR01 : T_{min}	28,6
AR01 : T_{mean}	31,1



Area	Temperature°C
AR02 : T_{max}	26,2
AR02 : T_{min}	19,6
AR02 : T_{mean}	21,5

Figure 9: Thermograms of the tights performed before (A) and after whole body cryotherapy (B) in male suffering from left tight *endophlebitis*.

Thermograms as well as data analyses collected in tables under them show clearly that difference between the mean temperature before cryotherapy of chosen regions (AR01 i AR02) was only ΔT_{mean} = 0,2°C. However after exposition to cold this difference increased nearly 10 times (ΔT_{mean} = 2,7°C). The healthy hand was cooled down while the hand with bacterial infection didn't reveal significant cooling. This effect clearly confirms the inflammatory state of the left hand (AR02). It was not seen before whole body cryotherapy. It should be noted that it was possible to bring out important diagnostic informations from the thermograms performed just after whole body cryotherapy.

Another interesting diagnostic effect of body cooling is presented in Figure 9. An elongated area characterizing with higher temperature on the left tight is visible on the thermogram performed before cold impact (Figure 9A). The widening of the temperature range in region of interest caused by whole body cryotherapy demonstrated clearly the vein with inflammatory state (Figure 9B). Three points with higher temperature along the vein (marked with arrows) were observed. These places could be related with wrong valves function. Such interpretation is compatible with diagnosis of inflammatory state of left tight vein with venous insufficiency.

Discussion

Our results prove that the infrared measurements are helpful in monitoring the skin temperature changes due to whole body cryotherapy. Obtained thermograms show that the whole body cryotherapy causes an essential drop of skin temperature. This temperature decrease is connected with a change in the thermal properties of the tissues as well as local blood flow in the superficial skin layer. The changes in thermal response of tissues lead to the widenining of temperature range of thermograms recorded after whole body cryotherapy. It follows from our studies that cold impact doubles at least the range of temperature inside the region of interest (compare Figures A and B). Therefore the resolution and sensitivity of thermal mapping after cryotherapy increase in comparison with that performed before cryotherapy. Moreover there are the differences in thermal behaviour of healthy and sick tissues that became more visible on the thermograms performed after whole body cryotherapy. It causes the significant increase of diagnostic evaluation by infrared technique.

Conclusions

Our studies show that infrared measurements performed after whole body cryotherapy give significant increase of the diagnostic information due to rising resolution and sensitivity of thermal imaging. Such information can be helpful in planning of the medical treatment by cryotherapy.

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