

Effects of a multiple mild infra-red-A induced hyperthermia on central and peripheral pulse waves in hypertensive patients

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Abstract—The paper reports on the effects of multiple whole-body infra-red-A irradiational (IRA) on 13 male patients known to have stage I or stage II essential arterial hypertension (WHO definition). The peripheral blood pressure was decreased significantly by IRA exposures. The lowered diastolic blood pressure lasted into post-treatment time. This effect is regarded as a consequence of an improvement in peripheral haemodynamics. A measure of this improvement is the different shape of the blood pressure pulse waves. Calculation and comparison of the spectral components of the recorded pulse signals show that these components are useful for a prediction of the blood pressure lowering effect.

Keywords—Blood pressure, Central body temperature, Hypertension, Infra-red hyperthermia, Pulse wave, Walsh transform

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1 Introduction

AT PRESENT in central Europe the prevalence of hypertension in persons aged 25–65 is between 23 and 33 per cent. Nonpharmaceutical treatments for stages I or II hypertension include sauna and physical exercises such as jogging, swimming or weightlifting. Of these sauna has been most discussed as an effective treatment. During sauna an increase of pulse frequency connected with a decrease of systolic and diastolic blood pressure has been found. The blood pressure lowering effect is maintained in two-thirds of the patients if the sauna is taken routinely over 3–5 years. The reason for the decrease in blood pressure is the improvement of the peripheral haemodynamics due to a widening of the vessels (BULAS *et al.*, 1983).

A disadvantage of hyperthermia by means of sauna is that the application of thermal energy is in a conductive manner only. This involves a special stress for the skin. If IRA hyperthermia is used the increase of the body temperature per time unit is comparable or faster and there is no thermal damage of the skin or feeling of discomfort. Compared with sauna the physiological and therapeutical effects are similar or amplified. That means that there is a correspondence between mild IRA hyperthermia and the classical principles of physical therapy.

Reports on the effects of single IRA irradiation have been given in the literature (SCHERF *et al.*, 1989; SIEWERT *et*

al., 1989). One main result of these test series was a decrease of blood pressure during one hour of treatment.

This paper deals with the results of multiple IRA treatments. The aim is to show that there is an effect of blood pressure lowering not only during one irradiation but also several weeks after the treatment series. To quantify this effect a pulse wave analysis has been used. This analysis results in special parameters which are useful to describe the efficiency of the therapy.

2 Equipment

The infra-red-A hyperthermia equipment 'IRA Therm II' of the Research Institute of 'Manfred von Ardenne' was used for producing whole-body hyperthermia. This irradiation machine is continuously tunable between 1.7 and 12 W dm^{-2} . The patient was placed on a thin knot-free net between two sheets of glass. The spectral characteristics of the radiation are described in DAUTERSTEDT *et al.* (1987). The IRA Therm II permits homogenous irradiation of the whole human body, thus allowing full hyperthermia in a demonstrably shorter time than other infra-red equipment (VON BRASCH *et al.*, 1989; HECKEL and HECKEL, 1979). Because of this shortening of the treatment time patient acceptance of IRA hyperthermia is improved.

3 Patients and methods

A group of 13 males suffering from essential arterial

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hypertension stage I or II (age 39.1 ± 13.8 years) underwent multiple whole-body irradiation with near infra-red. The hypertension was known to have been established from between 1 and 7 years. The pharmaceutical treatment was maintained during the tests. The patients were irradiated twice a week for 30 min over 6 weeks. Starting with 12 W dm^{-2} the power applied during each treatment was reduced after about 20 min to 5 W dm^{-2} to maintain the central body temperature level.

Before, during and after the treatment series the temperature, the peripheral and central pulse waves were continuously recorded, and the blood pressure and heart frequency were recorded discontinuously in definite time intervals. The pulse waves were recorded from the temporalis superficialis artery and the digitalis volaris propria artery by means of a noninvasive technique using piezoelectric and optoelectrical sensors. The blood pressure was taken using a calibrated mercury manometer.

4 Pulse wave analysis

Using a sampling rate of 200 Hz the central and peripheral pulse waves were digitised and saved for further offline processing. Fig. 1 shows typical pulse signals. To obtain a quantitative measure for the shape variations of

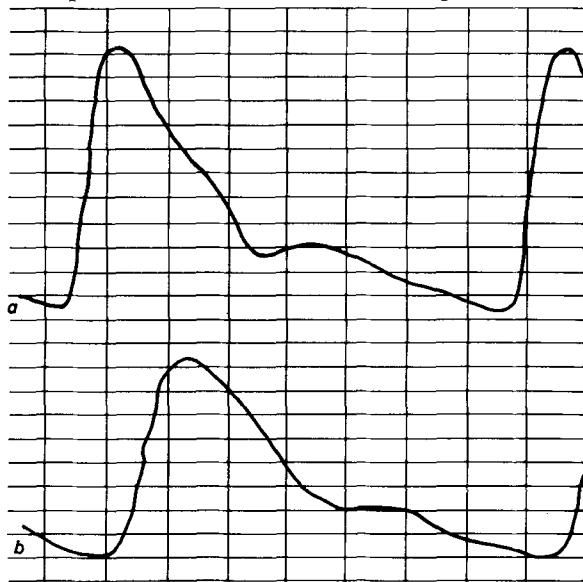


Fig. 1 Typical (a) temple and (b) toe pulse signal

the pulse signal an analysis of the pulse wave is necessary. In general, biosignals can be analysed in the time domain or the spectral domain. The main problem in the processing of biosignals is their description by means of only a few characteristic features. As long as visual evaluation is carried out it is useful to determine amplitudes, time intervals, slopes, areas under the waveform etc. in the time domain.

On the other hand it is also possible to characterise biosignals by spectral features. In addition to the well known Fourier transform the Walsh, Slant and Haar transforms (AHMED and RAO, 1975) are used for biosignal processing. Feature extraction by the Walsh transform provides a compromise between processing complexity and the number of actual useful features. Walsh functions form a complete orthogonal set of two-valued functions. They may be represented by a square matrix with entries +1 and -1. Details are given in the literature (AHMED and RAO, 1975; HARMUTH 1977). On the basis of this matrix representation fast algorithms for the computation of the Walsh transform have been developed (BESSLICH and LU, 1990).

The input signal for the transformation was a set of

samples of the pulse waves. The resulting array of Walsh coefficients or 'Walsh spectrum' provided a tool for solving two problems: first, determination of the natural period of the signal, i.e. isolation of the cardiac cycle; and secondly, giving a quantitative description of the shape of the pulse signal.

4.1 Isolation of cycles

To find a cycle in the continuously recorded pulse wave it was necessary to detect the upward reflections to determine the duration of the cardiac cycle. To describe this deflection an interval of 40 ms seemed adequate, i.e. a transformation of eight successive sampled values. In the following learning process the statistical analysis of this learning data set showed that only two of the eight Walsh coefficients are necessary for an accurate recognition of the deflection.

Before further processing is carried out a correction of the baseline noise and a normalisation of the number of samples per cycle has to be performed. The baseline deviation is compensated for by simple subtraction of a linear equation evaluated by the first and last sample of one isolated cycle. A total of 2^n samples was necessary for the transformation of the complete cycle to the Walsh domain. For this purpose a first-order Lagrange interpolation procedure was adequate to change the actual number of samples into a constant number of 128 samples per cycle.

4.2 Description of signal shape

The isolated cycles of the carotid arterial pulse signals showed a distinctive shape variation. A physician determined two types of patients from a more clinical point of view:

Type A: the blood pressure lowering effect is maintained several weeks after the therapy due to an improvement of the peripheral haemodynamics because of a longer lasting dilation of the peripheral blood vessels.

Type B: the blood pressure lowering effect is not maintained after treatment because of a universal vessel stiffening.

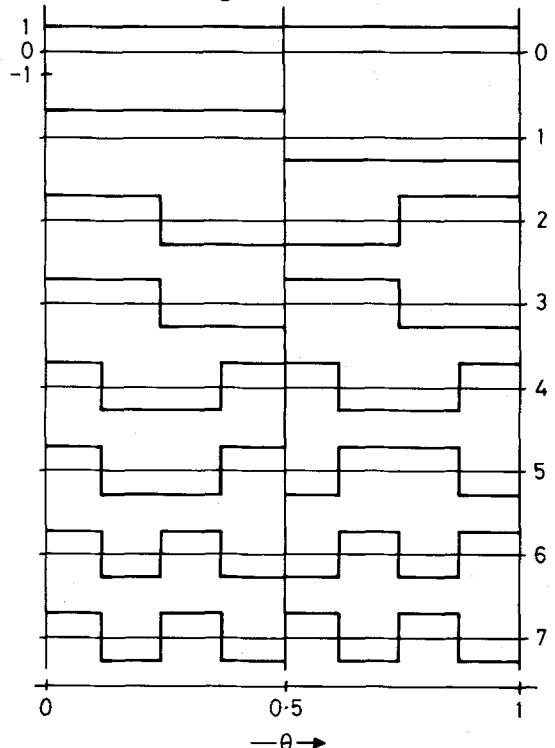


Fig. 2 Eight Walsh functions $wal (i, \theta)$

This known membership of definite classes was the basis for establishing the learning data set. The use of Walsh coefficients as features for these two groups was expected to be effective (MEFFERT and HOCHMUTH, 1987). Considering the known deviations in the case of hypertension and

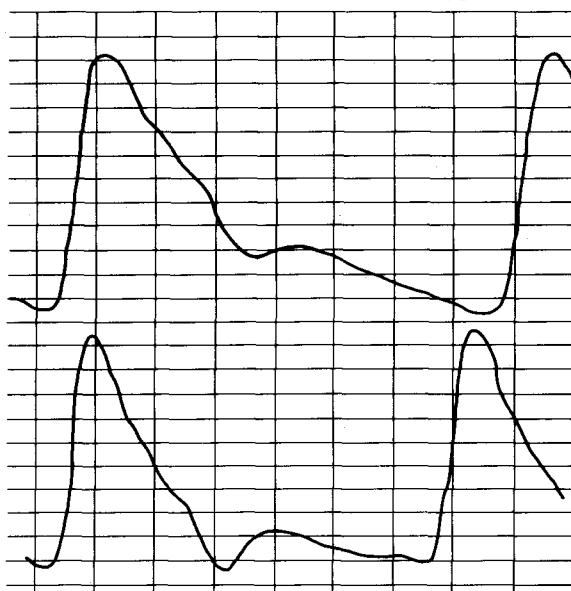


Fig. 3 Effect of lowering the dicrotic notch by a decreasing peripheral resistance

the connected large peripheral resistance it is most important to look for the level of the dicrotic notch. Blood pressure lowering means a rapid decrease of the dicrotic notch (GADERMANN and JUNGMANN, 1964). Comparing the first eight Walsh functions (Fig. 2) with this effect (Fig. 3), it can be expected that the first and second coefficients will contain the necessary information.

5 Results

The changes in the recorded values (temperature, heart frequency, systolic and diastolic blood pressure) during the

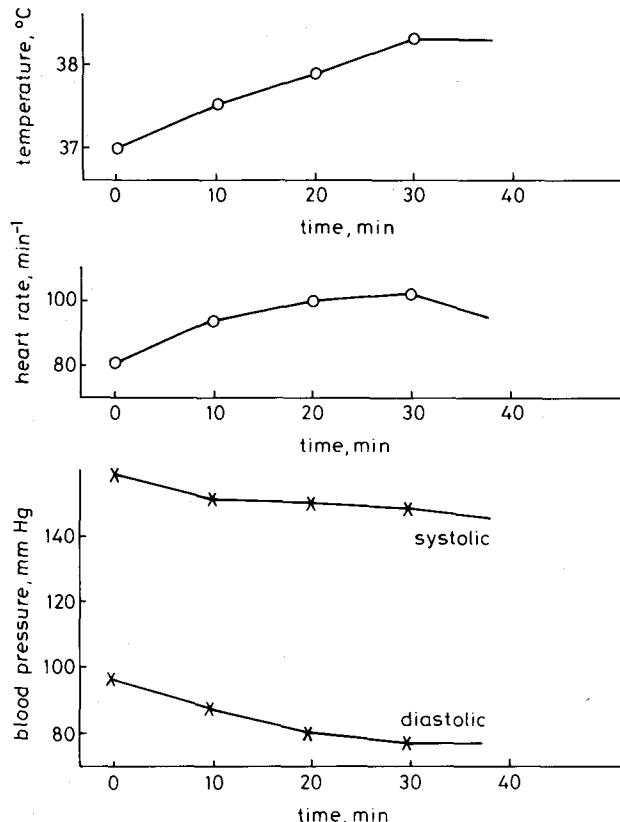


Fig. 4 Temperature, heart rate and systolic and diastolic blood pressure during the 30 min hyperthermia

30 min therapy time are shown in Fig. 4. The behaviour of these values during the 6 weeks treatment is shown in Fig. 5. Both above-mentioned Walsh coefficients were computed during the test series. The difference between the first two hyperthermias for the first and second coefficient

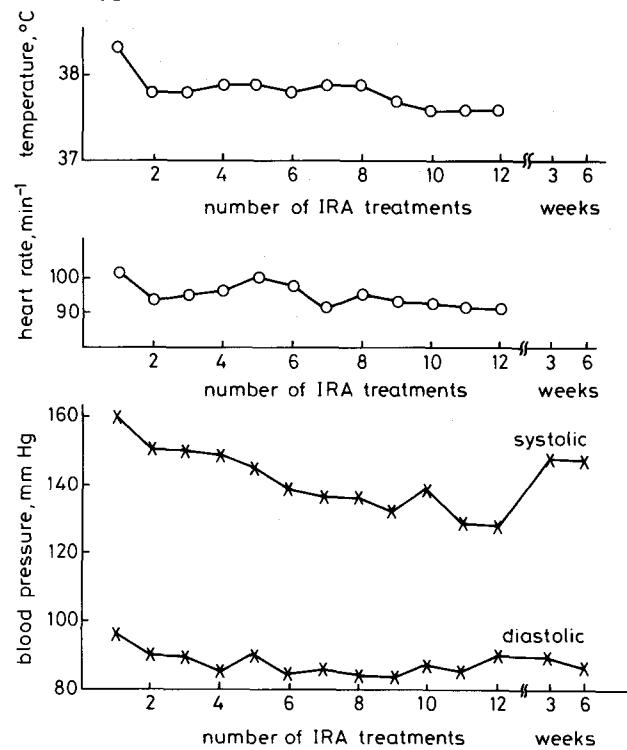


Fig. 5 Temperature, heart rate and systolic and diastolic blood pressure during the 12 IRA treatments and after 3 and 6 weeks

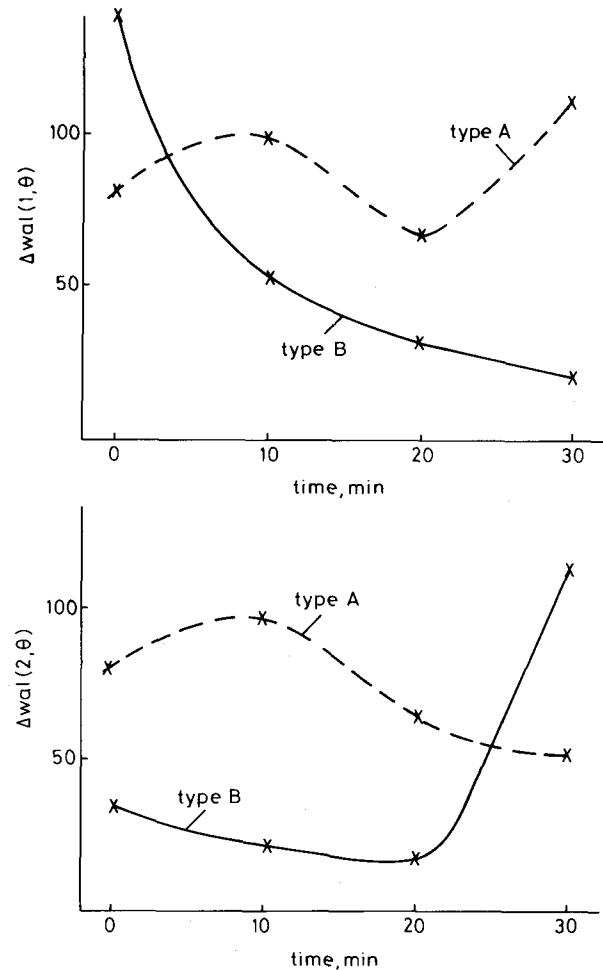


Fig. 6 Two Walsh coefficients (difference between first and second IRA) during the 30 min therapy

during the 30 min therapy is shown in Fig. 6. From this behaviour it can be concluded that type A and B patients act differently and that these differences can be described by Walsh coefficients.

6 Conclusions

Hyperthermia is an effective method for lowering the diastolic blood pressure connected with a decrease of the peripheral resistance. The maintenance of the low pressure depends on the state of the peripheral vessels. To evaluate this state an analysis of the central and peripheral pulse signals can be used. For this analysis the Walsh transform is preferable because of the compromise between expense and effectiveness. Only a few Walsh coefficients can describe the different behaviour of the patients. They can be used to predict the effect of blood pressure lowering.

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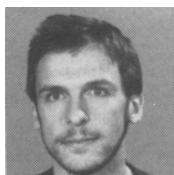
Authors' biographies



Beate Meffert was born in Lenzen (Elbe), Germany, in 1947. She received the Ingenieur degree in Electrical Engineering from the Technical University of Ilmenau, German Democratic Republic in 1971 and her Doctoral degree in electrical engineering specialising in information processing from the Humboldt University in East Berlin. Since 1971 she has been with the Department of Electronics, Humboldt University. Her teaching activities include fundamentals of electronics and signal processing. She has performed research on sequency theory and application of orthogonal transforms, and her current field of interest is biosignal analysis and pattern recognition.



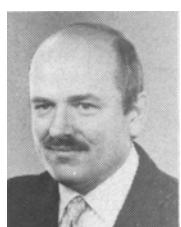
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