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Correlation of infrared thermography and skin perfusion in Raynaud patients and in healthy controls

Oliver Schlager, Michael E. Gschwandtner, Karin Herberg, Tanja Frohner, Martin Schillinger, Renate Koppensteiner, Wolfgang Mlekusch *

Division of Angiology, Department of Internal Medicine II, Medical University Vienna, Vienna General Hospital, Waehringer Guertel 18-20, A-1090 Vienna, Austria

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ABSTRACT

Background: We aimed to investigate the correlation of infrared thermography (IT) with laser Doppler perfusion imager (LDPI) among patients with primary Raynaud's phenomenon and healthy controls.
Methods: Forty-seven individuals were included: we examined 25 patients with primary Raynaud's phenomenon and 22 age and gender matched healthy controls. IT of the volar surface of the subjects' left hands was performed to record skin temperature while skin perfusion of the same area was determined using LDPI. All measurements were obtained at room temperature (baseline measurements) and following standardized cold provocation.
Results: Good correlation of baseline measurements was found between IT and LDPI in primary Raynaud patients and healthy controls ($r=0.868$, $p<0.0001$ vs. $r=0.790$, $p<0.0001$). Following cold challenge, correlation was weaker in both groups ($r=0.742$ vs. $r=0.766$, $p<0.0001$). Correlation after cold provocation was statistically significant among patients with primary Raynaud's phenomenon in contrast to controls (Chi Quadrat, $p=0.023$ vs. $p=0.306$).
Conclusion: A significant correlation was found between IT and LDPI in primary Raynaud patients and in healthy controls ($r=0.868$ and $r=0.742$, both $p<0.0001$). Following cold provocation, correlation decreases in both groups. Thus, at room temperature IT might substitute for skin perfusion measured by LDPI.

Introduction

Raynaud's phenomenon is a widespread clinical disorder that is characterized by paroxysmal vasospasms of the digital arteries and was first described by Maurice Raynaud in 1862 (Block and Sequeira, 2001). In the majority of cases, no underlying disease can be found which is classified as primary Raynaud's phenomenon (Block and Sequeira, 2001; Grassi et al., 1998; Ho and Belch, 1998).

In primary Raynaud's phenomenon cold induced, endothelium dependent and endothelium independent mechanisms provoke spasms of small muscular arteries and arterioles resulting in episodic digital ischemia. (Gardner-Medwin et al., 2001). These spasms cause a typical well-demarcated, triphaseal change of color of the fingers (pale-cyanotic-red flush) combined with pain and the sensation of cold. Usually, external heat supply promptly releases these spasms and consecutively normalizes skin temperature.

Local differences of skin temperature can be easily assessed utilizing the infrared thermography (IT). IT is an easily applicable, well-established imaging method creating temperature maps of the investigated skin area with a satisfying reproducibility (James, 1968; Murray et al., 2009; Zaproudina et al., 2008). In addition, cold provocation is routinely applied to reveal skin areas with an impaired thermoregulation (O'Reilly et al., 1992; Schuhfried et al., 2000).

Comparable to temperature measurements by IT total skin perfusion as well as local differences of skin, perfusion can be investigated using the laser Doppler perfusion imager (LDPI) (Clark et al., 1999; Del Bianco et al., 2001; Grassi et al., 1998; Picart et al., 1998). The LDPI is a non-contact imaging technique, which allows to determine the total microcirculatory blood flow of the subpapillary network of a predefined skin area (Tulevski et al., 1999). The subpapillary vascular network is known to be mainly responsible for the thermoregulation of the skin (Fagrell, 1986).

Nevertheless, comparing IT and LDPI, inconsistent results were found regarding the correlation of both methods in former studies (Bornmyr et al., 2001; Clark et al., 2003; Murray et al., 2009; Seifalian et al., 1994).

However, due to the thermoregulatory function of the subpapillary vascular network of the skin, we hypothesized that IT and LDPI should have a good correlation. Aiming to investigate if IT could substitute for LPDI, we initiated a head-to-head comparison of both techniques in Raynaud patients and in healthy controls at room temperature and following a standardized cooling challenge.

* Corresponding author. Fax: +431 40400 4665.
E-mail address: wolfgang.mlekusch@meduniwien.ac.at (W. Mlekusch).

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Materials and methods

Study design

Between December 2007 and April 2009, consecutive patients that were admitted to our department because of Raynaud's phenomenon routinely underwent oscillometric pulse wave measurements to exclude atherosclerotic causes for their circulatory disorder. Furthermore, antinuclear antibodies plus subsets and anticentromer antibodies were measured from blood samples and nailfold capillaroscopies were obtained to reveal microvascular involvement as predictor for development of a connective tissue disease (Caspary et al., 1991; Maricq et al., 1980; Meli et al., 2006).

All patients without signs for a concomitant connective tissue disease or other underlying illness were classified as primary Raynaud's phenomenon and were eligible for the present study. The use of vasoactive agents prior to study inclusion made the prospect study subject not eligible for the study.

Additionally, 22 volunteers without Raynaud's phenomenon and without known atherosclerotic disease or any other severe comorbidity served as healthy controls.

Patients

Demographic data (sex, age, body mass index), the presence of primary Raynaud's phenomenon and vascular risk factors such as hypertension, hyperlipidemia and smoking habits were recorded. The severity of pain during Raynaud attacks was quantified using a visual analogue scale (VAS; 0 = no pain, 10 = unbearable pain). Patients with known atherosclerosis or any other severe comorbidity were not included into the present study.

Thermography

IT was obtained using the same infrared thermography device (Thermo Tracer TH1100, SAN-EI) in all subjects. All examinations were performed in a sitting position in a quiet room at a constant room temperature of 23.3 ± 0. 6 °C following an acclimatization period of 20 min keeping the hands free of any contact to the rest of the body or other objects. Temperature maps were recorded of the volar surface of the left hand. Afterward, all participants had to put their hands into 20 °C tempered water for 1 min. Gloves were used to prevent skin from ongoing cooling due to evaporation following cool water exposure. Subsequently, a second IT map was recorded from the volar surface of the subjects' hands.

All temperature maps were archived using an attached computer. Acral skin temperature was measured from the center of each fingertip using device related software (PicWin_IRIS, Version 6.5). For the final analysis, the mean of all temperature values was determined and given in degrees Celsius (°C).

Laser Doppler

The LDPI (Perimed, Järfälla Sweden) is a non-invasive device, which allows determining the total skin perfusion of a predefined skin area. A laser beam (wavelength 632 nm, power 1 mW) that is directed to the patients' skin is able to measure skin perfusion of a predefined area by means of a meander-shaped scanning process. Interfering with moving blood cells the laser beam gets Doppler shifted. The reflected beam is recorded and processed to create color encoded perfusion maps. All laser Doppler measurements were obtained in the same room under the same standardized conditions as the IT was performed (room temperature: 23.3 ± 0. 6 °C). Following a resting period in a sitting position of 20 min, total skin perfusion of the volar surface of the patients' left hand was recorded. Similar to IT, a cold provocation maneuver was applied for 1 min and the investigation was repeated following the exposure.

Acral skin perfusion was measured from archived perfusion maps using LDPIwin 2 for Windows and mean perfusion values of all fingers were determined and given in arbitrary units (A.U.).

Data processing

Temperature and perfusion measurements were processed electronically using the device related software. Aiming to minimize imprecision caused by scattering of the reflected laser beam or thermoradiation, a standardized orthogonal distance of 15 cm between the camera/laser Doppler device and the skin surface of the subjects' left hands was used. Mean values and standard deviations of the measurements of the five fingertips of the patients' left hands were determined. Consecutively, the differences of the mean values of temperature and perfusion measurements before and after cold challenge were calculated and categorized as greater or less 1.5-fold of the previously determined standard deviations. The resulting variables were used for univariate comparison between both measurements.

Statistical analysis

We used Chi-square tests to compare proportions, and Mann–Whitney *U* tests for univariate comparison of continuous data. Correlations of the respective data were calculated by utilizing the method of Spearman. Continuous data are presented as the mean and standard deviation. Discrete data are given as counts and percentages. A two sided p-value <0.05 was considered as statistically significant. Calculations were performed with Stata (release 8.0) and SPSS for Windows (Version 16.0, SPSS Inc, Chicago, IL, USA).

Results

From December 2007 until April 2009 377, consecutive patients were admitted to our department because of Raynaud's phenomenon. According to serum antibodies, oscillometric pulse wave analyses and capillaroscopies, a primary Raynaud's phenomenon was diagnosed in 211 patients. Only patients with primary Raynaud's phenomenon and without any other vascular disease or other severe comorbidities were eligible for the present study. Finally, 25 patients (6 male, 24%) with a mean age of 43.9 ± 14.4 years were included into the present study. The severity of pain during Raynaud attacks was 6.0 ± 2.4 using the VAS.

Twenty-two healthy volunteers (5 male, 22.7%) with a mean age of 40.9 ± 11.5 years served as control group (Table 1).

Table 1
Demographic data of 22 healthy volunteers and 25 patients with primary Raynaud's phenomenon.

	Healthy controls	Raynaud patients	p value
N	22	25	
Age (years)	40.9 ± 11.5	43.9 ± 14.4	0.43
Male	5 (22.7%)	6 (24.0%)	0.92
Body Weight (kg)	71.4 ± 16.3	66.8 ± 16.3	0.34
Body Height (cm)	169.0 ± 0.1	169.0 ± 0.1	0.99
BMI (kg/m^2)	24.8 ± 4.5	23.3 ± 4.8	0.26
Smoker (y/n)	3	4	0.83
Arterial hypertension (y/n)	1	3	0.37
Hyperlipidemia (y/n)	1	10 •	0.003

Total cholesterol, 200.9 ± 42. 0 mg/dl; LDL-cholesterol, 119.1 ± 26. 1 mg/dl; HDL-cholesterol, 65.7 ± 16. 7 mg/dl; triglycerides, 104.0 ± 53. 7 mg/dl.
Data given as mean ± standard deviation, or as counts (%).