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The effects of a single carbon dioxide and hot water hand bath on acral perfusion in systemic sclerosis: A randomized, clinical study

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Abstract

Secondary Raynaud's phenomenon is the most common manifestation of systemic sclerosis, affecting more than 99% of systemic sclerosis patients, and a major cause of morbidity. Frequent and prolonged secondary Raynaud's phenomenon attacks not only cause severe discomfort and pain but also ischemic acral tissue damage. In addition to vasoactive drugs, carbon dioxide (CO_2) hand bath and hot water bath are potential non-pharmacological treatment options which can be self-administered by affected patients at any time. In order to compare the efficacy of these two physical measures, this randomized, clinical study evaluated the effects of a single CO_2 hand bath in patients with systemic sclerosis and secondary Raynaud's phenomenon and a healthy control group versus a single hot water hand bath on acral perfusion in systemic sclerosis by Doppler ultrasonography. None of the patients had currently digital ulcers, a vasoactive medication or a concomitant vascular disease. CO_2 immersion induced an acute hemodynamic response, whereas hot water immersion had no significant effect on acral perfusion in systemic sclerosis.

Keywords

Systemic sclerosis, carbon dioxide, hot water, Doppler ultrasonography

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Introduction

Systemic sclerosis (SSc) frequently manifests as secondary Raynaud's phenomenon (sRP). sRP's main symptoms are pain and digital ulcers. SSc is characterized by small digital arteries being constricted by overproduction of collagen, concentric intimal hyperplasia, and dysregulation of vasoconstrictive versus dilating molecular mechanisms.[1]

The physical medicine regimen for sRP in SSc[2,3] includes carbon dioxide (CO_2) hand immersion to increase distal digital blood flow. The treatment of peripheral vascular disorders has a long history of immersing the body into CO_2-enriched water based on the vasodilative effects of CO_2. CO_2 baths contribute to reactivation of capillary perfusion in patients with peripheral arterial occlusive disease.[4] Serial application in primary and secondary Raynaud's syndrome has the potential to improve tolerance to cold.[5]

In a pilot study that we previously presented, Doppler ultrasound with measurements of the resistance index (RI) of digital arteries[6–8] was used to quantify treatment effects of CO_2 hand immersion. These measurements served to supplement our previous work on synovial perfusion in wrist arthritis after local cryotherapy.[9] We demonstrated an acute hemodynamic response as well as a considerable short-term improvement of acral perfusion after a single carbon dioxide hand immersion in SSc.[10]

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Figure 1. SSc patient performing a CO_2 hand bath.

Table 1. Baseline characteristics of the SSc patients.

	SSc + CO_2 hand immersion	SSc + hot water hand immersion
Age (mean ± SD) (years)	57 ± 11	58 ± 10
Male	n = 2	n = 2
Female	n = 10	n = 10
SSc		
Limited cutaneous form	n = 6	n = 5
Diffuse cutaneous form	n = 6	n = 7
Disease duration mean ± SD (years)	6 ± 3	6 ± 4
Raynaud's phenomenon (RP)	n = 12	n = 12
Time since onset of RP (mean ± SD) (years)	6 ± 1	5 ± 4
History of digital ulcers	n = 3	n = 4
Abnormal nailfold capillaries	n = 12	n = 12
Anti-Scl-70 antibody positivity	n = 12	n = 12

SSc: systemic sclerosis; SD: standard deviation.

Thus, the aim of this study was to evaluate the effect of a single CO_2 hand immersion in SSc and a healthy control group versus a single hot water immersion on acral perfusion in SSc.

Patients and methods

A total of 24 patients with SSc (11 with limited cutaneous and 13 with diffuse cutaneous SSc) fulfilling the American College of Rheumatology criteria and sRP were assigned to two groups by computer-generated randomization: 12 patients received a CO_2 hand immersion and 12 patients a hot water hand immersion (Figure 1). In addition, 12 healthy age-matched controls received a single CO_2 hand immersion. Exclusion criteria included the presence of vasoactive medication, concomitant vascular disease, and digital ulcers. Baseline characteristics are presented in Table 1.

Table 2. Results (mean ± SD) of the resistance index (RI) measurements.

	SSc + CO_2 hand immersion	SSc + hot water hand immersion	Controls + CO_2 hand immersion
RI at baseline	0.83 ± 0.07	0.8 ± 0.08	0.7 ± 0.09
RI at T0 (immediately after immersion)	0.76 ± 0.08**	0.8 ± 0.08	0.7 ± 0.08
RI at T10 (10 min after immersion)	0.77 ± 0.09	0.81 ± 0.08	0.7 ± 0.07
RI at T20 (20 min after immersion)	0.79 ± 0.08	0.81 ± 0.07	0.7 ± 0.08

SSc: systemic sclerosis; SD: standard deviation.
**$p < 0.01$ (Wilcoxon signed rank test) T0 versus baseline.

All our examinations comply with the Helsinki Declaration. Approval was granted by the ethics committee of the Faculty of Medicine of the Justus Liebig University Giessen, Germany. We obtained written informed consent from each patient.

The following method has been extensively described in our pilot study.[10] Initially, a baseline ultrasound examination of the digital artery on ulnar side of the right index finger was performed. We used a Logiq 7 Pro ultrasound machine (General Electric Medical Systems, Milwaukee, Wisconsin, USA) with a wide-band linear transducer (4.7–13 MHz). After the ultrasound examination, standard hand immersion was performed 15 min using either a hot water hand immersion (40°C–42°C) or a Bastian® CO_2 hand immersion (2 g/L CO_2, 35°C; Bastian-Werk GmbH, Munich, Germany) for 15 min by a physiotherapist. The physician conducting the ultrasound examinations was blinded to treatment groups' allocation. RI calculations and further measurements were conducted using the internal software of the ultrasound machine at baseline (before immersion), directly after immersion (T0), 10 (T10), and 20 (T20) minutes after immersion (Figure 1) in the ultrasound examination room next door to the treatment room. Thus, the physician remained blinded to the treatment. We used a spectral Doppler curve to calculate the RI values with the following formula: $RI = (S - D)/S$, in which S is the peak systolic and D the end-diastolic velocity. An increased RI thus corresponds to increased vascular resistance and reduced arterial blood flow. For statistical analysis, we used the Wilcoxon signed rank test.

Results

The mean RI at baseline as well as the RI values during treatment was significantly higher in both SSc groups than in the healthy controls ($p < 0.01$ for each time point; see Table 2). However, the mean RI at baseline was not different between the two SSc groups. With respect to the aim of the study, the achieved treatment-induced reduction in RI

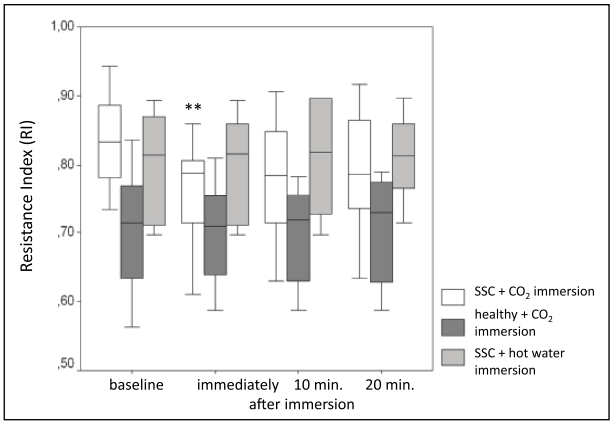

Figure 2. Changes in the resistance index in response to CO_2 and hot water hand immersion, respectively.

was significant ($p < 0.01$) in SSc directly after CO_2 immersion, with a lasting tendency (not significant) 10 and 20 min after the CO_2 immersion (Figure 2). In contrast, SSc patients receiving hot water immersion and the healthy controls with CO_2 immersion showed no significant changes of the RI at all time points.

Discussion

We attribute the higher baseline RI values in SSc to disease-related structural changes in the vasculature. Reduced vasodilatative capabilities are probably the cause for higher levels compared to the control group over. CO_2 ameliorated the functional alterations which led to a more significant decrease in the RI compared to hot water immersion and to a healthy control with CO_2 immersion.

Impressively, even a single CO_2 immersion showed a significant short-term improvement of acral perfusion immediately after bathing, with a tendency of a reduced RI (not significant) after 10 and 20 min. Based on these results of a single CO_2 hand immersion, we suggest that regular application of this treatment modality may lower the RI consecutively and thus facilitate improvement of acral perfusion in the long term by as part of a stimulus-response adaptation of the applied physical therapy modality. A recent small follow-up study underlined this hypothesis.[11]

We showed hand immersion as an easy-to-use and inexpensive, simple way for SSc patients to improve distal digital blood flow. There were no notable adverse effects. CO_2 hand immersion does not require any special equipment or experience. It can be used by physiotherapists on a daily basis and by patients for the treatment of sRP. It is also suitable to combine with drug-based vasodilatation therapies.

To clarify the question of whether a hot water bath induces the same hemodynamic effects as the CO_2 hand immersion, the temperature of the water bath was chosen above the indifferent temperature range. Although the higher temperature did not show any effects, the different temperature is a limiting factor.

In summary, this study confirmed the results of our pilot study about CO_2 effects on acral perfusion. Furthermore, we have shown for the first time that hot water immersion has no significant effect on acral perfusion in SSc and the capability of Doppler ultrasound to visualize the respective treatment effects.

Declaration of conflicting interests

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