Effect of Foot Baths containing Artificial CO2 on Peripheral Circulation

Yasuhiro HOSAKI1), Kozo ASHIDA1), Masanori HAMADA2), Makoto FUJII1), Naofumi IWAGAKI1), Shingo TAKATA1) and Kozue TABUKI3), Fumihiro MITSUNOBU1)

1) Division of Medicine, 2) Division of Rehabilitation, Misasa Medical Center, Okayama University Medical and Dental School. 3) Yamaguchi University Medical School

人工炭酸泉浴（パブ浴）を用いた足浴のご下肢末梢循環に及ぼす影響

保崎泰弘1）、芦田恵三1）、渋田全紀2）、
藤井誠1）、岩垣尚史1）、高田真吾1）、田迫梢3）、光延文裕1）
1）岡山大学医学部・歯学部附属病院三朝医療センター内科、2）同リハビリテーション科
3）山口大学医学部

抄録

閉塞性動脈硬化症（ASO）、糖尿病性末梢循環障害に合併する難治性下肢潰瘍、壞疽の治療、予防として人工炭酸泉浴は有用であると考えられている。今回、人工炭酸泉浴による足浴の末梢循環改善作用を定量的に明らかにする目的で、健常成人6例（年齢27～52歳、男性5例、女性1例）について検討した。右下肢踝骨外果より頭側10cmの背側にレーザードプラクラ血流計を固定し、さらに防水用のテープで覆った。42度の温水10ℓをハケに入れ、パブ錠1個を投入し、対象患者の両足を膝下まで10分間浸水した。観察は、浴前、浴中、浴後5分、15分、25分、35分に行なった。次に、足浴の全身の末梢循環血流量に及ぼす影響を検討する目的で、右上肢手関節より頭側10cmにレーザードプラクラ血流計を固定し、足浴と同時に上肢の末梢血流量を測定した。足浴前の血流量を100％とした時、足浴中10分では264±135（％）（p<0.05）、足浴後5分では256±174、浴後15分では146±60、浴後25分では112±23、浴後35分では107±24と減滅し、足浴前値に低下した。上肢の血流量は、浴前の血流量を100％とした時に、浴中10分では119±49、浴後5分では120±66、浴後15分では113±28、浴後25分では109±16、浴後35分では95±14と減滅し、浴前値に低下した。人工炭酸泉浴を用いた足浴の末梢循環に及ぼす血流増加効果が数値的に（2.6倍）認められた。しかし、その効果は浴後5分間を持続するものの15分後より低下する事が示された。簡易で効果的な人工炭酸泉浴を用いた足浴は、下肢の難治性潰瘍や壞疽の治療・予防に有効であることが示唆された。

Key words : diabetes mellitus, arteriosclerosis obliterans (ASO), peripheral circulation, carbon dioxide, foot bath
I INTRODUCTION

Recently, patients with arteriosclerosis obliterans (ASO) and peripheral circulation disorders as complications of diabetes mellitus are increasing because of changes in diet and the long lifespan in Japan\textsuperscript{1,2}. Foot-care is considered to be essential in preventing serious refractory leg ulcers and gangrene\textsuperscript{3}. We have been examining the effects of thermotherapy and spa therapy by using a laser Doppler blood-flowmeter for prevention and prediction of refractory leg ulcers and gangrene in those patients\textsuperscript{4-6}. Artificial carbon dioxide (CO\textsubscript{2}) warm water therapy, known to have a potent vasodilating action\textsuperscript{7}, has been shown to be effective for the treatment of ASO-associated ulcers\textsuperscript{8}. However, the quantitative effects of foot baths containing artificial CO\textsubscript{2} remain uncertain. In our study, the effects of foot baths containing artificial CO\textsubscript{2} on peripheral circulation of healthy volunteers were quantitatively evaluated by a laser Doppler blood-flowmeter. We used a tablet of "BUB" (45g, Kao Co., Tokyo, Japan) to obtain artificial CO\textsubscript{2} water. BUB is a tablet consisting of equimolar sodium hydrogen carbonate and succinic acid producing fine CO\textsubscript{2} bubbles in water that makes it possible to use baths containing artificial CO\textsubscript{2} at home.

II MATERIALS AND METHODS

Six healthy volunteers (ages from 27 to 52 years, 5 males and 1 female) were examined. First, they were asked to relax for 15 min in a room controlled at temperature 20°C, and relative humidity at 60%-70%. Second, each subject’s blood flow was measured using an ALF21D laser Doppler blood-flowmeter (Advance Co.). Detectors (ALC probe type C, Advance Co.) were placed using double-stick tape on the right calf (back side and 10 cm from Malleolus lateralis) and covered with waterproof tape (13cmx8cm, Ereban, Hakuzoumedical Co.). Then, each subject placed their feet for 10 min in a 42°C bath of 10 ℓ in which a tablet of BUB was dissolved. Measurements were taken each 15 sec, before, during and 5, 15, 25, and 35 min after each subject took a foot bath. We used the averages of each session as the measured values.

Next, in order to examine the effects of the foot bath on peripheral blood flow in the whole body, the laser Doppler blood-flowmeter was attached to subjects’ right arm, 10 cm above the wrist joint, and blood flow was measured using the same protocol as used for the feet.

III RESULT

The blood flow increased during the foot bath and decreased after the bath was removed. During placement of the feet in a bath for 10 min, the flow was 264±135(%) of the blood flow before the feet was placed into the bath) (Fig.1). This is regarded as a significant difference (p<0.05) by paired student's T-test. 5 min after the bath was removed, the flow was 256±174(%) of the original pre-bath rate. 15 min later it was 146±60(%), 25 min later it was 112±23(%), and 35 min later it was 107±24(%), returning to the flow rate before the feet were placed in the bath.

The arm blood flow also increased during whole patients’feet were in the foot bath and decreased after the foot bath was removed. When the feet were in the bath for 10 min, the flow was 119±49(%)
Effect of foot baths on circulation 271

of the blood flow before the feet were placed in the bath (Fig. 2). 5 min after the bath was removed, the flow was 120±66(%) of the original pre-bath rate. 15 min later the flow was 113±28(%), 25 min later it was 109±16(%) and 35 min later it was 95±14(%), as low as it was before the feet were placed in the bath.

**Foot Blood Flow**

![Foot Blood Flow Graph]

5 min after the bath was removed, the flow was 120±66(%) of the original pre-bath rate. 15 min later the flow was 113±28(%), 25 min later it was 109±16(%), and 35 min later it was 95±14(%), as low as the flow before the feet were placed in the foot bath.

**Arm Blood Flow**

![Arm Blood Flow Graph]

During placement of the feet in a bath for 10 min, the flow was 264±135(%) of the rate before the bath. This is regarded as a significant difference (p<0.05). 5 min after the bath was removed, the flow was still 256±174(%) of the original pre-bath rate. 15 min later the flow was 146±60(%), 25 min later it was 112±23(%), and 35 min later it was 107±24(%), as low as the flow before the feet were placed in the foot bath.

**Fig. 1 Effects of foot baths containing artificial CO2 on peripheral blood flow in legs.**

During placement of the feet in a bath for 10 min, the flow was 264±135(%) of the rate before the bath. This is regarded as a significant difference (p<0.05). 5 min after the bath was removed, the flow was still 256±174(%) of the original pre-bath rate. 15 min later the flow was 146±60(%), 25 min later it was 112±23(%), and 35 min later it was 107±24(%), as low as the flow before the feet were placed in the foot bath.

**Fig. 2 Effects of foot baths containing artificial CO2 on peripheral blood flow in arm.**

During placement of the feet in a bath for 10 min, the flow was 119±49(%) of the rate before the feet were placed in the bath. 5 min after the bath was removed, the flow was 120±66(%) of the original pre-bath rate, 15 min later it was 113±28(%), 25 min later it was 109±16(%), and 35 min later it was 95±14(%), as low as the flow before the feet were placed in the bath.

**IV DISCUSSION**

Iiyama9) reported a high increase of skin blood flow during carbon dioxide (CO2) bathing. Furthermore, Nishimura10) reported the effectiveness of full immersion in high density artificial CO2 spa water (1000 ppm, Table 1). Irie reported recently that carbon dioxide rich water bathing of ischemic hindlimb causes the induction of local VEGF11). Kawabata12) reported that the dissolved CO2 concentration was 847±43ppm in 10 min after dissolution of a tablet of BUB (45g / 6ℓ , at 38 ℃ ). Regarding the dissolved CO2 concentration, we obtained approximately 700 ppm at

| **Table 1** |
|-----------------|--------|-----|-----|-------|
| Kawabata12)     | 845±43 ppm | 38℃ | 6 ℓ | BUB 45g |
| Satou14)        | 817 ppm   | 40℃ | pH4.9 | 10 ℓ | BUB 90g |
| Eguchi11)       | 145.6 ppm | 38℃ | pH4.6 | 150 ℓ | BUB 50g |
| Nishimura10)    | 1000 ppm  | 39℃ | pH7.0 | 150 ℓ | MRE-SPA, |
| Irie11)         | 1000-1200 ppm | 37℃ |       | 20 ℓ |

(MRE:MitsubishiShieiyo Engineering)
42°C with a tablet of BUB (45g/ℓ) by calculating on a thesis of Eguchi13). Although the foot bath with “BUB” does not give a CO₂ concentration as high as that of a high density artificial CO₂ full immersion bath (1000ppm, Nishimura’s case10, and Satou14), it was quite easy to obtain a high CO₂ concentration using BUB. However, in a full immersion bath, we obtain low CO₂ concentrations of 50-60ppm because one tablet of Bubu is dissolved in 150ℓ.

From our results, these conclusions were made:

1) Peripheral blood increased by 2.6X using a foot bath containing artificial CO₂. The increase was maintained for 5 min but the blood flow decreased 15 min after the feet were taken out of the foot bath.

2) Taking a foot bath containing artificial CO₂ increased arm blood flow by 20%. However, the flow declined rapidly after the feet were removed from the foot bath; thus, we can infer that there is little effect on the whole body.

3) It was shown that a foot bath containing artificial CO₂ is effective not only for keeping legs clean but also for preventing refractory leg ulcers and gangrene, and for healing them by increasing peripheral blood flow in the legs.

We will have an increasing number of patients with peripheral circulation disorders because of the long lifespan in Japan. As a consequence, the need for bath services at home and at elderly care service stations will increase significantly. However, it is likely that many people will take a bath only every two days using the bath services. For these cases, the simple artificial CO₂ foot bath we describe is effective not only as a refreshing treatment but also as a treatment for refractory leg ulcers and gangrene. We suggest it is preferable to use this foot bath both at home and at the elderly care service stations.

References


Effect of foot baths on circulation


14) Satou H: private letter

Summary

Purpose: We examined the effects of foot baths containing artificial carbon dioxide (CO2) on peripheral circulation. Our goal was to obtain quantitative results bearing on the treatment and preservation of refractory leg ulcers and gangrene, which would occur in arteriosclerosis obliterans (ASO) and diabetic peripheral circulation disorders.

Procedures: The lower legs of six healthy volunteers were placed for 10 min into a 42°C bath of 10ℓ in which 45g of artificial CO2 “BUB” was dissolved. A laser Doppler blood-flowmeter was firmly attached. The measurements of blood flow were taken before, during, and 5, 15, 25, and 35 min after each subject took a foot bath. Next, in order to examine the effects of peripheral blood flow on the whole body during the foot baths, each laser Doppler blood-flowmeters was attached on the subject's right arm, 10 cm above the wrist joint.

Results: The blood flow increased during the foot bath and decreased after the bath was removed; during in a 10 min bath, the flow was 264±135(%) (p<0.05) of the flow before the feet were placed into the bath. 5 min after the bath was removed, the flow was 256±174(%) of the original pre-bath rate. 15 min later it was 146±60(%), 25 min later it was 112±23(%), and 35 min later it was 107±24(%), as low as the flow before the feet were placed in the bath. The arm blood flow also increased during the foot bath and decreased after the bath was removed. During a 10 min bath, the flow was 119±49(%) of the rate before the feet were placed in the bath. 5 min after the bath was removed, the flow was 120±66(%) of the original pre-bath rate. 15 min later it was 113±28(%), 25 min later it was 109±16(%), and 35 min later it was 95±14(%), essentially the same as the flow before the feet were placed in the bath.

Discussion: Our work demonstrates an increase in blood flow, by 2.6X, by using a foot bath containing artificial CO2. The increase was maintained for 5 min after removed of the foot from the bath. However, the blood flow decreased 15 min after the baths were removed. We hope that this simple and effective foot bath will be used both at home and elderly care service stations. Its use could see prevention from refractory leg ulcers or gangrene, particularly as average life span continues to increase in Japan.