The Effects of High Concentration Artificial CO₂ Warm Water Bathing for Arteriosclerotic Obstruction (ASO)

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抄 録

ASOによる潰瘍は予後不良で切断などに至る場合が多い。そこで、血管拡張作用を強く持つ高濃度人工炭酸温水の効果について、温水浴時の足背の末梢組織血流（pBF）および継皮酸素分圧（TCPO₂）を足浴10分前より足浴終了後30分まで、1分毎隔で連続測定した。

対象は、潰瘍が進行期あるいは安定期にあり血行再建術が可能であったFontaine II ～IV度の49例（平均66歳、男：女＝20：29）である。この虚血肢に週3回以上人工炭酸温水足浴（38℃、濃度1000ppm）を行った経過を写真評価した。1回の足浴時間は10分間とした。

その結果、治癒傾向の乏しかった潰瘍の多くは短期間に縮小ないしは治癒した。pBFは前1.1±0.5ml/min/100gで、1分後より上昇し始め10分後には4.4±1.8まで上昇したが（p<.01）、終了直後に前値に戻った。一方、TCPO₂は前40.7±18.3mmHgより10分後50.7±18.2と上昇し（p<.05）、終了20分後も50.3±20.8と前値を上回っていた（p<.01）。また、Fontaine各群別でもpBF、TCPO₂とも有意に上昇していた。

以上より、潰瘍を合併した虚血肢には血行改善が必要であるが、血行再建術や運動療法が行えないような症例に対しても、38℃・1000ppmの高濃度人工炭酸温水は効果があり、良好な治療成績を期待することが
I INTRODUCTION

Ulceration due to ASO is difficult to treat in general, because it usually has poor prognosis and often results in amputation\(^1\)). We report here the therapeutic effects of high concentration artificial CO\(_2\) warm water, which is known to have a potent vasodilating action\(^2\)), on bedsore etc\(^3\)). In 49 Fontaine II to IV cases, and also the results of time-related observations of the peripheral blood flow and transcutaneous oxygen partial pressure (TCPO\(_2\)) in dorsum pedis during the CO\(_2\) warm water bathing.

II APPARATUS

Artificial CO\(_2\) water was produced utilizing the artificial gas-permeable dialysis membrane developed by Mitsubishi Rayon Engineering shown on the right side of Fig. 1. This system resembles the hemodialyzer used by patients with renal failure, and when warm water is passed through the central portion, CO\(_2\) gas begins to dissolve into the warm water. This is the equipment for foot bathing actually used at hospitals. High concentration CO\(_2\) warm water can be obtained simply by connecting this equipment to a CO\(_2\) gas cylinder. In the present study, foot bathing was performed for 10 min per time using the warm water at an insensible temperature of 38°C containing CO\(_2\) at a nearly saturated concentration of 1000 ppm.

Recently, we have made the equipment compact so that small size CO\(_2\) gas cylinders such as those for beer and carbonated beverages at restaurants and for CO\(_2\) supply to vending machines can be used at home.

III SUBJECTS

We studied 49 ASO patients who had the lower limb subjective symptoms at Fontaine severity II or more, in whom circulation reconstruction was impossible, and whose ulcers were either at a progressive or stable stage. Male : female 20 : 29, mean age 66 ± 13. Diabetes mellitus was observed 18 cases (36.7%).

By Fontaine severity, 22 patients were 2nd (44.8%), 20 were 3rd (40.8%), and 7 were 4th (14.2%). All these patients were treated with artificial CO\(_2\) warm water more than 3 times per week, and the results were evaluated using the pictures of their course.

In addition, TCPO\(_2\) sensor and a laser doppler blood flow meter were attached firmly to the
dorsum pedis of a disease limb, and these values were measured at intervals of 1 min from
the time 10 min before starting foot bathing until 30 min after completing foot bathing.

IV CASES

Actual 7 cases are shown in the following figures.

Case 1 of fig.4 shows the necrosis developed from thermal burn on the right thumb in a
65 years old man with primary ASO. The right picture shows the result of CO₂ bathing per-
formed once daily for 4 months (Fig.4).

Case 2 of fig.5 is the necrosis developed from a shoe sore of a 58 years old woman with
primary ASO. As shown in the right picture, necrosis healed after the CO₂ bathing per-
formed once daily for 2 weeks (Fig.5).

Case 3 of fig.6 is the picture showing the crack developed from dryness on the right heel
of a 67 years old woman with primary ASO. Cure was obtained after CO₂ bathing once daily
for 3 weeks as shown on the right of the picture.

Case 4 of fig.7 is spontaneous necrosis of a 72 years old woman. Although once-a-day
CO₂ bathing could not be performed because of patient’s reasons but it was performed at a
frequency of only 3 times a week, necrosis was cured after 3 weeks.

Case 5 of fig.8 shows multiple spontaneous necroses of a 49 years old woman. Heel les-
sions were remitted by once-a-day CO₂ bathing, though 2 months were needed.

Case 6 of fig.9 is the necrosis developed from burn of a 68 years woman with mitral
valve insufficiency complicated with ASO. Multiple necroses were improved by the CO₂
bathing performed twice daily for 2 months.

Case 7 of fig.10 with spontaneous necrosis performed CO₂ bathing once daily for 1
month using a portable CO₂ bathing unit at home because of difficulty of visiting hospital. It
may be seen that the color tone of the right foot was improved and circulation was also im-
proved.

V RESULTS

Fig.11 shows the time course of changes in tissue blood flow before and after CO₂ warm
water bathing. The tissue blood flow was 1.1 mL/min/100 g before bathing, which began to
increase 1 min after starting bathing and significantly elevated up to 4.4 after 10 minutes,
and then rapidly returned to the pre-bathing level.

TCPO₂ was 40.7 mmHg before bathing and increased significantly to 50.7 at 10 min-
utes after starting bathing. Even 20 min after completing bathing, it was maintained at 50.3
which was still higher than the pre-bathing value (Fig.12).

In the fig.13, the tissue blood flow was compared with TCPO₂ classified by Fontaine
severity. Even when classified by Fontaine severity, significant increases from pre-bathing
values were observed. Marked differences were seen for Fontaine 2nd and 3rd, but even
Fontaine 4th with probable poor blood flow also showed a significant difference. This is
thought to indicate that high concentration CO₂ warm water is effective on ASO even when
a case is severe on Fontaine severity.
The Effects of Artificial CO$_2$ for ASO

Fig. 1 Artificial CO$_2$ water productive system.

Fig. 2 The equipment for foot bathing (38°C, 1000ppm, 10 min. bathing per time)

Fig. 3 Development of systems for home use, Size reduction

Used at restaurants serving beer and carbonated beverages CO$_2$ gas cylinder
Case 1: 65-year-old male, developed necrosis from burn on medial portion of the thumb.

Primary disorder: Diabetic nephropathy
Complications: DM (6 months) ASO

CO₂ treatment period: 4 months
Frequency of bathing: Once daily

10, Dec, 1999

Case 2: 58-year-old female, developed necrosis from injury to right toe.

Primary disorder: Diabetic nephropathy
Complications: DM ASO

CO₂ treatment period: 2 weeks
Frequency of bathing: Once daily

4, March, 2000

Case 3: 67-year-old female, developed spontaneous necrosis on right heel.

Primary disorder: Diabetic nephropathy
Complications: Angina pectoris ASO

CO₂ treatment period: 3 weeks
Frequency of bathing: Once daily

12, May, 2000

10, April, 2000

17, March, 2000

30, May, 2000
Fig. 7 Case 4: 72-year-old female, developed spontaneous necrosis on right heel.

Primary disorder: Diabetic mellitus  
Complications: Angina pectoris ASO  
CO2 treatment period: 3 weeks  
Frequency of bathing: 3 time/week

8, March, 2000  
31, March, 2000

Fig. 8 Case 5: 49-year-old female, developed spontaneous necrosis on right heel.

Primary disorder: Diabetic nephropathy  
Complications: DM ASO  
CO2 treatment period: 2 months  
Frequency of bathing: Once daily

26, April, 2000  
20, June, 2000

Fig. 9 Case 6: 68-year-old female, developed necrosis from burn on sole of foot.

Primary disorder: Mitral valve insufficiency  
Complications: ASO  
CO2 treatment period: 2 months  
Frequency of bathing: Twice daily

6, April, 2000  
4, June, 2000
Primary disorder: ASO

CO₂ treatment period: 1 month
Frequency of bathing: Once daily

2, Feb, 2000
24, Feb, 2000

Fig. 10 Case 7: 81-year-old female, developed spontaneous necrosis on right foot.

Fig. 11 Time course of changes in tissue blood flow before and after CO₂ warm water bathing.

Fig. 12 Time course of changes in TCPO₂ during CO₂ bathing.

Fig. 13 Comparison of TCPO₂ and the tissue blood flow stratified by Fontaine severity

Fontaine severity

p<0.01 for all differences between the values before and 10 min after, except for *.

Fig. 13 Comparison of TCPO₂ and the tissue blood flow stratified by Fontaine severity
VI DISCUSSION

The results presented are considered to prove the clinical effectiveness of the potent vasodilating action of 38°C, 1000 ppm high concentration artificial CO2 warm water4, 5) on ASO-related ulceration.

Vasodilatation-associated improvements of peripheral circulation and metabolism including improved local tissue blood flow and enhanced TCPO2 are thought to be the mechanism of action6, 7). The finding that the volume of circulating blood decreased at an early phase to maintain the oxygen partial pressure high is thought to suggest that vasodilatation occurs once8), then the tissue blood flow decreases as CO2 gas is removed, but the circulation then improved to maintain the oxygen partial pressure at a high level.

Circulation must be improved for the ischemic limbs complicated with ulcers3). Artificial CO2 warm water bathing is thought to show good therapeutic results even in cases whose circulation cannot be reconstructed and also in cases incapable of performing therapeutic exercise.

VII CONCLUSION

Artificial CO2 warm water bathing was effective for the treatment of ASO-associated ulcers. The peripheral blood flow and TCPO2 were significantly improved regardless of severity on Fontaine scale.

Thus, the artificial CO2 warm water therapy was suggested to be effective as one of treatments for ASO cases and is expected to be developed further.

References

1) Dillon RS: Fifteen years of experience in treating 2177 episodes of foot and leg lesions with the circulator boot. Results of treatments with the circulator boot. Angiology 1997 ; 48 (5 Pt 2) : S17-34.
Summary

The ulcer of the foot induced by arteriosclerotic obstruction (ASO) is poor prognosis that often comes to amputation. In the meantime, the CO₂ warm water is reported with that it has the powerful vasodilator action. In this research, it was made that the effects for the foot ulcer using the high concentration CO₂ warm water bathing was examined to be a purpose.

The subjects are the 49 cases (average 66-years, male : female=20 : 29) degree of Fontaine II～IV. We prepared high concentrated CO₂ warm water in approx. 1,000 ppm at 38°C technically utilizing an artificial gas-permeable dialysis membrane (MRE-SPA, Mitsubishi Rayon Engineering Co., Ltd.). Using the partial bathing with this CO₂ warm water, the progress was observed on the improvement of foot ulcer in the bathing of 10 min. as the period, and of 1–2 time/day. In addition, the peripheral tissue bloodflow and the transcutaneous oxygen partial pressure in dorsum pedis during the warm water bathing were observed.

The obvious improvement on each case of ulcer was confirmed within several months. The peripheral tissue blood flow (before bathing 1.1 ± 0.5mL/min/100g) was increased after 1min and it rose to 4.4 ± 1.8 after 10min from the beginning to bathing (p<0.01). Afterwards, it immediately returned to the previous value after the end. In the meantime, though the transcutaneous oxygen partial pressure was 40.7 ± 18.3 mmHg prior to the bathing, it increases after 10 min with 50.7 ± 18.2 mmHg (p<0.05), and it was maintained at 50.3 ± 20.8 mmHg in 20 min after bathing (p<0.01). And, in each Fontaine groups it significantly increase with the peripheral tissue bloodflow and the transcutaneous oxygen partial pressure.

As a conclusion, the partial bathing of the foot with high concentration CO₂ warm water is effective as the therapy for the foot ulcer caused by ASO. The mechanism indicated that the rise of transcutaneous oxygen partial pressure and peripheral tissue bloodflow was concerned without relating to the seriousness of ASO.