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Protective effects of topically applied CO_2-impregnated water

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Background/aims: The 'positive effect' of CO_2-impregnated water (mechanical process of producing carbonated therapeutic waters for medical use) on the skin of the hands was reported by 76% of 107 users questioned. The present study intends to evaluate this effect by using bioengeneering methods.
Methods: In 20 healthy volunteers, mild to moderate irritation was induced on both hands using a standardised washing procedure. One hand was rinsed with CO_2-impregnated water (carbonic acid) once daily for 1 min, the other with tap water as the control. Baseline values and values 30 min after application were recorded by measuring transepidermal water loss (TEWL), skin humidity (SH), microcirculation of the blood (BF) and skin surface pH. Wilcoxon's signed rank test was used for statistical analysis; *P*-values of less than 0.05 were considered to be significant.
Results: Baseline TEWL, BF and pH tended to be lower (in some cases significantly lower) in the test regions treated with carbonic acid, whereas baseline SH tended to be higher (in some cases significantly higher). TEWL and pH were significantly lower for the side treated with CO_2 30 min after application, whereas in some cases SH was significantly higher compared with the control side. Visual comparison revealed a lesser degree of irritation for the region treated with CO_2 in comparison with the control side.
Conclusions: The results show that the skin physiology parameters of irritated skin are favourably influenced by the topical application of CO_2-impregnated water. Although those test regions treated with carbonic acid did not remain uninfluenced by repeated irritation in clinical comparisons, the irritation was more intensive in the test regions treated with fresh water.

Key words: CO_2-impregnated water (carbonic acid) – skin surface pH – skin physiology parameters – hand protection

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NATURALLY occurring carbonated water was already being used in the fourth century A.D. to treat skin lesions. Throughout medical history, there have been many medical indications of the use of carbonated water baths, whereby carbonic acid was, *inter alia*, said to have healing powers, even in the case of 'skin rashes' and 'ulcers' (1).

At present, there is a consensus of opinion regarding the following effects of the use of carbonic acid: 1) opening of functionally-closed capillaries; 2) dilation of precapillaries; 3) improvement of blood fluidity; 4) influencing thermoreceptors; 5) antiseptic (2).

The immediate dilation of vessels after the application of carbonic acid was discovered empirically and has been proved in experiments in the last few years (3). Specific tests regarding the effect of topically applied carbonic acid on skin physiology parameters do not exist recently. However, hypotheses regarding the effects and the possible applications of carbonic acid resulting from these can be drawn from various available analyses.

Locher was able to show that eczematous skin has an alkaline pH, and bodily repair mechanisms to stabilise disorders in the physiological skin surface pH are less efficient (4). In all probability, the skin surface can be acidified by the topical application of carbonic acid. Several analyses (5, 6) demonstrate that acidification of the skin surface by the application of acidic substances leads to an easing of eczematic ailments. Although the skin surface could be acidified by applying weak acids other than carbonic acid, the latter seems to be especially suitable because it is a substance that can be applied to the skin that occurs naturally as a physiological component of the carbonic acid-sodium hydrogen carbonate-buffer system. This buffer system plays a decisive and important role in alkali neutralisation, especially when skin is damaged due to the lowering of diffusion resistance [dependent on irritation (7)]. It is therefore probable that the topical application of carbonic acid makes it possible to use the buffer capacity of carbonic acid and thereby favourably influence the alkali neutralisation

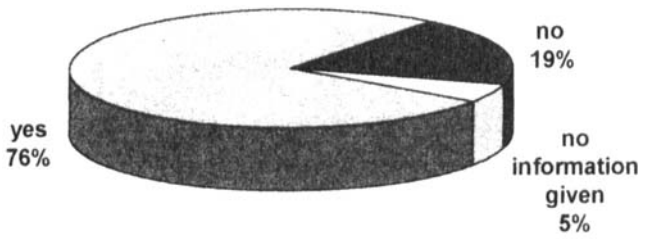


Fig. 1. Users' questionnaire: Did you observe any positive influence of CO_2-impregnated water on the skin of your hands? (n=107)

capacity (dependent on the available buffer substance).

Carbonated waters have come to be used for non-medical purposes over the past few years due to mechanical production by special impregnation devices. A survey of 107 people employed in professions potentially hazardous to the skin but working with carbonic acid, showed that 76% of those surveyed had observed the positive influence of carbonated water on the skin of their hands (Fig. 1).

The present study intends to evaluate whether carbonic acid can influence the damage to the skin's protective systems caused by irritation and examines the feasibility of the topical application of carbonic acid as a protective measure for the skin.

Material and Methods

Materials

For the standardised washing, a normal trade shampoo, containing 19% active washing substances (manufacturer's information), was diluted with aqua dest. to contain 10% active washing substances in the ready-to-use solution.

For the fresh water samples, tap water was used. The pH of the fresh water was relatively constant during the whole test period at 8.2±0.1.

The carbonated water used was mechanically produced with the help of an impregnation device, in which pressurised tap water was enriched with carbon dioxide. The pH of the carbonated water (pH 5.4) was constant during the whole duration of the examination.

All samples were applied at a temperature of 37°C.

Methods

The study concept was submitted in writing to the Ethics Commission of the University of Osnabrück, which gave it unanimous approval. The test was carried out on a half-half basis on 20 test subjects (13 women and 7 men aged between 23–28 years). The volunteer test subjects underwent no selection conditions apart from that of right-handedness. To randomise, one half of the participants was treated with carbonic acid on the right hand and the other half was treated on the left hand.

Over a period of 2 weeks, the back of one hand of the test subjects was rinsed once daily for 1 min with carbonic acid. The other was rinsed with fresh water as control. Simultaneously, the backs of both hands were repeatedly irritated by means of standardised washing with shampoo solution twice a day.

Two foam rolls, 3.5 cm in diameter and 7 cm in length and attached to a handle, were used for the standardised washing. They were dipped into the prepared washing solution and rolled back and forth 40 times per minute on the backs of the hands twice for a duration of 2 min. No pressure was applied – only the 200 g weight of the construction. After 2 min, both hands were rinsed for 30 s in 37°C warm water. The construction developed by us to this effect made it possible to treat both hands simultaneously (Fig. 2).

The influence of carbonic acid or fresh water on the skin physiology parameters of irritated skin was measured by using non-invasive skin physiological examination methods.

Transepidermal water loss (TEWL) as a measure of permeability barrier function was measured using the evapometry method. An Evaporimeter EP1 (Servomed & Co., Hässelby, Stockholm, Sweden) was used. Relative skin humidity (SH) was measured using the capacity measuring method. A Corneometer CM 820 PC (Courage & Khazaka Electronic GmbH, Cologne, Germany) was used. The skin surface pH was measured using the Skin.pH.meter 900 (Courage & Khazaka Electronic GmbH). The skin blood circulation was evaluated with the Periflux laser Doppler flowmeter (Perimed, Stockholm, Sweden).

The working principles of the equipment used as

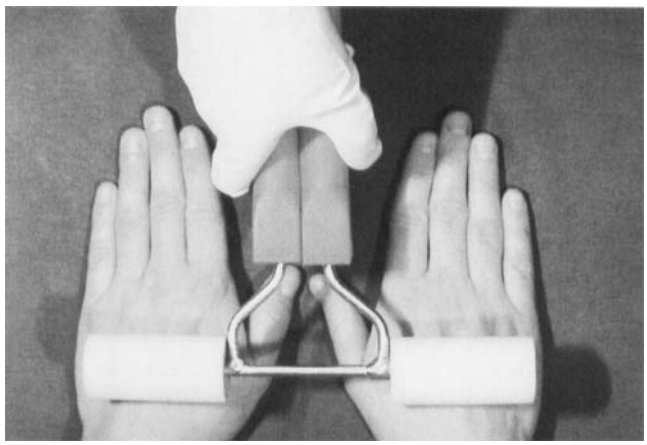


Fig. 2. Washing instrument for standardised washing.

well as the possible endogenous and exogenous influencing factors have been described extensively in various publications. The guidelines for measuring the various parameters laid down in these have been taken into consideration in this test (8–13). Measurements were expressed as the mean value of two recordings (evapometry) or three recordings (corneometry and laser Doppler flowmetry).

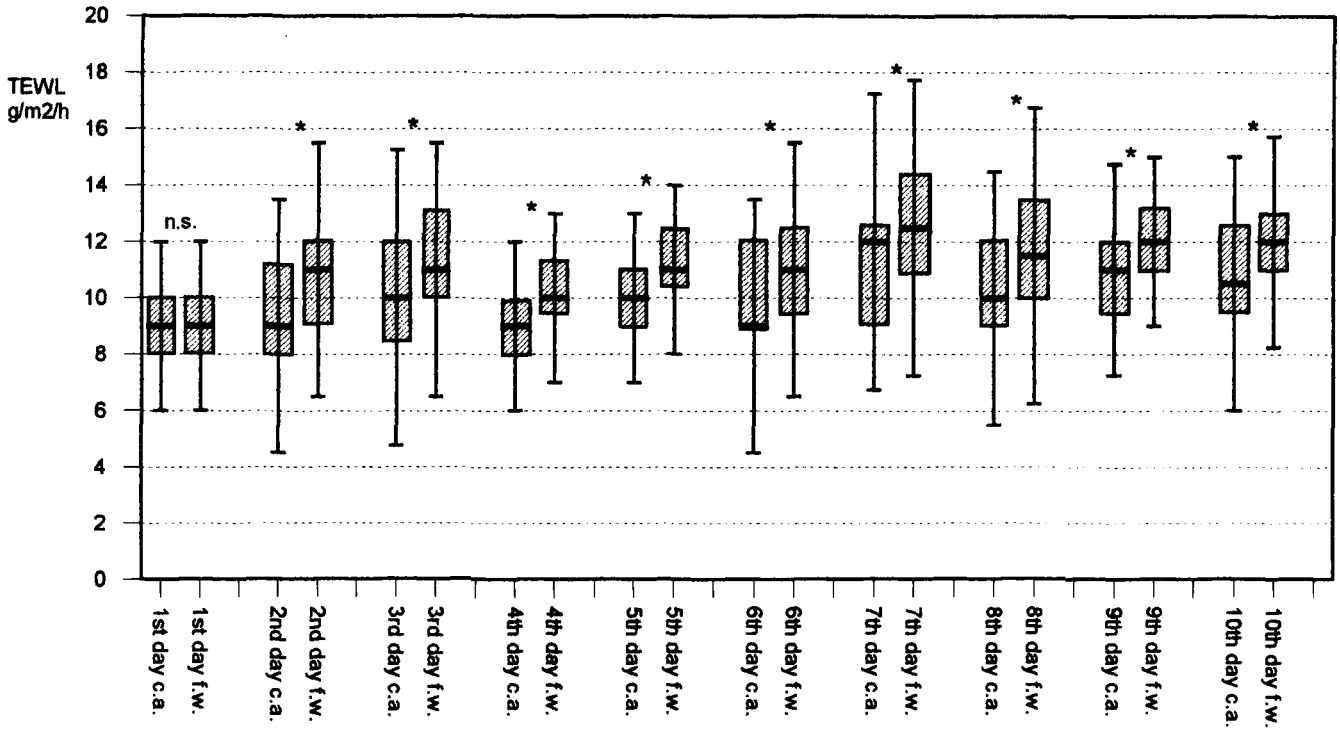
The tests took place in the partially air-conditioned skin physiology laboratories of the University of Osnabrück. As a result of the negligible changes in temperature (20°C±1°C) and air humidity (48%±4%), we could exclude fluctuations in temperature/air humidity and in the skin physiology parameters recorded. These could have distorted the results.

A 30 min acclimatisation phase was spent before all tests to make certain the test subjects adjusted to laboratory conditions. During the acclimatisation phase, a patch test area with a diameter of 1.5 cm was marked on the backs of the hands of the volunteers near the middle metacarpo-phalangeal joint. Following the acclimatisation phase, the baseline TEWL, SH, BF and skin surface pH were measured in all test regions. Immediately after this, the first washing took place according to the procedure described above. Then, the backs of the hands were rinsed with carbonic acid and fresh water, respectively. The second measurements occurred 30 min after application, as water, both in the course of washing and rinsing, causes a temporary but nevertheless considerable rise in the hydration of the stratum corneum. Finally, the second washing took place in a similar fashion to the first.

At the end of the study, all test subjects were surveyed using a structured and standardised questionnaire. The questions related to the clinical appearance of actual changes in the skin, to differences in the extent of the skin alterations in the various test regions and to differences in the test subjects' impressions during treatment on their left and right hands. The treatment process of carbonic acid versus fresh water wasn't revealed to the volunteers.

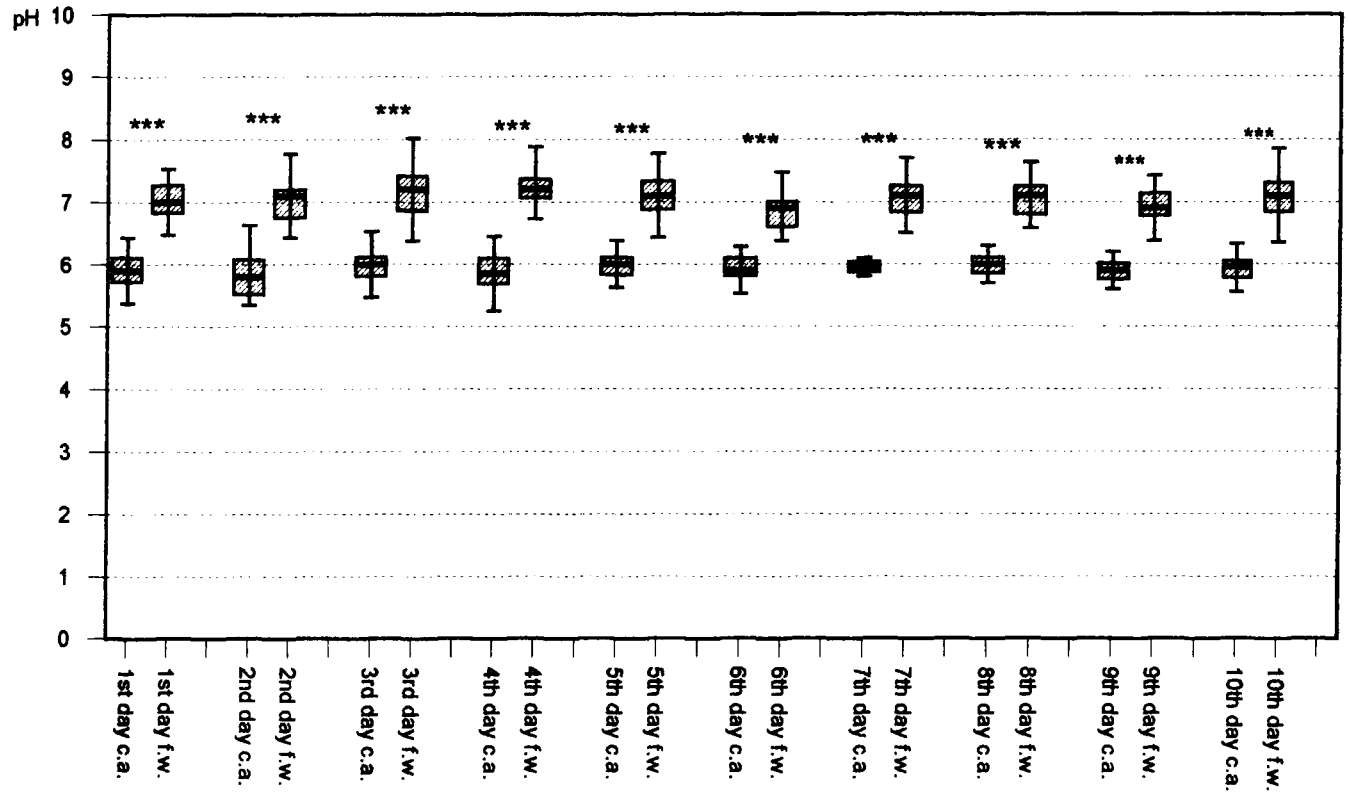
Statistical analysis

The median and 25/75 percentile was chosen as the standard for the descriptive statistics. Wilcoxon's signed rank test was used for the non-parametric statistics. This is regarded as a distribution-free analogue to the paired *t*-test and is seen as a symmetrical test to find the mean difference (14).



Plots: The bottom and top edges of the box are located at the 25th and 75th percentile. The center horizontal line is drawn at the sample median. The central vertical lines (whiskers) extend from the box as far as the data extend to a distance of at most 1.5 interquartile ranges. n.s.: not significant
*=P<0.05.

Fig. 3. TEWL median, 25th and 75th percentiles 30 min after treating the backs of the hands with fresh water (f.w.) versus carbonic acid (c.a.).



Plots: The bottom and top edges of the box are located at the 25th and 75th percentile. The center horizontal line is drawn at the sample median. The central vertical lines (whiskers) extend from the box as far as the data extend to a distance of at most 1.5 interquartile ranges. ***=P<0.001.

Fig. 4. pH median, 25th and 75th percentiles 30 min after treating the backs of the hands with fresh water (f.w.) versus carbonic acid (c.a.).

Apart from the correlation between positive and negative differences, which tend to make statements possible concerning connections between two parameters, the following level of significance was chosen: $P<0.05$.

Results

The irritation caused by repeated washing led to a significant rise in the baseline TEWL, both in combination with the fresh water samples and in combination with the carbonic acid samples. The comparison of the mean values, however, showed a smaller rise in TEWL in those test regions treated with carbonic acid. The difference arising from the smaller rise became clear in Wilcoxon's signed rank test: On day 3, 6, 7 and 8, the baseline TEWL was significantly lower in the test regions treated with carbonic acid than in those treated with fresh water. This positive influence of topically applied carbonic acid on the TEWL of irritated skin became even clearer in the comparison of the values 30 min after application. Apart from on the first day, the TEWL of the test regions treated with carbonic acid was significantly lower 30 min after application than that of test regions treated with fresh water (Fig. 3).

The baseline SH and the SH 30 min after application tended to be higher (in some cases significantly higher) in those test regions treated with carbonic acid than in those treated with fresh water.

The BF was shown to have lower baseline values (significantly lower on day 2 and 7) in the test regions treated with carbonic acid. Similarly, the baseline pH tended to be lower (significantly so on day 2 and 7) in those test regions treated with carbonic acid. The pH of the test regions treated with carbonic acid was significantly lower 30 min after application than the pH of those treated with fresh water (Fig. 4).

The subjective appraisal of the test subjects, which was collated by means of a questionnaire, supports and supplements the results of the experimental study. Fifteen of those questioned observed a difference in the changes in the skin between those parts treated with fresh water and those treated with carbonic acid. Eleven of these were of the opinion that the skin alterations in those areas treated with carbonic acid were less extensive (Fig. 5).

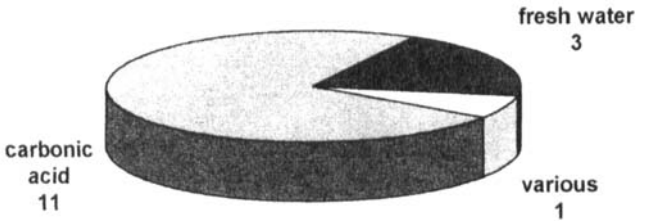


Fig. 5. Users' questionnaire: On which hand were that individual skin changes less noticable? (n=15)

Of those surveyed, 83% regarded the carbonic acid treatment as more pleasant than the fresh water treatment. Seventeen percent noted no difference.

The results of the experimental examination show that the topical application of carbonic acid can favourably influence the skin physiology parameters of irritated skin in comparison to applications of fresh water. The reduction of toxic damage was also clearly visible in the clinical appearance.

Discussion

As a result of the available test results, the following possible uses for the topical application of carbonic acid can be deduced: As expected, the topical application of carbonic acid leads to an acidification of the skin surface that could be experimentally proved in the present examination. Since it has been proved that eczematous ailments can be eased solely by acidifying the skin surface (5,6), it would appear sensible to recommend the topical application of carbonic acid to eczema sufferers as a skin care measure. With regard to the positive effect of the use of carbonic acid on skin surface pH, the importance of bacteria resistance and the dependence of this protective mechanism on skin surface pH (15,16) should not be overlooked when looking for possible uses for the topical application of carbonic acid. It seems thoroughly plausible that infectious diseases of the skin could be favourably influenced by the ability of carbonic acid to reduce pH.

A surprising result was the significantly lower TEWL in those test regions treated with carbonic acid as opposed to those treated with fresh water. This result points to the fact that a controlled improvement of the permeability barrier, whose functioning correlates directly with TEWL (17), can be achieved by the topical application of carbonic acid. When it is considered that a variety of skin diseases, such as atopic xerosis, dry skin in old age and irritative and contact allergic eczema of the hands are associated with a disorder of the permeability barrier (18), then the importance of a controlled improvement in the permeability barrier, which could be proved in experimentally produced cumulative subtoxic eczema of the hands, becomes clear. The results of previous studies give weight to the assumption that carbonic acid or carbon dioxide acts as a 'biocatalyst' after permeating the epidermis, i.e., it improves and/or accelerates certain metabolic processes (19–21).

In conclusion, the protective effects of the topical application of carbonic acid could be proven in this study. We are engaged in finding an explanation for the biochemical effects of carbonic acid in the epidermal tissue that account for the positive influence of topically applied carbonic acid in irritated skin. Possible therapeutic uses for topically applied carbonic acid may result from this.

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