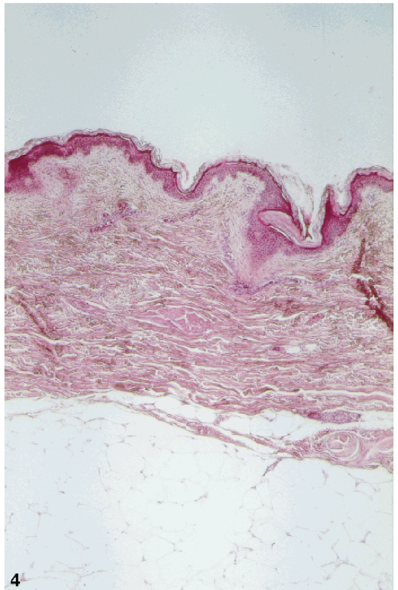

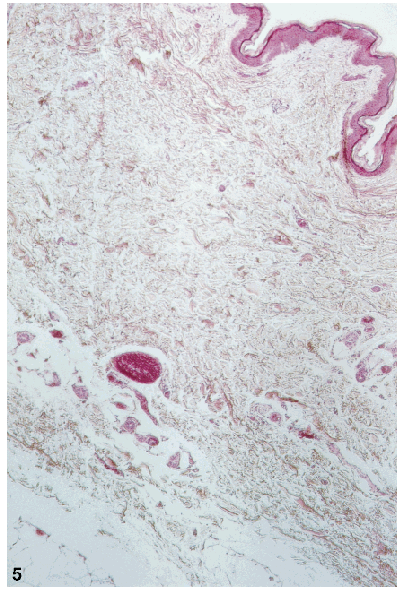

Fig. 4. Patient 1. Histological appearance of the dermis before CO_2 treatment.
Fig. 5. Patient 1. After CO_2 treatment, thickening of the dermis and rearrangement of collagenous fibers is shown.

tissue, regional blood circulation, and biochemistry between affected and nonaffected areas.

Sexual dimorphism in the subdermal connective tissue has been reported, consisting in a different orientation in women and men of the subcutaneous fibers which extend from the dermis to the fascia, probably linked to hormonal causes and, in particular, to the absence of the effect of androgens [3,7,8]. Some authors have noted the coexistence of fat accumulation or so-called “lipodystrophy” and anomalies in the microcirculation and lymphatic drainage [2]. Though not a pathological condition, the unestheticism associated with fat accumulation, typically located on the lower limbs and abdomen, has pressed for research on methods aimed at the treatment thereof. The use of carbon dioxide therapy has been seen to have a positive effect on the microcirculation in treated arteriopathic patients, without any associated risks [4,5,9]. In this respect, our study also did not reveal any significant side effects, and any negative effects that were observed never created esthetic or functional problems. Our data regarding changes in both Doppler laser signal and transcutaneous PO2 measurements confirmed a significant increase in the values obtained after treatment. Such an effect in improving circulation in treated areas confirmed our initial hypothesis about using this technique [1,10] (Table 1). In our study, the effectiveness of carbon dioxide therapy was confirmed both by histological data and by those regarding variations in the maximum circumference of the areas subjected to treatment. With respect to the former, the damaging effect on adipose cells without damage to the connective tissue explains, on the one hand, the reduction in the circumferences observed and, on the other, the absence of serious side effects (Figs. 1–3). The statistically significant reduction observed in the areas treated (Table 1) was attributable to both a direct effect on adipose tissue, as revealed by the lysis of adipose cells, and to an indirect effect. The latter seems to be related to the significant changes in the microcirculation observed by Laser Doppler measurement combined with the $tcPO_2$ method (Table 1). In conclusion, we believe that the absence of toxicity, the simplicity of the procedure, and the favorable results obtained in our study indicate that this is a valid method in treating localized adiposities.

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Aesth. Plast. Surg. 25:170–174, 2001
DOI: 10.1007/s002660010116

Aesthetic Plastic Surgery

Carbon Dioxide Therapy in the Treatment of Localized Adiposities: Clinical Study and Histopathological Correlations

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Abstract. The authors report their experience using carbon dioxide (CO_2) therapy for the treatment of 48 female patients presenting adipose accumulations, located on the thighs, knees, and/or abdomen; a Carbomed Programmable Automatic Carbon Dioxide Therapy apparatus was used. In light of the effects of CO_2 on the microcirculation recently described in the literature, we expected this gas, which we administered subcutaneously, to positively affect the physiological oxidative lipolytic process. The aim of our study was to evaluate the effect of this therapy on localized adiposities. As such, we describe the method we used and report the results observed in the areas treated (in terms of reduction in maximum circumference) as well as side effects. Furthermore, we assessed the effect of subcutaneous administration of CO_2 on the microcirculation by showing changes in the Laser Doppler signal and in the concentration of transcutaneous oxygen tension ($tcPO_2$). Pre- and posttreatment biopsies of tissues were performed in seven patients in order to study the changes induced by the use of CO_2 on both adipose and connective tissues. All data obtained were statistically analyzed; values of $P < 0.05$ were considered significant.

Key words: Carbon dioxide—Cellulite—Localized adiposity

Carbon dioxide (CO_2) therapy refers to the transcutaneous administration of CO_2 for therapeutical purposes. Historically, this treatment originated in 1932 in France, at the Royat spas, with the treatment of patients affected by obliterating arteriopathies. Recent studies have demonstrated the results of this therapy on arteriopathies (stage II), by showing vasomotor effects studied with Doppler and Laser Doppler examinations. An increase in femoral blood flow and blood pressure of the lower limbs, as well as an improvement in treadmill test perimeters were observed [4,5,9]. The effect of CO_2 administration proved effective not only in improving local parameters of circulation and tissue perfusion but also in inducing a partial increase in $tcPO_2$. Such might be due to a hypercapnia-induced rise in capillary blood flow, a drop in cutaneous oxygen consumption, or a right shift of the O_2 dissociation curve (Bohr effect) [5]. As such, the effect of carbon dioxide therapy on the microcirculation, and therefore the probability of a positive effect upon the physiological oxidative lipolytic process, led us to use this gas in the treatment of localized adiposities. Some authors have furthermore demonstrated the coexistence of an increase in subcutaneous localization of fat with alterations in blood and lymphatic drainage [2]. The aim of our study was to assess the effectiveness of carbon dioxide therapy in the treatment of adiposity localized in the lower limbs and abdomen, by reporting the variations in maximum circumference and the side effects observed. Furthermore, we evaluated the effects of subcutaneous CO_2 administration on the microcirculation studied by Laser Doppler and on oxygen tension measured by $tcPO_2$ [1,6,10]. Finally, we performed a histological study on treated tissue in order to assess the changes, both in adipose and connective tissues, induced by this treatment.

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Material and Methods

The present study includes 48 female patients (mean age: 34 years, range: 24–51 years) presenting adipose accumulations on the thighs, knees, and/or abdomen, who were under our observation from November 1998 to May 1999. No other physical, drug, or dietary treatment was in course. The treatment cycle consisted of two weekly subcutaneous applications of CO_2 for 3 consecutive weeks (total of six sessions) using the Carbomed Programmable Automatic Carbon Dioxide Therapy apparatus and 30GA1/2 0.3 × 13 Microlance needles. The subcutaneous injections were made, anteriorly and posteriorly, at the medium, medial, and lateral thirds of the thigh, below a plane tangent to the apex of Scarpa's triangle for the lower limbs, and in the paraumbilical region, bilaterally, for the abdomen. The infusion velocity was 50 cc/min, with a total of gas administered equal to 300 cc for the limbs and 150 cc for the abdomen in each treatment. The circumference of the abdomen, thighs, and knees was measured at the first treatment session and the day after the last session. In all the patients, we treated adiposities localized on the thighs, which were accompanied by adiposity localized on the abdomen in 14 cases and with adiposity localized on the knees in 36 cases. In all patients we performed a Laser Doppler examination combined with $tcPO_2$ using the Periflux System by Perimed both before treatment and 30 min after the end thereof. The probes were placed bilaterally in all cases, on the anterior medial quadrant of the thigh. The patients were examined at a constant temperature (22°C) in a supine position and for 30 min for each measurement. In order to determine the values of $tcPO_2$ (in mmHg), the probe was kept at a temperature of 44°C and the apparatus was calibrated by monitoring the values of barometric pressure. The data regarding the signals obtained with the Laser Doppler were expressed in perfusion units (PU). In four cases of abdominal localization and in three cases of localization on the thighs, cutaneous and subcutaneous biopsies were taken on the days preceding treatment and at the conclusion thereof. The patients were examined for a follow-up period of 3 months in order to check the results and identify any side effects caused by the treatment. For statistical analysis we used the Student's *t*-test for paired data; the mean and standard deviation of the results were reported and a value of $P < 0.05$ was considered significant.

Results

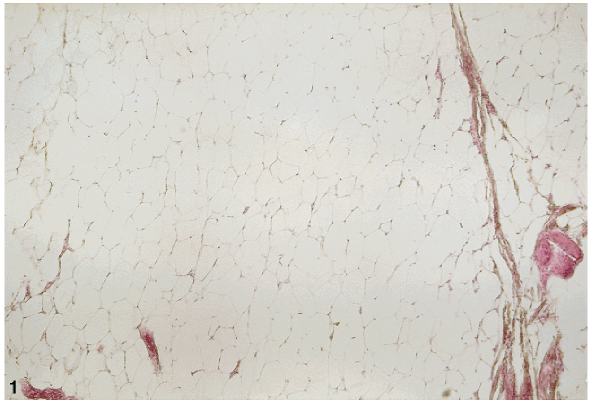
In the present study, we observed few side effects, all of which were quickly resolved. *All* patients reported the presence of a crackling sensation beneath the skin, which was limited to the first hour of treatment; in 30% of the patients, the injection caused slight hematomas which eventually disappeared, without causing any esthetic damage. The pain felt at the site of injection, although frequently observed (70% of the patients), was always short-lasting and never so intense that gas administration had to be interrupted. The study regarding changes in the signals observed using the Laser Doppler technique demonstrated a significant increase in the values (expressed in PU) observed after treatment. In particular, the mean of the values observed before and after treatment were 12.29 (standard error (SE) = 2.02) and 20.65 (SE = 2.47), respectively, ($p < 0.01$). The increase in $tcPO_2$ (in mmHg) was also significant. The data obtained regarding the means (and standard errors) of $tcPO_2$ before and after subcutaneous administration of CO_2 were 61.17 (SE = 2.31) and 80.30 (SE = 4.41), respectively, ($P < 0.01$). The data regarding measurements of the maximum circumference of the thigh, knee, and abdomen, taken before and at the end of treatment showed a significant reduction in all the patients. For the thigh, the mean (and SE) of the values observed were 56.1 cm (SE = 0.6) and 54.2 cm (SE = 0.6) ($P < 0.01$), for the knee 37.8 cm (SE = 0.5) and 36.7 cm (SE = 0.4) ($P < 0.01$), and for the abdomen 78.4 cm (SE = 2.4) and 75.7 cm (SE = 2.0) ($P < 0.01$), respectively, (Table 1). The results of structural examination at light microscopy, which were overlapping in the different areas subjected to examination, showed fracturing of the adipose tissue with the release of triglycerides in the intercellular spaces and adipocytes presenting thin fracture lines in the plasma membrane (Figs. 1–3). Of particular interest was the fact that the fracture lines did not involve the connective spaces where the major vascular structures are located. The dermis presented a thicker appearance than before treatment, with the collagenous fibers distributed more diffusely (Figs. 4,5).

Table 1. Values before and after CO_2 treatment: comparison by Student's *t* test for paired data

	Mean	SD	MSE	*P*
PU				
Before	12.29	9.46	2.02	$P = 0.012$
After	20.65	11.58	2.47	
PO2				
Before	61.17	11.76	2.31	$P < 0.01$
After	80.30	17.40	3.41	
Thigh				
Before	56.1	4.3	0.6	$P < 0.01$
After	54.2	3.9	0.6	
Knee				
Before	37.8	3.0	0.5	$P < 0.01$
After	36.7	2.7	0.4	
Abdomen				
Before	78.4	8.9	2.4	$P < 0.01$
After	75.7	7.5	2.0	

Discussion

The presence of dimpling on the thighs and buttocks due to the infiltration of fat in the dermis has been defined in various ways by different authors. In particular, the absence of inflammatory processes dissuades most authors from referring to such a condition with the general term "cellulite." Recent studies have not shown significant differences in the morphology of subcutaneous adipose



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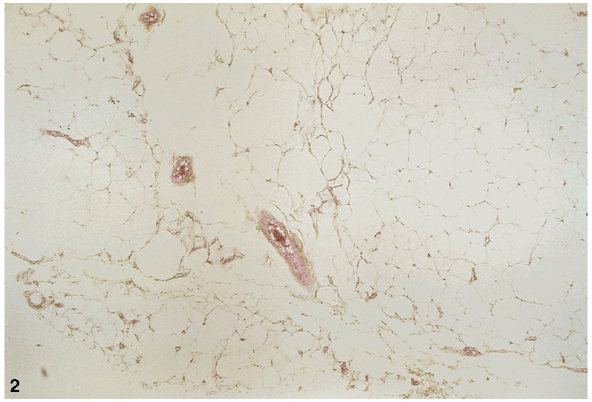

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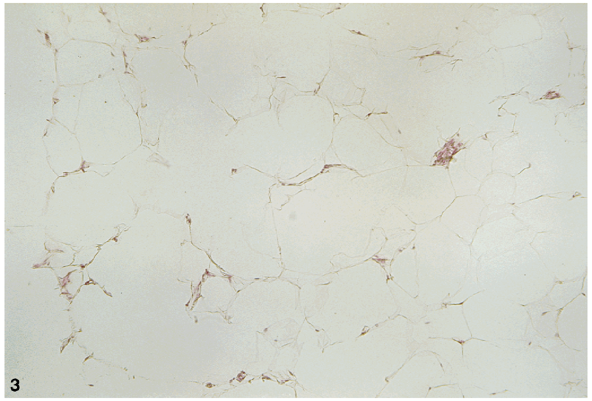

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Fig. 1. Patient 1. Histological features of the subcutaneous layers before CO_2 treatment.
Fig. 2. Patient 1. Histological appearance of the subcutaneous layers after CO_2 treatment, showing lysis of the adipocytes not involving the vascular structures.
Fig. 3. Patient 1. Detailed microphotography showing lysis of the adipocytes.