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Cold Air in Laser Therapy: First Experiences With a New Cooling System

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Background and Objective: **Analgesic cooling technologies are firmly established in dermatologic laser therapy. We present cold air as a novel method of cooling and compare it with those methods that are already in use.**
Study Design/Materials and Methods: **We treated 166 patients with the diagnoses hypertrichosis, port wine stains, hemangioma, essential telangiectasias, and tattoos with different laser systems (long-pulsed alexandrite laser [LPIR], pulsed dye laser, Q-switched Nd:YAG laser, Q-switched ruby laser). In a prospective study, we collected data about the analgesia of the cooling method and the thermal protection of the epidermis (reduction of the extent and duration of erythema, purpura, blisters, hyper-/hypopigmentations, edemas, crusting), compared with the cooling method with ice gel. Additionally, we measured air and skin temperatures with an infrared thermometer at different application modalities.**
Results: **Three percent of the treated patients refused the cold air therapy altogether. Eleven percent found that it was as good as the other cooling methods; 86% clearly preferred the cold air therapy. Leaving out the perinasal area, the percentage rises to 97%. On average, the analgesic effect was by 37% better than through cooling with ice gel. The increased thermal protection of the epidermis made it possible to use laser energy levels that were higher by 15–30% and, at the same time, to reduce the rate of side effects (in 63% of the patients erythema persisted for a shorter period, in 70% the purpura was reduced, 83% had less crusting).**
Conclusion: **In dermatologic laser therapy, the use of cold air in analgesia can be considered as an effective, inexpensive, and well-accepted (by both patients and doctors) alternative to currently applied cooling methods. Nevertheless, further prospective studies are necessary to determine whether treatment results can really be improved by using higher laser energy levels. Lasers Surg. Med. 27:404–410, 2000.**

Key words: analgesia; cryotherapy; cryoanesthesia; dermatologic laser therapy; epidermal thermal protection

INTRODUCTION

As early as in classic antiquity, snow and ice have been used in the field of medicine. In his writings, Hippocrates of Kos, for example, recommends cold drinks to fight fever as well as cold compresses and crushed ice to relieve gout and burn pains. Nowadays, cryotherapy is an indispensable part of everyday treatment in the fields of rheumatology, orthopedics, sport medicine, and neurology [1]. For some time now, cryotherapy or better cryoanesthesia, has gained in importance as an additive in dermatology as well, especially in dermatologic laser therapy [2–9]. The objectives are an analgesic effect, which makes the treatment much more bearable for the patients and thermal protection, which makes it possible to use higher levels of therapeutical energy.

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TABLE 1. Laser Types and Indications for the Use of Cold Air Therapy (n = 166 Patients)

Laser type	Wavelength (nm)	Energy (J/cm^2)	Pulse duration	Indication	Number of patients
Long-pulsed alexandrite laser	755	23–34	20–40 ms	Hypertrichosis	124
Long-pulsed alexandrite laser	755	15–24	5–20 ms	Tattoo	3
Pulsed dye laser	585–600	3.5–7.0	0.45 ms	Essential telangiectasias	4
Pulsed dye laser	585–600	3.5–8.5	0.45 ms	Port wine stains	10
Pulsed dye laser	585	3.5–7.0	0.45 ms	Hemangioma	7
Q-switched Nd:YAG laser	532/1064	2.0–7.0	5 ns	Tattoo	12
Q-switched ruby laser	694	6–40	10 ns	Tattoo	6

In contrast to its classic use, cryoanesthesia is ideally meant to cool only the epidermis to anesthetize and thermally protect it, as well as to avoid an influence on the target structures of the laser beam. Furthermore, cryoanesthesia is to influence the laser beam as little as possible in intensity and direction. There are a wide variety of methods to apply cryoanesthesia. We differentiate between contact cooling and contact-less cooling. In contact coolings, the cooling medium—mostly liquid or gaseous—is put directly onto the skin. Examples: moistening of the skin (evaporative cold), application of ice packs (direct cooling), application of ice (gel) (direct cooling and evaporative cold), the use of cold conductors, e.g. the “Chilled Tip”™ handpiece for the long-pulsed Nd:YAG-laser [6,10], the metal “cooling finger” for the ruby laser [11], the sapphire lens for the diode laser.

For contact-less cooling, it is usual to transfer the cold to the skin by means of an appropriate gaseous medium. Contact-less cooling methods are, for example, cooling with cold air and cooling with other cold gases, especially with liquid nitrogen.

The use of cold sprays, in particular halogenized hydrocarbon (such as chlorethyl), has an interim position because there is a contact phase and a contact-less phase. In dermatologic laser therapy, mainly contact cooling has been used so far [2,3,6,10,11]. In this study, the use of cold air as a cooling medium in dermatologic laser therapy is investigated in a group of 166 patients.

MATERIALS AND METHODS

Patients

From April to September of 1999, we treated 166 patients (131 women, 35 men) with the skin types I and II and the diagnoses hypertrichosis, port wine stains, hemangioma, essential telangiectasias, and tattoos with different laser systems (long-pulsed alexandrite laser (LPIR), pulsed dye laser, Q-switched Nd:YAG laser, Q-switched ruby laser). In a prospective study, we collected data regarding the analgesia of the cooling method and the thermal protection of the epidermis compared with the cooling with ice gel. Furthermore, we measured air and skin temperatures with an infrared thermometer at various application modalities. Patients who had local frostbites or suffered from arterial circulation disturbance or cryoglobulinemia have not been included in this study.

Lasers

Most of the patients (124) underwent an epilation therapy with the long-pulsed alexandrite laser (755 nm, impulse length 20–40 msec, Cynosure® Apogee). The areas treated were face (78 female patients), ear (1 patient), nostrils (1 patient), bikini zone (18 female patients), armpits (13 patients), breast (11 female patients), back (4 patients).

Next, we treated 21 patients with the pulsed dye laser (585 nm, impulse length 0.45 msec, Cynosure® V); they suffered from essential telangiectasias, port wine stains, and hemangioma in the following areas: face (13 female patients), armpits (4 patients), legs (3 patients), breast (1 patient).

Lastly, there were treatments of various tattoos with the Q-switched Nd:YAG laser (532 nm and 1,064 nm, impulse length 5–10 nsec, Continuum Photometrics), the Q-switched ruby laser (694 nm, impulse length 20 nsec, Lambda Photometrics) and the long-pulsed alexandrite laser (755 nm, impulse length 5–40 msec, Cynosure® Apogee). Treatment areas were arms (12 patients), legs (3 patients), back (1 patient), face (1 patient). The distribution of laser types, parameters, and treatment indications are shown in Table 1 and that of treated areas are shown in Table 2.

TABLE 2. Distribution of the Treated Areas

Localization	Number of patients
Face	90
Ear	1
Nostril	1
Bikini zone	18
Arms	16
Armpits	13
Breast	13
Legs	6
Back	5

Cooling System

For cooling, we used the cold air machine "Cryo 5" (Zimmer Elektromedizin, Germany). This machine uses a compressor system as in a refrigerator to generate out of room air a permanent stream of cold air with a flow of 500 to 1,000 L/min and a temperature as low as –30°C, depending on the desired cooling level (range 1 to 6). Up to now, this machine had been mainly used in cold therapies of orthopedic diseases [1].

For testing purposes, the machine—in an unmodified state—was used in different dermatologic laser treatments. We found that the integrated air transport tube was unwieldy and too thick and that the diameter of the application nozzle was too big to be directed precisely to the area that should be cooled. Furthermore, the air stream spread out in all directions, which led to eye and respiratory problems during facial treatments.

For these reasons, the air transport system was optimized (LaserMedical, Germany). The modified system consists of a thinner tube with a special cooling adapter (Fig. 1). The stream of cold air hits the skin exactly at the place of the laser beam application. There is no modification necessary to use Cynosure® handpieces together with this cooling adapter. The adapter can also be easily fitted onto other laser types. Treatments with Cynosure® lasers have been done by using the cooling adapter. For other laser systems, the air transport tube has been separated from the adapter and the doctor or an assistant directed the tube to the area to be treated. Most of the time, the cooling machine was operated on the levels 4, 5, and 6. We always used the highest possible level the patient could tolerate.

Parameters

All patients had undergone one or several treatment sessions without the cold air therapy. In these sessions, contact cooling with ice gel had been used (Coupling Gel; ESC®). The frozen gel in the shape of an ice pop was applied to the corresponding skin areas directly before laser treatment and removed after a contact time of 3 seconds. Then the area was treated for 5 seconds and after this, the cooling was repeated.

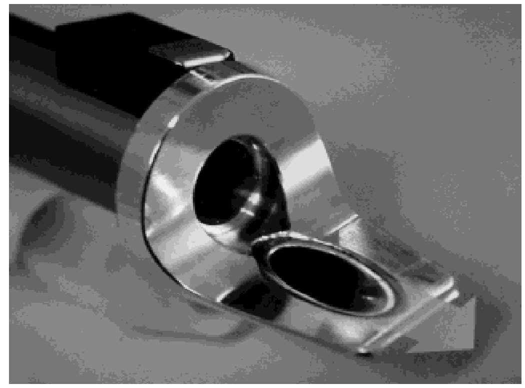

Fig. 1. Cooling adapter. The arrow indicates the direction of the air stream.

In the treatment sessions evaluated in this study, cold air cooling was compared with the ice gel cooling of previous sessions by using the following parameters: We assessed the *analgesic effect* of cold air cooling by comparing it with that of ice gel cooling. For this purpose, we used scales ranging from –3 (meaning: analgesia with cold air is >75% less than with ice gel) to +3 (meaning: analgesia with cold air is >75% better than with ice gel) with a granularity of 25%, on which the patients evaluated the analgesic effect of cold air cooling.

The *thermal protection* of the epidermis (reduction of intensity and duration of erythema, purpura, edema, blisters, hyper-/hypopigmentations, crusting) was assessed during and directly after treatment, as well as after 4 to 6 weeks. This assessment was done by both the treating doctors and the patients themselves. Here again, cold air therapy was compared with ice gel cooling by using the above-mentioned scales for each of the side effects (for example the development of erythema with cold air cooling was assessed by using a scale between –3 [meaning: erythema with cold air is >75% more than with ice gel] to +3 [meaning: erythema with cold air is >75% less than with ice gel]). Additionally, peculiarities during treatment were recorded. The effects of cooling on the *clearance* of the skin lesions was assessed qualitatively after 4 to 6 weeks by doctors and patients (worse, no change, better).

RESULTS

Three percent of the treated patients refused the cold air therapy altogether. The reasons given were eye and respiratory problems with facial treatment, shoulder pain caused by the cold air, and the high level of noise. Eleven percent of the treated patients found that it was as good as the other cooling methods; 86% clearly preferred the cold air therapy. Leaving out the area around the nose, the percentage rises to 97%. All female patients whose armpits or bikini zone were epilized said that the cold air therapy had a better analgesic effect. On the average, this effect was better by 37% than when cooling with ice gel.

On the evaluation sheets which the patients filled in, the most frequently quoted advantages of the cold air therapy are: treatment is more bearable, constant cooling, cooling "on the spot", less pain, faster treatment, fewer side effects (less intense erythema, fewer edemas and crusting), more hygienic (no application of substances).

Because of the good analgesic effect of the cold air cooling, it was possible to increase laser energy levels by an average of 15–30% (we could not increase the energy level with only 12% of the patients). Nevertheless, the rate of side effects was lower (in no case was it higher): In 63% of the cases, erythema did persist for a shorter time than before; in no case did they persist longer. Additionally, they were less intensive in 74% of the cases. This was especially obvious in the treatments with the pulsed dye laser. No or very little purpura developed in 70% of the cases. There was only a slight effect on reducing the development of edemas. Only 7% had fewer edemas. Particularly significant was the reduction of crusting. Despite higher laser energy levels, 83% of the patients had weaker or no crusting compared with the previous treatments. When assessing the clearance, we could not see any significant changes. These results are shown in Table 3.

TABLE 3. Advantages of Cold Air Cooling Over Ice Gel Cooling (Patient Results)

Parameter	Cold air cooling (%)
Preferred therapy	97
Preferred therapy outside face	100
Possible increase of laser energy	15–30
Erythema persisting shorter in	63
Erythema less intensive in	74
Analgesic effect better by	37
Less purpura in	70
Less edema in	7
Less crusting in	83
Clearance	No difference observed

In addition to the evaluation sheets, we measured the temperatures of both the air stream and the skin. The skin temperature was measured with an infrared thermometer. The measurement results are listed in Tables 4, 5, and 6.

As for the doctors who performed treatment, it was observed that the therapy is more practical, safer, and more pleasant with cold air. The work can be done quicker; there is no need for breaks to apply the cooling medium. The area to be treated is always visible. There are no breaks necessary for the cooling down of handpieces during very long treatment sessions. It is not necessary to prepare and dispose of the cooling medium. After treatment, the patient does not have to clean remaining cooling substances off him- or herself, the amount of waste is reduced. Scattered cooling substance does not dirty the laser handpiece and protection gear; this could lead to a contamination of the lens, particularly with ice gel cooling.

DISCUSSION

Contact Cooling

There is no doubt about the analgesic and thermally protective effect of cooling in dermatologic laser therapy [2,4,5,10]. Up to now, mostly contact cooling methods have been used. In more recent studies, even mathematical simulation models have been developed to describe how they work [3]. Aside from their analgesic effect, contact cooling methods have disadvantages that can, depending on the case, be more or less significant. Chess et al. [4], for example, used a cooling device with icy water. The authors say that there were no refraction losses if the handpiece of the laser was held upright, but that is open to doubt because there are several interfaces to penetrate. Adrian and Tanghetti [10] used a "Chilled Tip"™. With this method, we also expect optical losses (condensation, reflection, dispersion). The same applies to the use of ice cubes, through which the laser beam is applied [12,13]. There is the addi-

TABLE 4. Air Stream Temperature With the New Cooling Adapter at Various Cooling Levels

Cooling level "Cryo 5"	Temperature air stream from the cooling adapter (°C)
1	−9
2	−10
3	−11
4	−12
5	−13
6	−15

TABLE 5. Skin Temperature After 8 Seconds (Initially 32°C)

Cooling level "Cryo 5"	Skin temperature after 8 seconds (°C)
2	20
4	18
6	15

TABLE 6. Skin Temperature After 1 Second (Initially 32°C)

Cooling level "Cryo 5"	Skin temperature after 1 second (°C)
2	31
4	29
6	28

tional danger of losses in intensity due to air bubbles in the ice cube. Even if the absorption rate in water is low due to the wavelength (as described in Werner et al. [13]), the other optical losses still persist. In all of these cases, the skin area to be treated is not directly visible. It becomes even harder to assess the skin because the added cooling devices produce mechanical compression of the skin. This study is not to judge how far these theoretical disadvantages lead to a worse effectiveness of the laser treatment, but the disadvantages can, in many cases, be avoided by using contact-less cooling methods.

Contact-Less Cooling

The general advantage of contact-less cooling methods in dermatologic laser therapy is that no medium disturbs the way of the laser beam. There is, in particular, no interface, which is mostly connected with losses because of dispersion, transmission, and reflection. As there is no substance to be applied to the skin, it is also possible to work quicker, which means that the treatment becomes more pleasant for both the doctor and the patient.

A special advantage of contact-less cooling methods is that they are not dependent on the topography of the area to be treated. Parts of the body with an uneven surface, mucus membranes or openings such as the oral cavity, ears, and nostrils are hardly or not at all accessible for methods of contact cooling. In some cases, cooling can be achieved with complicated procedures (application of cold Ringer-solution after intubation) [13], but contact-less cooling methods are, in most cases, the easier way.

There is no compression of the skin area to be treated. This can be particularly important in cases of superficial vascular lesions. On the other hand, it may sometimes be desirable to compress the structures to be treated, e.g., in the case of voluminous hemangioma [13,14]. In such cases, the use of a contact cooling method can be advantageous.

The use of halogenated hydrocarbon in the form of cryogen sprays ([7,8]: dichloro-difluoro-methane, [9]: 1,1,1,2-tetrafluoro-ethane) has been repeatedly described in published material [7–9]. Their use has an interim position, because the medium is liquid when applied to the skin and becomes gaseous with a certain delay. Mathematical simulation models about the bioheat transfer during treatment of port wine stains are available [15]. An in vitro comparison of cryogen spray cooling and contact cooling shows that they produce the same cooling profile in the skin [16], but it is unclear whether this is true for the in vivo case. Cryogen sprays improved the patients' tolerance of the therapy and reduced the pain, but they are even more expensive than treatments with nitrogen. Moreover, the production and use of halogenized hydrocarbon must be regarded critically from the ecological point of view.

Cooling with liquid nitrogen has been known for some time. The advantage of achieving low temperatures can easily turn into the opposite because there is—without cautions—the danger of skin damage from frostbite. From the business point of view, the use of liquid nitrogen must also be regarded critically because of the high operating costs (nitrogen, transport and storing costs).

Cold Air Cooling

The use of cold air is a new form of therapy in the field of contact-less cooling methods. This concerns cold air at a temperature of between −20 and −30°C that is applied, in adjustable quantities, to the parts of the body that are to be treated. With this method, the danger of frostbite is clearly lower than with the use of nitrogen, because the minimum temperatures are significantly higher. In addition, the cold air therapy incurs much lower operating costs; aside from the needed electricity, there are no further running costs or disposal problems. The use of the air transport system that we optimized for our purposes has the following advantages compared with the original air transport system: Tube and handpiece are connected, so that only one hand is needed to conduct treatment. The air stream hits the skin exactly at the place of the laser application. The handpieces remain cool, which is especially important during long treatment sessions. The air stream is more gentle and can be directed with precision, a fact that patients find quite pleasant. Due to its construction there is one direction in which the air cannot flow. This is an advantage, particularly for facial treatments, because nostrils and eyes, thus, can be protected from the air stream. The application temperature is higher (approximately −12°C), which was also reported to be more tolerable.

Concerning the question of the lowest attainable temperatures with a working time of 1 second (typical repetition rate for treatments with the long-pulsed alexandrite laser, for example), it is important to know that they refer to an initial skin temperature of 32°C. Treatment is done consecutively in neighboring areas, so that the cooling effect can be intensified by a pretherapeutic reduction of the skin temperature. Knollmann et al. [17] noticed that the reduction of the skin temperature by applying cold air (45% of the initial temperature) is quite similar to that when using ice gel (49%) or liquid nitrogen (41%). In the laser duplex signal, circulation in the skin decreases by approximately 40% in all of the observed procedures. This shows that the cold air therapy is quite similar to the other cooling methods, at least in what concerns the quoted objective parameters. Furthermore, Kröling et al. [8] have proved in electromyographic examinations of the radiohumeral epicondyle that cold air is considerably quicker and more intensive in increasing the pain threshold than liquid nitrogen and ice gel.

The measurements of skin temperatures presented in this study are the basis for further research work. At present, we are preparing a study in cooperation with the university of Ulm, the purpose of which is to closely examine the physiological-biological effects of cold air therapy in dermatologic laser therapy.

The acceptance of cold air therapy is very high among patients and doctors. Not considering treatments in the areas of nose and eyes, 97% of the patients preferred the cold air cooling method. To avoid the problems with facial treatments, we either used a nose clip or told the patients to hold their nose and used closed protective goggles for the eyes. Thus, we were successful in solving most of the eye and respiratory problems. Therefore, it is of great importance to thoroughly inform the patients about the problems caused by cold air therapy for facial treatments. We were able to take away initial feelings of fear from almost all of the concerned patients. The high compatibility of cold air therapy was also confirmed in other studies [17], in which contact-less cooling methods with cold air and liquid nitrogen were the patients' clear favorites. The ease of use by the operator and the speeding up of treatment are important factors for a high acceptance among the treating doctors.

Despite higher laser energy levels, the fact that the rate of side effects remained unchanged or was even reduced makes the thermal protection of the epidermis apparent. If these higher energy levels lead to better results or not remains to be seen in further studies.

Critical Remarks

Aside from all these positive aspects, some critical remarks must be mentioned, as well. The use of a separate cooling machine causes prime and maintaining costs. The additional space required must be considered if the practice rooms are small. The problems in using the machine for facial treatments have already been discussed.

A study examining the effects of cold therapy in general and cold air therapy in detail on the result of treatments in dermatologic laser therapy has not yet been done. In the patients we treated, we did not observe any weakening of the effect of laser treatment. However, we noticed, for example, an alteration of the skin color caused by the cooling. This could possibly have an influence on treatment results in the treatment of port wine stains or hemangioma with the pulsed dye laser.

CONCLUSION

On the whole, we consider the analgesic use of cold air in dermatologic laser therapy to be a practicable, inexpensive, well-accepted—by both patients and doctors—and innovative alternative to previous cooling methods. However, it is necessary to carry out further prospective studies to find out whether better treatment results are achievable by using higher laser energy levels.

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