Cooling Devices in Laser therapy

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Abstract

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INTRODUCTION

The primary objective of laser therapy for patients with specific dermatoses is to maximise thermal damage to the target chromophores while minimising injury to the normal skin. However, in some cases, the threshold dose of incident laser beam for epidermal injury can be very close to the threshold for removal of the chromophore, thus questioning the administration of high doses. Dark-skinned patients are more susceptible to these problems on account of their increased epidermal melanin which competes as a significant chromophore for laser energy, leading to increased rate of pain, blistering, scarring and dyspigmentation. A method of dealing with this problem is to selectively cool the most superficial layers of the skin. It should be remembered that absorption of energy by melanin may lead to production of heat, but subsequent cooling of the epidermis shall prevent the elevation of temperature beyond the threshold temperature responsible for thermal injury.[1]

Cooling protects the epidermis, as a result of which we can deliver high fluence laser beams to the skin. This is referred to as the 'theory of spatial selectivity of the cooling'. To target the chromophores within blood vessel, stem cells, hair follicles, etc., a particular temperature should be reached. However that temperature will significantly damage the epidermal keratinocytes and melanocytes.[2] Cooling devices ensure the maintenance of a lower temperature at the epidermal level, yet reaching the required higher temperature at the target level. This is essential for the proper functioning of the laser beam.[3] Besides, cooling will diminish the amount of oedema, which often develops as a complication of laser procedure.[4] To be precise, the basic principle is to protect the superficial layers of the skin from collateral thermal damage. It can be achieved by cold air convection, contact cooling or cryogen spray (dynamic) cooling.[1,5,6,7,8]

Since cooling is a mainstay in patient safety and helps achieving better results, it has become mandatory to ensure the presence of a cooling device in the laser set-up. It is recommended to have a cart carrying cooling device (about 2.5 feet × 2.5 feet) in the laser room. External cooling devices like Zimmer contain a compressor, so it is essential to have a separate electric circuit for the same. Provision should also be made for ice cubes or ice packs.[9]

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METHODS OF COOLING

Cooling can be achieved before, during or after laser treatment, referred to as pre-cooling, parallel cooling and post-cooling, respectively.[10] On the basis of methods, cooling is of two types: contact cooling and non-contact cooling. Contact cooling can be achieved by active (copper, sapphire tips) or passive (ice or cold gels) methods. In contact cooling, tissue cooling is achieved by conduction of heat from the skin to the cooling device or substance placed directly onto the skin. In passive contact cooling, the device removes heat from the surface of the skin by energy transfer from the warm skin surface to a cold cooling agent by heating up the agent. However, in active contact cooling, the heat transposed to the device is actively removed by thermoelectric elements or flowing liquid cooling agents. In non-contact cooling, heat is actively removed from tissues through either evaporation or convection. Non-contact cooling can be achieved using cryogen spray or cold air. The various techniques are summarised in Table 1.

Method of cooling	Indication	Remarks
Contact skin cooling (active and passive)		
Active (copper, sapphire tips)	Indicated for anaesthesia in dermatosurgery. Highly effective in cases where longer pulse durations (>10 ms) are required.	Limiting factors include cost of the handpiece, expensive lasers and cooling agents and the requirement of a good technical expertise
Passive (ice cubes)	Indicated for prevention and/or reduction of inflammation following procedure. Used in the management of port-wine stains, telangiectasias and laser hair removal	Ice cube cooling is an easy method. Good option for bulk cooling. Disadvantages include a waiting period before the cooling starts, production of bubbles and melting water on the skin, posing a discomfort to the patient
Passive (aqueous gels)	Indicated for leg telangiectasias and port-wine stains	Not advised nowadays. Cannot provide prolonged cooling. Persistence of lesions is a major problem
Non-contact skin cooling		
Cryogen spray (liquid nitrogen)	Used in the past, not recommended now	Cryonecrosis can be a serious issue
Pulsed cryogen spray (dynamic cooling device)	Indicated for lasers with pulse durations <5 ms. Useful in laser hair removal and management of birthmarks	The inbuilt software makes this technique extremely user-friendly. The settings can be adjusted as per requirements. Since it provides uniform cooling, it is the method of choice now. Not effective when pulse length >10 ms
Forced refrigerated air	Used for port-wine stains, hair removal and tattoos	This method is compatible with most of the laser devices. The comfort level for the doctor and the patient is high. However, post-inflammatory hyperpigmentation has been reported

CONTACT SKIN COOLING

This is done using cooled sapphire metal or glass plates integrated into the handpiece, ice or chilled aqueous gels. It is in practice over decades, mainly used for anaesthesia in dermatosurgical procedures. To prevent or reduce swelling after a laser procedure, cooling with ice packs is advised on areas such as cheeks and neck until the pain and/or erythema disappears. The ice pack is ideally wrapped in a soft cloth and applied for 10-15 min/h for a maximum of 4 h until the burning sensation persists. Skin surface temperatures of 12°C can be achieved after 10 seconds of cooling. Application of ice packs may not be a very handy procedure, and it is best suited for large areas and in cases where sapphire tip cooling method is not available. It is mainly used in the treatment of port-wine stains, leg telangiectasia and hair removal. Ice cube cooling is a user-friendly method due to the simple process of placing an ice cube on the skin for several minutes. Besides, it is suitable for every laser device because it is either removed before laser therapy or therapy is performed through it (pre-cooling or parallel cooling). However, there are a few demerits of using ice cubes. The physician has to use both the hands to perform the therapy, and the cooling may take a few minutes before the laser irradiation can be started. The production of bubble-free ice cubes which is necessary for laser therapy may be a serious problem. In addition to the above problems, the patients might feel uncomfortable due to the melting water on their skin. Ice and chilled gels can be easily used to cool large areas of skin (bulk cooling), although it is messy in clinical practice.

It should be noted that application of aqueous gels is the least effective method. It involves the application of a sterilised, single use, hydrocolloid gel pad (non-adherent wound dressings) (e.g., ‘Vigilon’), which is pre-cooled in a household refrigerator and placed on the treatment area. The gel pad is cooled down to 8°C. After application, skin temperature rapidly decreases from 32°C to 23.5°C within 5 seconds but increases to 26.5°C after 10 seconds and to 27°C after 60 seconds, which is insufficient for laser treatment. Classical indications for this device are leg telangiectasias and port-wine stains. It can merely extract heat from the skin passively, which means that it is not capable of providing a prolonged cooling. Besides, the pressure and the low temperatures lead to blanching of the underlying blood vessels. As a result of this, there is diminished absorption of energy by haemoglobin, which often causes persistence of lesions.[11] There are a few disadvantages associated with this method. The skin lesion is covered by the pad, thus restricting the view of the treatment area and the gel pad leads to a defocused laser beam by scattering the light which reduces the effectiveness of the treatment. This method is rather discouraged these days.

Sapphire tip cooling or chill tip cooling is available in most of the lasers now. It offers a good method of cooling throughout the procedure (pre-, during- and post-cooling). It should be noted that the temperature of the tip is 4° before the shot, 0° during the shot and 4° again, after the shots are over.[10] It is most useful for treatment with longer pulse durations (>10 ms).[12] The sapphire tip contact cooling devices with thermoelectric elements are mostly integrated into the handpiece, those with liquid cooling agents are removable and attachable as required. The sapphire tip represents one of the most effective cooling devices. However, the cost of the handpiece, special laser, energy expenditures and cooling agents are limiting factors. Besides, the treatment needs to be performed blindly since the cooling device is non-transparent and directly integrated into the laser handpiece. In addition to being more efficient in heat extraction, active contact cooling offers manually controlled skin compression, diminishing the blood flow in superficial blood vessels; therefore, decreasing the oxyhaemoglobin which is an active chromophore. Furthermore, skin compression brings deeper targets like the hair follicles closer to the skin surface thus, maximising the absorption of the laser energy, so less fluence can be used to heat these targets. However, these devices require frequent cleaning after every 5–10 pulses to remove debris and disinfection of the tip between patients is mandatory to prevent skin infections.

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NON-CONTACT SKIN COOLING

Cryogen spray

The first device for spray cooling was liquid nitrogen spray used at a distance of 20 cm from skin. The skin is cooled down by evaporation of the droplets on the surface. However, unsupervised use may lead to cryonecrosis and overuse may cause suffocation in the perioral and nostril area.

A newer cooling device used for selective cooling of the epidermis is the dynamic cooling device (DCD) which is either an add-on device or integrated within the laser, where the cooling agent is pulsed cryogen spray. The inbuilt software allows the user to set the DCD spray and delay settings. The cryogen is sprayed to the skin just before the laser pulse which leads to cooling of the skin.[2] This device sprays the skin with a short and consistent spurt of liquid cryogen immediately before the application of laser. A cryogen, usually the non-toxic 1,1,1,2-tetrafluoroethane also known as R-134a (boiling point: −26.2°C) is delivered in programmed pulses of not more than (10–100 ms) duration with an equal time delay between the cryogen pulse and the laser pulse. Liquid carbon dioxide has been investigated in trials as an alternative to R-134a.

The technique results in the reduction of skin temperature to 5°C and −9°C. This is to be noted that the temperature reduction achieved is twice as low as temperatures attained by the technique of contact cooling. It is particularly useful for pulse durations shorter than 5 ms. Another significant advantage of DCD is that it causes selective cooling. The temperature reductions are localised to approximately 200 μm of superficial tissue. Therefore, with the help of DCD, we can safely use high fluences with a good margin of safety. Besides, the patient discomfort is minimal. This is particularly useful in laser hair removal where there is a need for utilising high fluences. The reduction in pain is significant in patients with darker skin types, which is relevant in our setting. Besides, it has been documented that when the DCD spurt duration is increased in laser hair removal, the pain reduction achieved is significant, particularly in Type V patients.[13] DCD is also found to be helpful in 585-nm pulsed dye laser treatment of port-wine stain birthmarks.[14]

The biggest advantage of using this device is that it coordinates cryogen spray and laser pulse in accordance with operator specifications. It delivers uniform cooling with each pulse and every treatment. However, in contact cooling, the temperature reduction varies according to the pressure applied by the operator.[14,15] The spurt is however disturbing in the perioral, periorbital or nostril regions and rarely, it might lead to suffocation. The hissing sound of the spurt may scare children, but this can be easily managed. One important disadvantage is that the effectiveness of DCD decreases with pulse lengths over 10 msec. In such cases, parallel cooling methods such as cold air or contact cooling are needed during the laser treatment. Besides, fluoroethane is a polluting agent and can damage the ozone layer, a point which should be kept in mind in the era of global warming and environmental concerns.

Cryogen sprays are useful when working with low pulse width lasers. Spray coolants are used both for anaesthesia and cryosurgery.[16] Cryogen spray cooling (CSC) is effective in protecting the epidermis and papillary dermis, while achieving deep tissue photocoagulation during Nd: YAG laser irradiation.[17] CSC provides a huge safety margin in terms of prevention of epidermal injury. This technique promotes rapid and spatially selective cooling of the epidermis without affecting the target chromophore temperature. Spraying human skin with cryogen leads to a reduction of surface temperature to −30°C, but the epidermal basal layer temperature does not drop below 0°C. The cryogen spurt duration and the delay between spurt termination and the laser pulse can be controlled electronically, which results in reproducible cooling with predictable spatial selectivity.

DCD has also shown promising results in the treatment of inflammatory acne lesions with high fluence infrared 1450 nm diode laser beams (14 J/cm^2).[18] Recently, an innovative

CO_2 laser/radiofrequency device successfully utilised dynamic cooling system with a jet of cool air to reduce patient discomfort.[19]

For superficial chromophores (blood vessels in port-wine stain and dermal collagen in non-ablative skin rejuvenation), we need a large temperature gradient at the skin surface which can be achieved by CSC using short cryogen spurts and delay times. For deeper chromophores (hair follicles) prolonged cooling times can be allowed.[20] However, arcuate-shaped hyperpigmentation has been reported with cryogen skin cooling.[21]

Zimmer (forced refrigerated air)

Unlike other cooling methods (contact cooling, cryogen spray, ice packs, etc.) Zimmer can cool the epidermis before, during and after laser energy has been applied, that too without interfering with the laser beam. The device minimises pain and thermal injury during laser and dermatological treatments and for temporary topical anaesthetic relief for injections. It delivers chilled air throughout the procedure and ensures a high level of patient comfort. By convection cooling, the skin surface temperature decreases to approximately 15°C in 8 s. Indications are port-wine stains and other vascular lesions, hair removal and tattoos. Advantages are the compatibility with every laser device, unrestricted view of the lesion, as well as the high comfort level for both patient and the physician. Demerits include a feeling of suffocation and a risk of frostbite in case of exaggerated cooling. The latest generation of non-contact cooling devices utilises convection method of cooling by delivering a continuous flow of chilled air at −30°C at adjustable flow rates, that too without interfering with the laser beam. This method was first evaluated by Raulin *et al*. in 2000 and found to be safe and inexpensive.[22] In fact, this method is also not free of any adverse effects. Increased incidence of post-inflammatory hyperpigmentation has been demonstrated with continuous cold air cooling.[23]

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CONCLUSION

Cooling is now an integral part in the rapidly evolving discipline of laser dermatologic surgery. There are various methods to achieve the same, which if chosen properly can minimise the temperature-induced epidermal damage, apart from acting on the target chromophore for which the particular laser is being employed.[24]

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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