Dynamic Cooling for Laser Photocoagulation : *In Vivo* & *Ex Vivo* Studies

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Abstract

When a cryogen spurt is applied to the skin surface for an appropriately short period of time (on the order of milliseconds), the cooling remains localized in the epidermis, while leaving the temperature of the deeper vessels of hemangiomas unchanged. The purpose of our study is to examine the effectiveness of dynamic cooling in protecting superficial tissue structures during continuous Nd:YAG laser illumination of in vivo and ex vivo models for hemangiomas. The bovine liver and highly vascularized chicken combs were selected as the models for hemangiomas. The Nd:YAG laser illumination ranged from 20 to 60 W. A feedback system utilizing infrared radiometry monitored the surface temperature and controlled delivery time of the cryogen spurt. When the surface temperature during laser illumination reached 36-45℃, a 30-100 m/sec cryogen spurt was delivered. Animals were observed 1 hour to 14 days following each experiment. Gross and histological analyses were performed. Nd:YAG laser illumination resulted in deep (up to 1.0 ± 0.2 mm) tissue photocoagulation, while dynamic cooling preserved the overlying epidermis and papillary dermis. In conclusion, dynamic cooling is effective in protecting the epidermis and papillary dermis, while achieving deep tissue photocoagulation during Nd:YAG laser illumination. This procedure is effective for the treatment of hemangioma in the humans.

Keywords: Dynamic cooling, Hemangiomas, Chicken combs, Nd:YAG laser.

Introduction

Hemangiomas are benign vascular tumors that occur in up to 10% of children during the first year of life.[1] They differ from vascular malformations, such as port wine stains, in that they are not conglomerates of dilated vessels, but consist of plump, proliferating endothelial cells that may infiltrate the entire dermis, and extend several millimeters in depth.[2] Due to psychological and social factors, as well as functional impairments such as difficulty in eating, visual and breathing obstructions, early treatment is indicated.[3,4]

Apfelberg et al [5] and Hobby [6] first reported use of the argon laser (λ =488 and 514 nm) for treatment of hemangiomas in early infancy. However, due to relatively shallow penetration of the argon laser into the tumor, therapeutic effect is restricted to superficial lesions. For thick hemangiomas, the Nd:YAG laser has been shown effective due to deep penetration of 1064 nm light.[7-9] A particularly problematic complication that can occur when using lasers is thermally induced damage to the epidermis and papillary dermis.[10]

Cooling of skin, using ice or chilled water in conjunction with laser illumination, has been used to prevent epidermal thermal injury.[11-13] However, computed temperature distributions following sustained cooling (e.g., 15-60 s) by 0℃ ice at the skin surface show that in addition to cooling the epidermis, temperature of blood vessels is also reduced.[14] Thermal energy removed to protect the epidermis from injury will be offset by additional laser energy required to heat the blood vessels to a sufficiently high temperature for destruction.

When a cryogen is sprayed on skin surface, the epidermis can be cooled selectively.[15-17] For an appropriately short cryogen spurt duration (on the order of tens of milliseconds), the spatial distribution of cooling remains localized in the epidermis, while leaving the temperature of deeper vessels unchanged.

In this paper, we present: (1) a theory to predict temperature distributions, and thicknesses of protected and photocoagulated tissue in response to repetitive cryogen spurts during continuous Nd:YAG laser illumination; (2) experimental results of a study performed *in vivo* and a study of *ex vivo* on utilizing highly vasculized bovine liver tissue

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