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Optical coherence tomography analysis of hydrofluoric acid decontamination of human cornea by mannitol solution☆

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ABSTRACT

Purpose: To evaluate the efficacy of mannitol solution as a decontamination agent on the chemical burn of the human corneas.
Methods: Eight donor corneas from an eye bank were exposed to 25 μl of 2.5% hydrofluoric acid (HF) solution on a filter paper for 20 s. Three eyes were rinsed with 1000 ml of mannitol 20% for 15 min immediately after removal of the filter paper, 3 other were rinsed with sodium chloride (NaCl) 0.9% (1000 ml for 15 min) and two eyes were not rinsed. Microstructural changes were monitored in the time domain by optical coherence tomography (OCT) imaging for 75 min.
Results: NaCl reduced the penetration depth to approximately half the thickness of the cornea at 15 min; scattering within the anterior cornea was higher than that for the unrinsed eye. With mannitol, no increased scattering was observed in the posterior part of the corneal stroma within a time period of 1 h after rinsing. OCT images revealed low-scattering intensity within the anterior stroma at the end of the rinsing period.
Conclusion: In eye bank human corneas, mannitol proved to be an efficient agent to decontaminate HF burn.

1. Introduction

Chemical burns to the eye may account from 7.7% up to 26.5% of all ocular trauma [1–7]. Although most injuries are trivial and self-limited, a number of eyes develop permanent visual impairment and years of visual rehabilitation [8]. The majority of victims of chemical burns are young male and the exposure occurs as the result of occupational activity, whereas assault and chemical warfare are becoming common [6,9,10]. Alkali burns are more frequent than acids; they penetrate more rapidly and are more deleterious for eye tissues [11].

Immediate care requires copious irrigation with liquid solutions to dilute and remove the chemical agent, and to neutralize it by buffer capacity in order to minimize the chemical effects. A number of different solutions exist for this purpose, *e.g.*, sodium chloride (NaCl) 0.9%, Ringer lactate, balanced salt solution, phosphate buffer, tap water, and diphoterine to name a few [12]. All currently used irrigation solutions fulfill the cleansing requirements; however, the

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buffer capacity and osmolarity may vary. Whereas some are readily available in different parts of the world, others are not found everywhere given its high cost.

Mannitol, chemically 1,2,3,4,5,6-hexanehexol ($C_6H_8(OH)_6$), is a polyol widely used in the food and pharmaceutical industries because of its unique functional properties [13]. It is used, on clinical grounds, primarily for its osmotic diuretic properties to reduce cerebral edema after head trauma, to reduce intraocular pressure in acute angle closure glaucoma and to facilitate clearance of mucus in patients with bronchiectasis. It is one of the most abundant energy and carbon storage molecules in nature, produced by a number of organisms and plants.

The purpose of this study was to evaluate the efficacy of mannitol 20% solution as a decontamination agent on the chemical burn of the human corneas. We hypothesize that mannitol as an osmotic agent can mobilize the causative chemical out of the corneal stroma down the concentration gradient.

2. Material and methods

2.1. *In vitro eye irritation model*

Enucleated human eyes from Eye Bank donors discarded for corneal transplantation were used for the *in vitro* experiment. The Institution Ethics Committee was consulted about the ethical acceptability of the proposals involving research on human tissue and approved the study according to local and international regulations. As a sample of human biological material, the tissue was treated as donation and all procedures involving these samples were conducted with respect and transparency. The tissue was stored in tissue culture medium (Optisol GS, Bausch & Lomb Inc., Rochester, NY, USA) at 2–6 °C (hypothermic storage method) and rinsed with saline solution immediately prior to the procedure. It was then placed in a Barron artificial anterior chamber (Katena Products, Inc., Denville, NJ, USA) to simulate the anatomical position of the cornea in the eyeball. The device was filled with balanced salt solution (Alcon, Fort Worth, TX, USA), the intraocular pressure was maintained between 10 and 18 mmHg and the cornea epithelium was removed with the Clear Cut HP crescent knife (Alcon, Fort Worth, TX, USA). This was done in order to augment tissue penetration within the cornea stroma by chemical agent to get a possibly even deeper effect.

The eye irritating test followed the technique described by Spöler et al. [14]. In brief, a standardized 7.75 mm circle filter paper was soaked with 2.5% hydrofluoric acid (HF), 25 ml (1.25 mol/l) solution and placed on the center of the cornea for 20 s at baseline (time point 0 s) allowing a continuous film of the corrosive to be attached to the surface of the cornea. After removal of the filter paper from the cornea, the tissue was rinsed with 1000 ml of mannitol 20% for 15 min (three eyes) or 1000 ml of NaCl 0.9% for 15 min (three eyes) and two eyes were not rinsed (controls). Rinsing was started at a fixed time point (25 s after burning) and lasted for 15 min at a stable flow of 66.7 ml/min, using an intravenous infusion system connected to a precision pump (Mediflux DL 200, Romed Industria de Equipamentos Medicos Ltda, Brazil). The open-ended flow was targeted directly over the center of the cornea.

2.2. *Anterior segment optical coherence tomography imaging*

Anterior segment optical coherence tomography (ASOCT) images were achieved using the Visante ASOCT (Carl Zeiss Meditec Inc., California, USA). It generates *in vivo*, cross-sectional scans of the tissue to assist in analyzing the cornea, anterior chamber angle, iris and lens. ASOCT uses a 1310 nm wavelength superluminescent light-emitting diode as the light source, to capture data at a rate of 256 A scans per line sampling, and 0.125 s per line acquisition time. The ASOCT acquires multiple A-scans and aligns them to construct 2-dimensional images.

The Barron artificial anterior chamber containing the tissues was attached to a head model used in training cataract surgery. For Visante ASOCT, the model head was positioned as for a real patient with a headrest (Fig. 1). To acquire images of the cornea, the focus of an internal-fixation target was adjusted accordingly. A real-time charge-coupled device displaying the position of the scan and the position of the eye was available to enable scan alignment. ASOCT scans were acquired with the cornea scan protocol (3 mm deep by 10 mm wide, with 512 A-scans per line sampling); one single horizontal scan line bisecting the pupil was selected as the image. Images were taken at baseline (time point 0), then at 15, 30, 45, 60 and 75 min after HF application. Images were then qualitatively analyzed as to the ASOCT signal of tissue amplitude. The corneal thickness was used as a surrogate for tissue edema. The images were compared among the groups for possible differences.

Fig. 1 – Prototype of the model head positioned on the OCT head rest.

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