Caustic Soda and H_2SO_4 decontamination of the cornea ex vivo demonstrated via OCT.

Spöler F (1), Foerst M (1), Frentz MF (2), Kurz H (1), Schrage NF (3)

(1) Institute of Semiconductor Electronics at the RWTH-Aachen University, Germany; (2) Aachen Center of Technologytransfer in Ophthalmology (ACTO), Aachen, Germany; (3) Cologne Medical Centers Dept. of Ophthalmology Merheim Hospital, Germany

Abstract

Objective: Efficacy of rinsing substances in case of caustic soda burn of the eye is up to now estimated to be similar for water and amphoteric solutions. Methods: By means of high resolution OCT we are able to demonstrate penetration of caustic soda (2 molar) and H2SO4 (1 molar) into the excised rabbit's animal cornea derived from slaughter house. Thus our interest was to demonstrate corneal decontamination with different two types of rinsing solutions recommended for this purpose: saline solution and diphoterine. Results: We found penetration of both substances for untreated corneal burns of 20 sec duration. Rinsing with saline solution showed deep penetration of the caustic substance and dilution compared to non rinsed corneas. In case of diphoterine rinsing for 15 min we found stop of the penetration in the middle of the cornea and no penetration into deep stroma for acid and alkali until 60 minutes of observation whereas in saline solution rinsing the deep stroma was affected after rinsing therapy stopped. Conclusion: There are considerable differences in quality and quantity of decontamination achieved by means of amphoteric hyperosmolar rinsing of the burnt cornea with diphoterine compared to saline. By this experiment we are able to give indication of enlargment of therapeutical possibilities in case of caustic damage of the eye by use of appropriate decontamination systems.

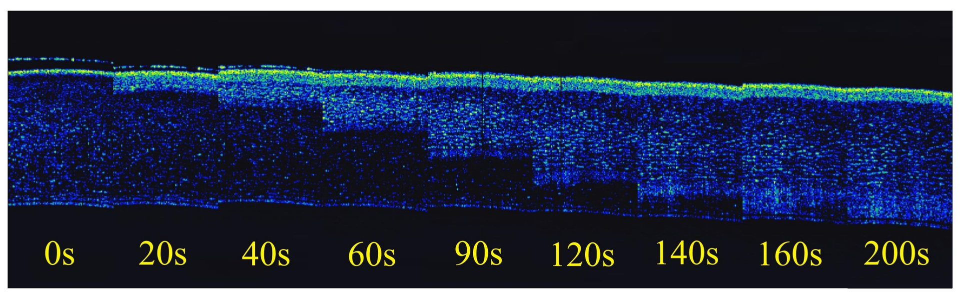

Fig. 1: High resolution OCT image of an untreated rabbit cornea *ex vivo* burned with 25% H_2SO_4
Compared to that the tissue damage, shown in the following images caused by chemical interaction of the cornea with 1 mol/l NaOH is obviously faster, total penetration occurred at approx. 60 sec., the increase in light scattering is likewise more prominent.

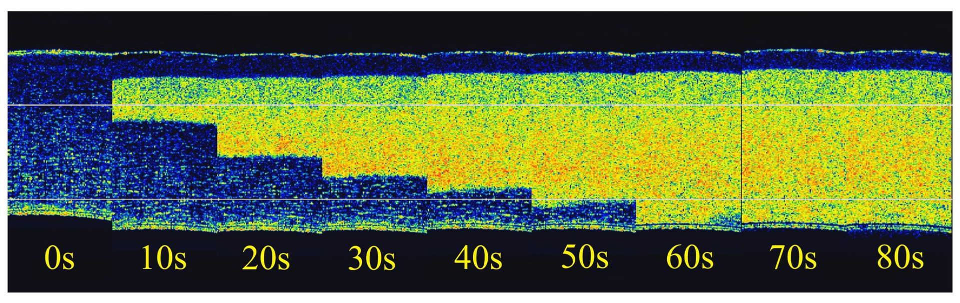

Fig. 2: High resolution OCT image of an untreated rabbit cornea *ex vivo* burned with 1 mol/l NaOH

Materials and Methods:

A. OCT System

For the high resolution OCT system employed in this study, a Ti:sapphire laser oscillator (GigaJet 20, GigaOptics GmbH, Konstanz, Germany) centred at 800 nm was used as a low-coherence light source. Additional dispersion management within the laser cavity was deployed to optimize its coherence length to 3.6 µm in air. The light source was coupled in the fiber based interferometer of a commercially available OCT system (Sirius 713, Heidelberg Engineering GmbH, Lübeck, Germany). The latter was modified to support the superior axial resolution specified by the coherence length of the Ti:sapphire oscillator. The A-scan rate was 50 Hz and the number of data points for each A-line data acquisition was 512. The axial and lateral resolutions were 3 and 8 µm, respectively. (1)

B. Ex Vivo Eye Irritation Test (EVEIT)

In this study, enucleated white rabbit eyes were used. Rabbit heads were obtained from abattoir. The globes were stored at 4°C in a humid atmosphere. Only clear corneas without any epithelial defects were processed within 12 hours using the following protocol: (2)

Acid burns: Eyes were burnt with 500µl of 25% sulphuric acid splashed on top of the cornea using a Eppendorf 1000µl pipette. The rinsing of the eyes was withheld for 20sec.

In each group we measured three eyes from different animals.

One group was not treated, the others were, rinsed with:

Diphoterine, Prevor (Inc.), with a flow rate of 500ml/ 3min (recommended by Prevor)

0.9% saline solution used for hydroxide burn, Delta select, Germany with a flow rate of 2.5 Litre/ 15min. 0.9% saline solution used for acid burn, Aquette Versol, France with a flow rate of 2.5 Litre/ 15min. An intravenous infusion system (Braun-Melsungen, Melsungen, Germany) connected to a bag of diphoterine or to a reservoir containing the needed amount of the other solution respectively, then linked to a precision pump to ensure a constant flow, was placed open ended directly over the middle of the cornea.

Burns with sodium hydroxide: The experiments were performed in the same way described as above using a 1 mol/l sodium hydroxide solution as corrosive agent.

C. Measurement

OCT images were composed of up to 1000 A-scans with a lateral step size of 6µm for static tissue examination. Images with a width of 600 µm (100 A-scans per image) were taken at a rate of 30 frames per minute for time resolved measurements.

OCT measurements were performed at the centre of the cornea. For comparison, the cornea of each eye was imaged directly before application of the chemicals.

Results:

Rinsing with saline and diphoterine altered the diffusion of acid and alkali into the anterior chamber of the rabbit cornea considerably. In OCT images the depth of diffusion was diminished clearly with diphoterine rinsing of 0.5 l during 3 min. The rinsing with saline used a 5 fold amount of fluid and 5 times longer as recommended by the FDA.

In OCT Images the depth limitation of burns is very clearly identifiable in images 5 and 6 for alkali and less pronounced as being expected from Fig. 1.

The pH change without rinsing is high with pH after 60 min of 3.83 for acid and of 9.23 for alkali. Both solutions arrive to modify the internal pH within limits of 7,6 to 8.3 after 60 min.

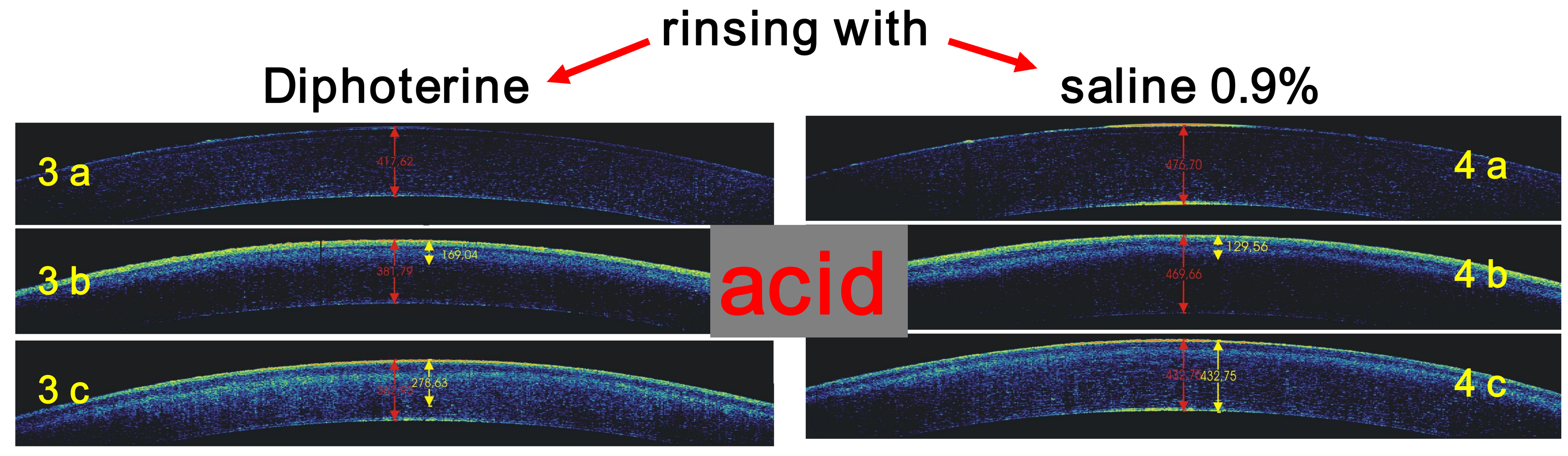

Fig. 3: OCT image of a cornea exposed to H2SO4 25% burn for 20 sec. then:
rinsing with **Diphoterine** (0.5l/3min)
3 a: untreated rabbit cornea ex vivo
3 b: after 15min after rinsed burn
3 c: 60min after rinsed burn

Fig. 4: OCT image of a cornea exposed to H2SO4 25% burn for 20 sec. then:
rinsing with **saline 0.9%** 2,5 l / 15 min
4 a: untreated rabbit cornea ex vivo
4 b: after 15min after rinsed burn
4 c: 60min after rinsed burn

Table 1
H2SO4 burns: pH change in anterior chamber liquid after 60 min

	Without rinsing	NaCl 0.9%	Diphoterine
cornea 1	3,09	8,23	7,73
cornea 2	4,18	7,87	7,66
cornea 3	4,19	7,66	7,56
Mean	**3,82**	**7,92**	**7,65**
Stdev	0,52	0,23	0,069

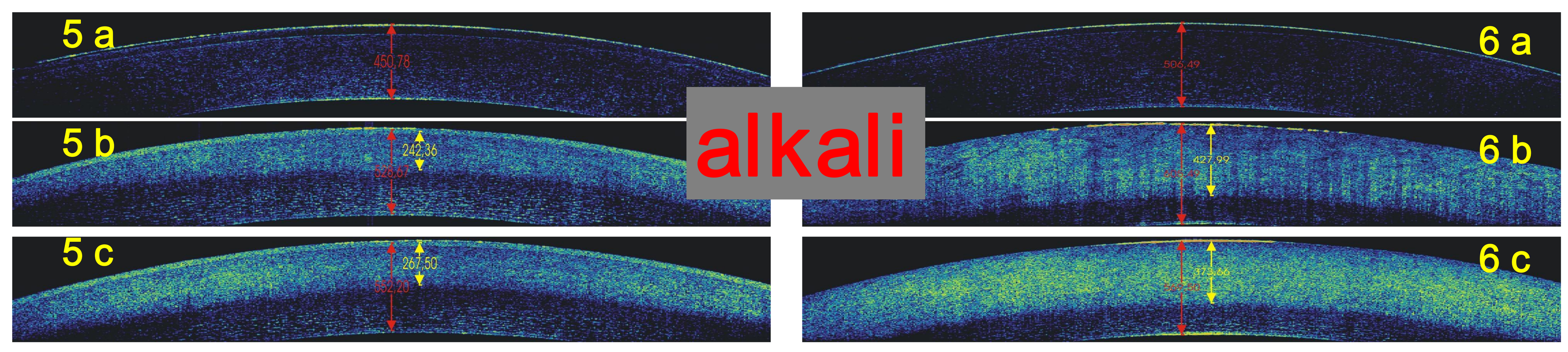

Fig. 5: OCT image of a cornea exposed to 1 mol NaOH burn for 20 sec. then:
rinsing with **Diphoterine** (0.5l/3min)
5 a: untreated rabbit cornea ex vivo
5 b: after 15min after rinsed burn
5 c: 60min after rinsed burn

Fig. 6: OCT image of a cornea exposed to 1 mol NaOH burn for 20 sec. then:
rinsing with **saline 0.9%** 2,5 l / 15 min
6 a: untreated rabbit cornea ex vivo
6 b: after 15min after rinsed burn
6 c: 60min after rinsed burn

Table 2:
NaOH burns: pH change in anterior chamber liquid after 60 min

	Without rinsing	NaCl 0.9%	Diphoterine
cornea 1	9,25	8,05	8,20
cornea 2	9,21	8,30	8,39
cornea 3	9,23	8,44	8,30
Mean	**9,23**	**8,263**	**8,30**
Stdev	0,016	0,16	0,078

Discussion:

Corneal rinsing after acid and alkali burn is essential. Waiting too long will result in severe alteration of the cornea with non healing sequela (2). Therefore immediate within one minute action is required. We focussed on effectiveness of currently distributed first aid rinsing solutions.

There is no doubt that there are differences in effectiveness of those solutions. Saline solution is recommended but high volumes and times are required. There are more efficient rinsing solutions beneath the available fluids (3,4). We can see differences by means of depth limiting with lower volumes of rinsing in Fig. 3-6.

We have clear indication that as lower the affected corneal stroma is touched by the chemical process of burn, and as faster this is reversed the clinical damage will be less.

Therefore we recommend the most efficient solutions being available in the market for first aid rinsing especially in case of unknown corrosives and in delayed rinsing.

Literature:

(1) Spöler F, Först M, Kurz H, Frentz M, Schrage NF. Dynamic analysis of chemical eye burns using high-resolution optical coherence tomography. J Biomed Opt. 2007 Jul-Aug;12(4):041203.

(2) Rihawi S, Frentz M, Becker J, Reim M, Schrage NF.: The consequences of delayed intervention when treating chemical eye burns. Graefes Arch Clin Exp Ophthalmol. 2007 Oct;245(10):1507-13.

(3) Rihawi S, Frentz M, Schrage NF.:Emergency treatment of eye burns: which rinsing solution should we choose? Graefes Arch Clin Exp Ophthalmol. 2006 Jul;244(7):845-54.

(4) Kompa S, Redbrake C, Hilgers C, Wüstemeyer H, Schrage N, Remky A. Effect of different irrigating solutions on aqueous humour pH changes, intraocular pressure and histological findings after induced alkali burns. Acta Ophthalmol Scand. 2005 Aug;83(4):467-70.

(5) Schrage N, Wuestemeyer H, Langefeld S. Do different osmolar solutions change the epithelial surface of the healthy rabbit cornea? Graefes Arch Clin Exp Ophthalmol. 2004 Aug;242(8):668-73.