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CASE REPORT

Thermodynamic measurement after cooling the cornea with intact epithelium and lid manipulation

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Abstract
Purpose: To characterize the rate of change of ocular surface temperature (OST) under lid manipulation after cooling the intact cornea with balanced salt solution (BSS).
Methods: In a patient for refractive surgery, prior to the ablation, the temperature of the cornea was continuously recorded with a high speed infrared (350 Hz) camera. Two millilitre of chilled BSS with a temperature of 8.6 °Celsius (°C) was instilled for about 3 s. Using exponential functions, the three contributions have been determined, subjacent corneal layers, environment, and chilled BSS.
Results: The mean temperature of the cornea preoperatively was 34.5 °C. After applying the chilled BSS the temperature decreased about 14 °C down to an OST of 20 °C and the time needed afterwards to get the normal (OST) temperature of about 30 °C was 40 s. Due to the inserted speculum and missing blink, OST did not reach the original OST of 34.5 °C and faded at about 32.5 °C. According to our best fitted model, absolute value of each contributing component was 31.4 °C (subjacent corneal layers), 26.8 °C (environment) and 8.6 °C (BSS).
Conclusions: Applying chilled BSS to the cornea quickly reduces the temperature of the cornea with a thermal relaxation time of 3 s and a amplitude decrease of 8.6 °C. This together with a relaxation time of 7s for subjacent corneal layers, and 184 s for environment after instillation of BSS combined with a well-controlled environment provides a period of 40 s of corneal temperature below baseline, which may be of clinical benefit when applying chilled BSS immediately before or immediately after ablation.

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PALABRAS CLAVE
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Monitorización termodinámica tras el enfriamiento de la córnea con el epitelio intacto y manipulación del párpado

Resumen
Objetivo: Describir el índice de cambio de la temperatura de la superficie ocular (OST) con manipulación del párpado tras el enfriamiento de la córnea intacta con solución salina balanceada (BSS).
Métodos: En un paciente sometido a cirugía refractiva, con anterioridad a la ablación, registramos continuamente la temperatura de la córnea con una cámara de infrarrojos de alta velocidad (350 Hz). Instilamos durante alrededor de 3 s dos mililitros de BSS a una temperatura de 8,6° Celsius (°C). Utilizando funciones exponenciales, se determinaron los valores de las tres contribuciones: capas corneales subyacentes, ambiente, y BSS fría).
Resultados: Preoperatoriamente, la temperatura media de la córnea fue de 34,5 °C. Tras aplicar la BSS fría, la temperatura descendió alrededor de 14 °C hasta alcanzar una OST de 20 °C, precisándose un tiempo posterior de 40 segundos para alcanzar la OST normal de unos 30 °C. Debido a la inserción del espéculo y a la ausencia de parpadeo, la OST no alcanzó el valor original de 34,5 °C, permaneciendo en unos 32,5 °C. De acuerdo a nuestro modelo de mejor ajuste, el valor absoluto de cada componente participante fue de 31,4 °C (capas corneales subyacentes), 26,8 °C (ambiente) y 8,6 °C (BSS).
Conclusiones: La aplicación de BSS fría a la córnea reduce rápidamente la temperatura de la misma, con un tiempo de relajación térmica de 3 s y un descenso de amplitud de 8,6 °C. Estos hallazgos, junto con tiempos de relajación de 7 s para las capas corneales subyacentes, y de 184 s para el ambiente tras la instilación de BSS, junto con un entorno bien controlado, proporciona unos 40 s de temperatura corneal inferior a la basal, lo que puede suponer un beneficio clínico cuando se aplica BSS fría inmediatamente antes o inmediatamente después de la ablación.

Temperature of the cornea is a function of the equilibrium of heat transfer between the cornea and the surrounding tissues or atmosphere. Therefore, any change that affects the heat loss or gain may affect the corneal temperature.[1,3,4] The normal corneal surface temperature has been reported to range from 32.9 to 36 °C.[5] Under LASIK settings, when lid speculum has been applied, the dynamic heat balance shifts towards heat loss from the cornea to the surrounding cooler air and baseline corneal temperature (prior to initiating surgery) decreases to approximately 31 °C. When excimer laser is initiated, every single pulse adds heat to the cornea and contributes to the marginal increase in the local corneal temperature.[6] Laser refractive surgery is based on the sequential delivery of multiple laser pulses, with each pulse ablating a small amount of corneal tissue and in the process causing a marginal increase in the local corneal temperature around the laser spot. In general, Excimer laser treatments may cause a significant increase in corneal temperature mainly due to the heat generation exceeding the heat dissipation during the laser treatment.[6]

These thermal effects may cause tissue damage and potentially reduce the predictability of the refractive outcomes.[1] Usually cold balanced salt solution (BSS) is applied after the ablation procedure to reduce the postoperative increment of the ocular surface temperature (OST) which leads to several problems which by definition can be later introduced as haze and scattering. It is really important to use either a laser technology like the flying spot and spot size,[4,5] or other ways to reduce the temperature with cold fluid prior or after the ablation. Our motivation is to characterize the response in OST with the use of BSS, and explore a potential method to reduce OST below the baseline temperature prior to ablation, to compensate the heat generation during the laser treatment.

Methods

Our objective was to characterize the rate of change of the temperature of the corneal surface after cooling the cornea with balanced salt solution (BSS). We used cooled balanced salt solution (BSS) from the refrigerator with a temperature of 8.6 °C and 2 ml of this solution was applied on an eye prior to excimer laser refractive surgery. For measuring the cornea temperature, we used a high frequency infrared camera, VarioCAM® HR (Jena, Germany), which takes 350 measurements per second. The camera provides thermal images with a resolution of 640×480 pixel and measures the ocular surface temperature (OST) within the spectral range of 7.5–14 μm with a resolution of ±0.08 K using a micro bolometer-FPA detector. The typical error of a similar set up used in one of our previous study was approximately ±0.5°,[2] but we did not measure the typical error with this set up although this error was expected to be lesser than ±0.5°. An elliptical region of interest of size ∼9 mm was positioned manually such that it covered the