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Infrared thermography on ocular surface temperature: A review

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ABSTRACT

Body temperature is a good indicator of human health. Thermal imaging system (thermography) is a non-invasive imaging procedure used to record the thermal patterns using Infrared (IR) camera. It provides visual and qualitative documentation of temperature changes in the vascular tissues, and is beginning to play an important role in the field of ophthalmology. This paper deals with the working principle, use and advantages of IR thermography in the field of ophthalmology. Different algorithms to acquire the ocular surface temperature (OST), that can be used for the diagnosis of ocular diseases are discussed.

Contents

1. Introduction

Temperature has been used to investigate the physiological and pathological changes in human body since 400 B.C. using different techniques. Galileo invented the thermoscope in 17th century and then it evolved into modern mercury-in-glass thermometer, radiometers for middle-ear temperature and disposable sterile thermocouple which is widely used these days. Liquid crystals such as cholesteric esters, found in 1877 had the property of changing color with temperatures, were used to display the distribution of temperature on skin topographically. Such detectors were inexpensive, had relatively short life span and may alter surface temperature due to large area of contact. Schlerian photography

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enabled researchers to see the convection currents surrounding the body, but is limited to the study of heat transfer around insulated clothing [1]. Except Schlerian photography, most of the methods developed in past had limitations of either requiring contact with subject or incapable of displaying distribution of temperature.

Infrared (IR) thermography is a non-contact and non-intrusive temperature measuring technique, with an advantage of no alteration in the surface temperature and capable of displaying real-time surface temperature distribution. It was first introduced by Lawson in 1956 to modern medicine and discovered the association of elevated skin temperature with breast carcinoma [2] and later investigated the feasibility and potential of using IR thermography as a tool to study breast lesions [3]. This technology has revolutionized the field of temperature measurement in the last 50 years and is widely employed nowadays.

In the field of thermo-fluid dynamics IR thermography was applied to measure convective heat fluxes, and for the comprehension of fluid dynamics phenomena on the flow field behaviour over complicated body shapes [4]. The process of ice nucleation and ice propagation in flowers of fruit trees and other frost sensitive plants were studied using IR thermography in agriculture [5]. It was used for the measurement of size, depth and thermal resistance of materials and components [4], and also for environmental monitoring such as sea, river pollution, information about indoor climate [6], inspection of plants and assistance in the reduction of maintenance cost of mechanical equipment [4]. In polygraph testing, a standard security procedure favoured by US government, IR thermography was applied to perform facial image analysis [7].

In medical field, IR thermography has been used to assist in decision making in open heart surgery due to its ability to provide real-time information [8]. It was also used for the management of neuropathic pain [9,10] and the assessment of patient response to chiropractic care by measuring the temperature gradient in clinical setting [11]. So far, IR system has been used to diagnose breast cancer [12,13], rheumatism [1], skin lesion [14], fever [15], impotence [16] and thyroid gland disease [17]. Currently, it has been applied to ophthalmology to diagnose eye diseases [18].

The ocular anterior anatomy and physiology nowadays can be studied using a number of ophthalmic imaging techniques: slit lamp biomicroscopy, confocal microscopy, corneal topography, optical coherence tomography, computerized tomography, ultrasonic biomicroscopy, and magnetic resonance imaging. These techniques are capable of providing accurate description of anatomical features and help to diagnose the ocular diseases better.

Infrared thermography is renowned for its ability to detect the pathological and physiological changes in the eye which are obscured or unreachable under anatomical examination. A typical ocular thermogram of normal eye is shown in Fig. 1. It has been used to study the inflammation of human lacrimal drainage system [19], dry eye [20], carotid artery stenosis [21], glaucoma [22], unilateral exophthalmos [23], Tolosa–Hunt syndrome [24], and ophthalmic post-herpetic neuralgia [25]. It was also used to diagnose retinoblastoma in children [26] and vascular neuritis [27] of the optic nerve. The OST can be used in the diagnosis of different ocular diseases.

The invasive methods of measuring eye temperature require direct contact with human cornea. Among the invasive measuring techniques, needle probe was mainly employed. During measurement, needle probe acts as a cooling fin when inserted into the eye [28] and error inevitably exists if the penetration depth is below 40 mm. Topical anesthesia is often required, and this instilled solution often lowers OST. In addition, the penetration of needle can be traumatic, which often induces further blood flow in eye and thus alters OST. Hence, this invasive method, is not comfortable to the subjects and the reported discrepancies in temperature in some cases can be up to 6 °C [28].

Infrared thermometry and thermography can measure OST without causing trauma on subjects. However, they are unable to measure the intraocular temperature. These techniques remotely measure the emitted IR radiation and acquire temperature data of a specific surface. During measurement there will be no alteration in the surface temperature and also the data collected is of higher precision. With this technology researchers are able to study OST with greater ease, and accuracy.

2. The principles of infrared thermography on human eye

In general, IR thermography refers to the recording of temperature, or the distribution of temperature utilizing infrared radiation emitted from a body surface, forming an image called thermogram. The 2-D thermogram presents the distribution of temperature distinctly unlike IR thermometry, which gives a single temperature value. IR thermography also differs with IR photography, where in the latter records infrared radiation reflected back from objects in the presence of some external infrared energy sources. The

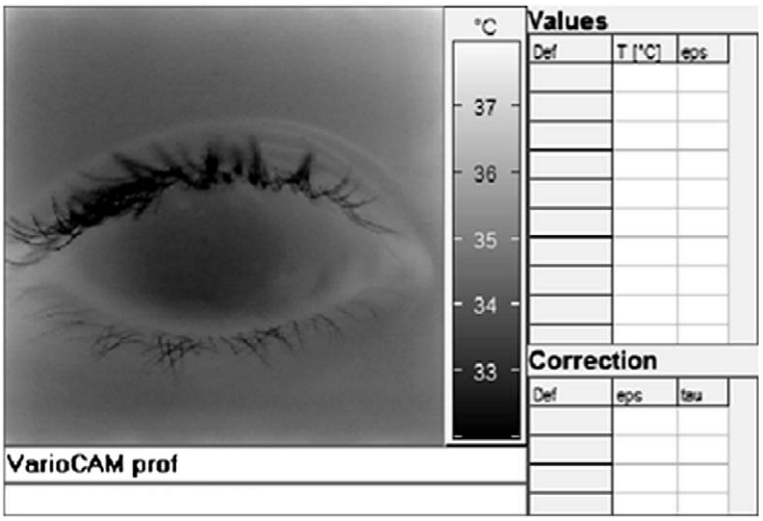

Fig. 1. Typical thermogram of normal eye.