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Invited article

Influence of Imaging and Object Conditions on Temperature Readings from Medical Infrared Images

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Abstract

Several circumstances influence the accuracy and precision of temperature readings from thermal images: the object imaged, the camera systems, standards, imager calibration and image analysis affects both accuracy and precision, but object position, image capture, information protocols and resources have only an impact on the repeatability of measurements. The Medical Imaging Research Group at the University of Glamorgan investigated the influence of imaging and object conditions on temperature readings from thermal images. The results indicated that following strictly standard procedures for camera calibration, image capture, subject preparing, body positioning and image analysis reduces errors and increases both accuracy and precisions of temperature measurements.

Keywords: thermal image, accuracy, precision, temperature measurement

Introduction

Infrared Imaging is used in medicine for 50 years, but this technique has only diagnostic potential when used as a method for measurement. Although proposals of standard protocols for medical thermal imaging has been made previously (see 1 for further references), factors influencing accuracy and precision of temperature measurements from medical thermal images were not comprehensively investigated in the past.

The Medical Imaging Research Group at the University of Glamorgan conducted a number of studies to understand the contribution of the object imaged, the objects´s position, the camera system, the calibration of the imager, the standard procedures for image capture, subject preparation and image analysis to the accuracy and precision of temperature readings from thermal images.

Experimental Procedures

6 papers from the Medical Imaging Research Group will reported. The first study used a heated metal plate showing lines and spots of different sizes 1-5mm to investigate spatial resolution and possible optical distorsion of four different infrared cameras (one camera with either 16° or 32°lens), manufactured between 1982 and 1999 [2].

Recently, Plassmann et al. reported a set of 5 tests to control for start-up drift, long term drift, off-set variation, image non-uniformity and thermal flooding effects of the imaging equipment [3]. Common available heat sources such as ice-water and water of 40° temperature were used to control the performance of infrared imagers.

In 2001, the Glamorgan protocol established a series of standardized positions of the body for image capture. Repeatability of these body positions was investigated in two other studies [4, 5]. The distance, measured in pixels,

from the upper or the lower edge of the image to anatomical landmarks was used for evaluation in one study [4], and the size of the object imaged in the other [5].

The Glamorgan protocol created also a complete standard for the definition of regions of interest in thermal images based on anatomical limits. The repeatability of accurate positioning of regions of interest was evaluated by comparisons of temperature readings from the same image after repeated definition and placement of measurement areas by the same and different image readers. The reliability coefficient alpha and interclass correlations were calculated as measures of repeatability. The individual measurement error was defined by the difference between the mean value of all measurements and the mean value of individual measurements.

Finally, temperature readings from hands of different sizes in thermal images were compared and readouts were related to the size of the measurement area and also to the room temperature, represented by the background temperature in the images. Hand sizes were allocated to 5 classes, and background temperatures were assigned to 3 classes. Mean, standard deviation, 95% confidence interval and nonparametric tests were used for statistical analysis.

Results

Ring & Dicks showed differences of older and newer thermal imagers in spatial resolution and also differences in optical features of equipment for recording infrared images [2]. For a field of view of 20x20 cm, the spatial resolution for both horizontal and vertical bars was 3mm for the Agema 782, 2 mm for the Agema 570 , and 1mm for the Inframetrics Thermacam with both lenses and and the Nikon Laird 3A. Point resolution for the same field of view was 5mm for the Agema 782, 2 mm for the Inframetrics with the 32° lens and 1mm for al other cameras. Increasing the field of view to 50X50cm resulted in reduced resolution for bars (range between 2 and 5mm) and spots (range between 1 and 5mm).

The quality assurance study [3] obtained a start-up drift up to 5°C over 2hours in some older infrared cameras The long term drift over months was within the specifications of the manufacturers. The off-set variation within the thermal image was non linear in 3 of 4 investigated cameras, which affects the accuracy of temperature readings from thermal image seriously. Image non-uniformity may be as much as 1.4 °C and thermal flooding effects occur in imaging equipment with focal plane arrays only, caused by the image processing programme in the camera [3].

Based on images from the database of normal thermal images in healthy subjects at the University Glamorgan, the variation of the standard views “Face”, “Dorsal Neck”, “Upper Back”, “Anterior Left Arm”, “Dorsal Hands”, “Both Knees Anterior”, “Lateral Right Leg”. “Lower Back”, “Both Ankles Anterior”, and “Plantar Feet” was obtained [1, 4]. Variations in views of the lower part of the body were bigger than in views of the upper part. The highest degree of variation was found in the view “Both Ankles Anterior”, but the smallest variation in the view “Face”.

Two groups of trainees in the technique of thermal imaging, recorded two separate images the hands of a volunteer [5]. The mean size of the hands varied in repeated image capture in one group by approximately 6.7% of the mean number of pixels of the imaged hands, and by 1.4 % in the other group.

The reproducibility of temperature measurement from thermal images was shown [4, 5, 6] with reliability coefficients between 0.7 (region of interest (ROI) at the right ankle) 0.96 (hour-glass shaped ROI at the left anterior knee). The biggest variation of temperature readings can be detected when the same body region is imaged from a different angle of view. The measurement error may be as much as 1 degree C [4]. The range of the individual errors of temperature measurements from regions of interest over small finger joints ranged between -0,26 to 0.17°C and -2.35 to 2.35°C [5].

A minor error occurs in slight variations of body position or different size or shape of measurement areas [6]. In the standard view upper back, the mean individual error of measurements in a circular ROI at the shoulder was 0.07 °C, and 0.13° in an alternative, polygonal shaped measurement area.. However, individual errors up to 0.49 °C were found. The reliability coefficient between first and second measurement was high with alpha values of 0.94 for the left shoulder, but with 0.139 poor for the right shoulder. Determination of mean temperature from half of the face showed reliability coefficients 0.97 and 0.88. However, the reliability of the standard deviation of this highly reproducible mean values was poor (alpha 0.018), probably caused by variation and structures in the background such as hair on the edge of the region of interest.

Variation in the size of ROIs of 100 or more percent lead to significantly different temperature readings from these areas [7]. However, variation of the room temperature in repeated image recordings have a higher impact on the temperature readings than variation in the size of measurement areas.

Discussion

Both variations in body position during image recording and variations of shape and size of measurement areas affect the precision of temperature measurements. However, variation of the room temperature in repeated image recordings have a higher impact on the temperature readings than variation in the size of measurement areas. In conclusion, following strictly standard procedures for camera calibration, image capture, subject preparing, body positioning and image analysis reduces errors and increases both accuracy and precisions of temperature measurements from thermal images.

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