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Identification of Thyroid Papillary Carcinoma and Adenoma through Thermal Imaging: Preliminary Results †

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Abstract: Infrared thermography (IRT) is a non-invasive technique used to discriminate thyroid carcinoma (TC) patients from healthy controls (HC) employing cold-stress protocols. This study investigated the capability of IRT to identify TC, thyroid adenoma (TA), and HC without cold-stress protocols. Eleven participants were enrolled, and the maximum temperature showed the best performance in discriminating the three groups, with a difference between the pathological and healthy sides (left vs. right for HC) of 1.15 °C (±0.34 °C) for TC, 0.51 °C (±0.12 °C) for TA, and 0.11 °C (±0.09 °C) for HC. These results could foster the employment of IRT for a non-invasive thyroid tumor diagnosis.

Keywords: infrared thermography (IRT); papillary cancer; microcarcinoma; machine learning (ML)

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1. Introduction

Thyroid cancer is the most common endocrine tumor, and its incidence has highly increased over the past few years [1]. Particularly, follicular neoplasms of the thyroid gland can be distinguished between benign adenoma (TA) and carcinoma (TC). The timely identification of malignant neoplasms enhances the probability of efficacious intervention and augments the overall survival rate of individuals afflicted with cancer [2]. Several medical screening tests are available for detecting cancer, including Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET) scans, and ultrasonography. Various tumor segmentation techniques, including thresholding, clustering, histogram-based, and edge detection methods, are capable of differentiating the tumor from the adjacent healthy tissue and generating the corresponding tumor image [3]. In the field of medical diagnostics, infrared thermography (IRT) has emerged as an ecological, contactless, and non-invasive technique for detecting various pathologies, including brain tumors, skin cancer, microcirculatory diseases, and Raynaud phenomena [4–7]. Concerning the employment of IRT for the identification of thyroid tumors, Bahramian and Mojra found that, after a cooling procedure of the neck, the local temperature rose by 1–1.5 °C in front of the thyroid cancerous tumor compared to the surrounding healthy tissue [8]. Moreover, Bahramian and Mojra also developed an artificial neural network for assessing correlations between the thermo-physical parameters of the thyroid and the temperature profile on the neck skin [9]. Furthermore, according to the findings of González et al., IRT applied to the neck region in patients with thyroid cancer revealed a higher metabolic activity in the tumor tissue compared to the healthy tissue [10].

The objective of this study is to examine the capability of IRT applied to the neck skin to distinguish TC, TA, and HC without the use of cold-stress protocols. Thermal images were obtained from a sample of 6 participants, and thermal features were selected over specific regions of interest (ROIs) to identify TC, TA, and HC.

2. Materials and Methods

2.1. Experimental Procedure and Data Acquisition

A total of eleven individuals were recruited for the study (age: 65.76 ± 8.18 years, 6 M), consisting of three participants in the TC group, four participants in the TA group, and four participants in the HC group. The neck skin temperature was recorded using the FLIR SC660 (FLIR, Wilsonville, OR, USA) thermal camera. The camera has a 640 × 480 bolometer FPA and a sensitivity/noise equivalent temperature difference of <30 mK @ 30 °C. The camera was positioned at a distance of 60 cm, directed toward the subject's nake. The sampling frequency was 10 Hz. The acquisitions were conducted following the established protocols for thermal measurements as outlined in Ref. [11].

2.2. Data Processing and Statistical Analysis

The maximum, minimum, and average values of the temperature distribution within two regions of interest (left and right sides of the thyroid) were computed. The ROIs were placed as shown in Figure 1, completely covering the area surrounding the thyroid. The difference between the thermal metrics evaluated for the ROIs placed on the thyroid tumor and the healthy side (left vs. right for the HC) was computed. A one-way ANOVA was employed to the differences between the thermal metrics of the two thyroid sides to assess differences between the two groups. A multiple comparison analysis was performed, and the results were Bonferroni corrected.

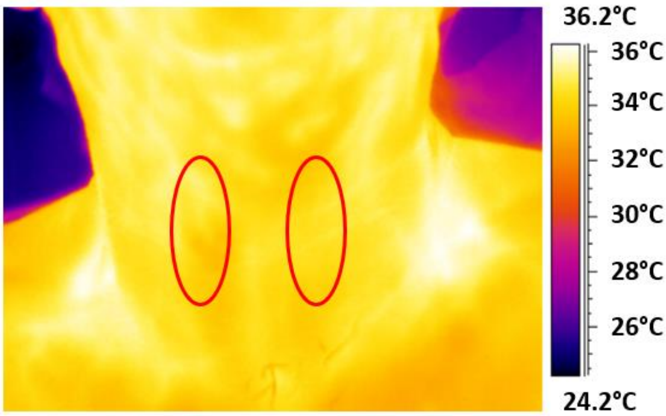

Figure 1. Thermogram of a representative participant. The red circle indicate the ROIs considered on the skin covering the thyroid region.

3. Results

The maximum temperature showed the best performance in discriminating the three groups, with a difference between the pathological and healthy sides for this parameter being 1.15 °C (±0.34 °C) for the TC patients, 0.51 °C (±0.12 °C) for the TA patients, and 0.11 °C (±0.09 °C) for the HC. Concerning the minimum temperature, the differences between the two sides were 0.54 °C (±0.21 °C) for the TC patients, 0.61 °C (±0.37 °C) for the TA patients, and 0.08 °C (±0.04 °C) for the HC. Regarding the average value of the temperature, the differences between the two ROIs were 0.80 °C (±0.26 °C) for the TC patients, 0.56 °C (±0.29 °C) for the TA patients, and 0.09 °C (±0.06 °C) for the HC.

Figure 2 reports the bar graphs of the distribution of the average, minimum, and maximum temperature of the three groups.

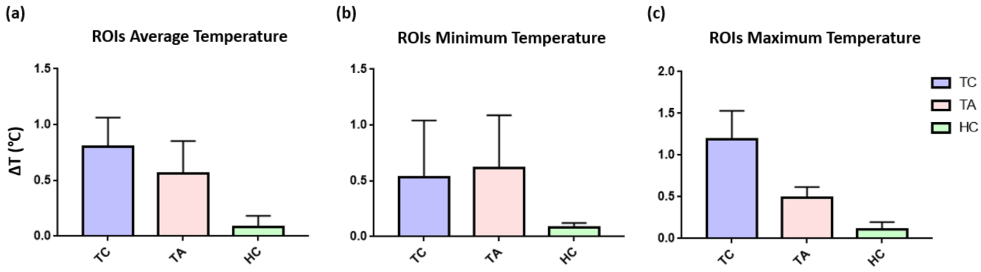

Figure 2. Bar graph of the distribution of the (**a**) average, (**b**) minimum, and (**c**) maximum of the difference between the thermal metrics of the two thyroid sides.

The ANOVA showed significant differences for the maximum ($p = 0.023$) and average temperature ($p = 0.002$), whereas the minimum temperature did not exhibit significant differences between the two groups ($p = 0.288$). The multiple comparison analysis delivered Bonferroni-corrected statistical differences only between TC and HC for the average temperature ($p = 0.027$), whereas the maximum temperature resulted in being different between TC and TA ($p = 0.021$) and between TC and HC ($p = 0.002$).

4. Discussion

This study demonstrated the capability of IRT to identify patients with TC, TA, and HC without the employment of cold stress. Specifically, the difference between the maximum temperature between two ROIs placed on the two sides of the thyroid was found to be indicative of the presence of TC and TA. In fact, the ANOVA and the multiple comparison analysis revealed significant differences between not only TC and HC but also between TC and TA. Notably, no differences were assessed between HC and TA. The best performance associated with the maximum temperature with respect to the minimum and average temperature could be ascribed to the change of the metabolic features of the tumoral area, increasing the skin temperature covering the zone [8]. However, it is noteworthy that the extent of the regional temperature elevation and the asymmetry of the infrared thermal pattern are contingent upon various factors such as the dimensions, category, and depth of the neoplasm, along with the physiological age and gender of the individual, which exert an influence on the thyroid gland's performance [12].

The temperature variations assessed in this study could be further analysed, paving the way for tumour early detection, which is critical in managing the disease and improving patient prognosis. In fact, this approach significantly reduces the discomfort, risks, and complications associated with invasive diagnostic procedures such as fine-needle aspirations and scintigraphy. While the results are promising, further investigations with larger participant groups are necessary to standardize and validate this method, as well as to understand its full potential and limitations.

5. Conclusions

This study has presented evidence supporting the feasibility of utilizing IRT as an innovative, non-invasive tool for the evaluation of thyroid cancer. Our results indicated a distinct thermal pattern correlation with the presence and severity of thyroid cancer. These results could foster the employment of IRT for a non-invasive thyroid tumour diagnosis.

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