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Thermographic analysis of thyroid diseases at the Lagos university teaching hospital, Nigeria

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ABSTRACT

This paper presents the results of thermographic study of thyroid dysfunctions as an alternative clinical diagnostic technique. 37 patients confirmed with thyroid diseases and 16 volunteers as control at the Lagos University Teaching Hospital Nigeria were studied. Cytological methods were used for confirming the thyroid disease while the images of skin temperature maps were obtained using the FLIR Infrared Cam Flip (USA) infrared camera operated in self automatic calibrated mode. The thermographs were compared with ultrasonographs. The mean temperature ± standard deviation of 36.63 ± 0.56 °C was obtained for hyperthyroid, 34.93 ± 0.32 °C for hypothyroid and 35.76 ± 0.49 °C for control groups respectively. There were variations in the mean skin temperatures of malignant (37.63 ± 0.29 °C) and benign (36.21 ± 0.73 °C) diseases. The results show that thermography could be relevant and if used in combination with other imaging modality, could play a vital role in the diagnosis of thyroid diseases. This study also confirmed that female are more susceptible to thyroid diseases than male and that hyperthyroidism is commoner than hypothyroidism.

Keyword: Thermography, Hypothyroidism, Hyperthyroidism, Ultrasonography, Malignant, Benign Thyroid Diseases

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INTRODUCTION

Temperature, thermal properties and heat flow characteristics of materials are important parameters that are being extensively and intensively studied for improved understanding of the properties of materials [1-5]. This concept and trend are the same in Medical and Biomedical Sciences for the purpose of diagnostic and/or therapeutic applications. The correlation between the body temperature and diseases has been known for many years. Skin temperature has been used as a convenient and effective diagnostic indication of diverse pathologies. Human physiological temperature is approximately 37 °C but this value may vary depending on the pathophysiological conditions of the body [6 - 9]. The first documented application of thermography was in early and preclinical diagnosis of breast cancers in 1956 [10]. Infrared thermography is a non–contact, non–invasive, non–traumatic and simple method of mapping the body skin temperatures. It has a wide range of applications ranging from condition monitoring in the industries to medical diagnostic imaging. Medical infrared thermal imaging has earlier been used to study the flow of blood, detection of breast cancers and muscular performance of the human body. Thermal images have been used not only to quantify sensitive changes in skin temperature in relation to certain diseases, but also blood flow can be assessed apart from the washout technique and LASER Doppler flowmetry. Of all these, infrared thermography has the advantage of being non-invasive, non-traumatic, fast, reliable, with non-contact, capable of producing multiple recordings at short time intervals and absolutely safe for patients and staff. Infrared radiation is an electromagnetic radiation with wavelengths in the range 750 nm to 1 mm and frequencies between 0.003 and 4×10^{14} Hz and quantum energies between 0.0012 - 1.65 eV. Its wavelength is slightly longer than the red in the visible in the electromagnetic spectrum. Considering the range of wavelengths of infrared radiation, the human body emissions that are traditionally measured for diagnostic purposes occupy a narrow band of wavelengths from 8 to 12 µm.

The actual temperature varies somewhat with the individual and time of the day but only within about 1°C. With vigorous exercise or in a disease state [11], the core body temperature could vary from a lower extreme of approximately 35.5°C to an upper extreme of about 40 °C. The Law of Conservation of Energy forms the basis for the study of thermoregulation [12].

The main constituents of heat exchange are metabolic heat generation which is about 100 W for an adult and physical activity that ranges from 100 W to 400 W for sustained activity. Radiation exchange which depends upon the temperature difference between the skin and environment also convective heat exchange depend upon air temperature, air velocity, and exposed skin surface [13]. The heat emanating onto the surface from the heat source and the surrounding blood flow can be quantified using the Penne's bio-heat equation [14] (Penne H.H., 1948):

$$\mathbf{K\Delta^2T - C_bW_b\,(T - T_a) + q_m = 0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1.$$

where K = conductivity
q_{m} = volumetric metabolic rate of tissue and it is the product of the specific heat capacity and the mass flow rate of blood per volume of tissue.
T = unknown tissue temperature and T_a = aerial temperature.
C_b = the specific heat capacity of blood per unit volume
W_b = the mass flow rate of blood per unit volume

MATERIALS AND METHODS

Approval to conduct the study was obtained from the Research and Ethics Committee of the Lagos University Teaching Hospital. Informed consent of the patients was obtained after explaining the purpose of the procedure. 37 patients of which 10 were male and 27 are female were recruited for the study with a mean age of 40 years, and range between 24 - 71 years. 16 healthy volunteers, 11 women and 6 men served as control, with their mean ± SD was 46 ± 1.7 years and range was between 25 and 72 years. Anthropomorphic parameters were determined for calculating the body mass index (BMI). The participants declared that they did not take any medication of recent that may affect thyroid activity.

The infra-red camera FLIR (from the USA), model ThermaCAM™ S65 system with 24° optics was used for the skin temperature mapping. The spectral range of this camera lies between 7.5 and 13 µm. The patients were treated under conducive conditions described elsewhere [15 - 16]. The infra-red camera was operated in automatic self–calibration mode for best result and the mean value is recorded at the point corresponding to the position of the pathologic gland. The same processes were employed for both the patients and control.

The cytological study was performed using a 23-gauge needle attached to a 20 ml disposable syringe to aspirate from the thyroid swelling. This was done for each lobe, giving 4 direct smears which were stained with the usual air dried smears, Papanicolaou stain. The smears were interpreted as benign colloid goitre, benign cystic goitre. Neoplasms included follicular neoplasms (combined benign and malignant). Ultrasonography examination was also performed for comparison of results. The echo textures and patterns of lesions obtained were classified as cystic, solid, mixed or coarse. Some sample thermographs for hyperthyroidic and hypothyroidic cases are shown in figure 1.

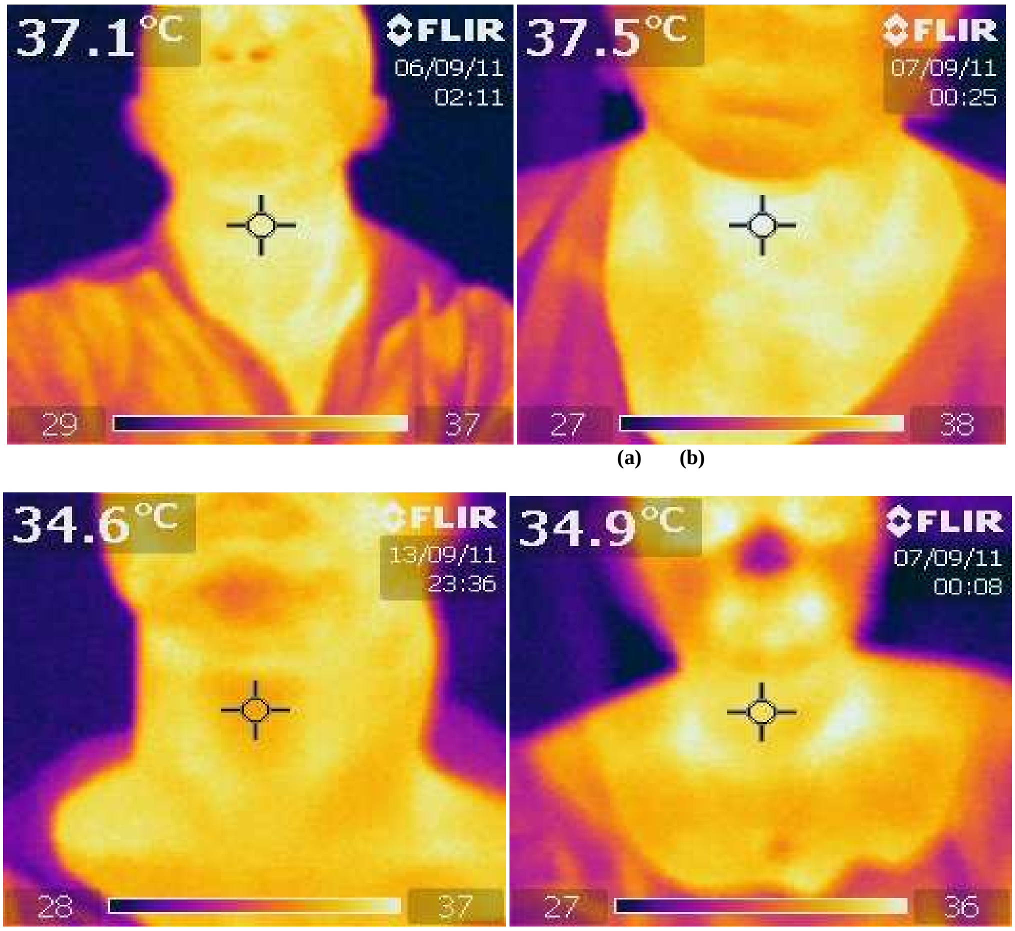

Fig 1: Typical thermographs of (a) hyperthyroidic and hypothyroidic patients.

RESULTS

Table 1. presents the results of cytological classification of thyroid diseases and the frequency distribution according to sex. The fine needle cytology showed that 4 (11 %) patients are malignant and 33 (91 %) are benign, out of 37 patients, only 6 cases showed hypothyroid while the remaining 31 cases were hyperthyroid. The sex distribution shows that 73 % of the patients were female and 27 % were male.

Figure 2. shows the variation of the patient skin temperature according to hyperthyroidic and hypothyroidic disease. The mean skin temperature of the former is 36.63 ± 0.56 °C while it was 34.92 ± 0.32 °C for the latter. The control had mean value of 35.76 ± 0.49 °C in between the two.

Figure 3. Compares the skin temperature variation with thyroid diseases and with sex, while figure 4. Compares the temperature variation according to whether the disease is benign or malignant. The thermograms showed mean skin temperature of 37.63 ± 0.29 °C for malignant and 36.21 ± 0.73 °C for benign gland disease. There was no significant temperature difference on sex distribution among the control but it varied among the patients studied

Ultrasonographic findings revealed cystic echo texture in 10 cases (27 %), a solid echo texture in 12 (32 %), mixed echo texture in 14 cases (39 %) and coarse echo texture in only 1 case (2.7 %). Results showed that thyroid swellings prevail among middle-aged and the mean age of the patients was 40.97 ± 08.72 years.

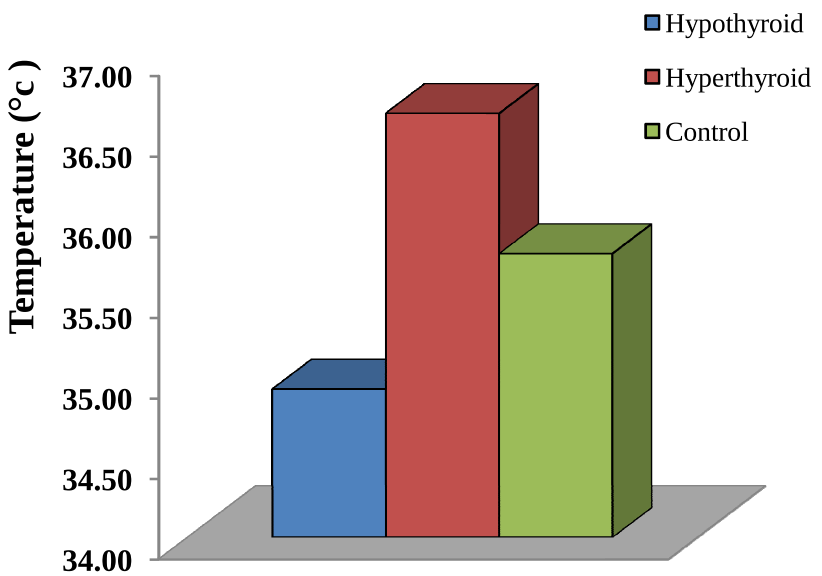

Figure 2: Variation of mean skin temperature with disease type

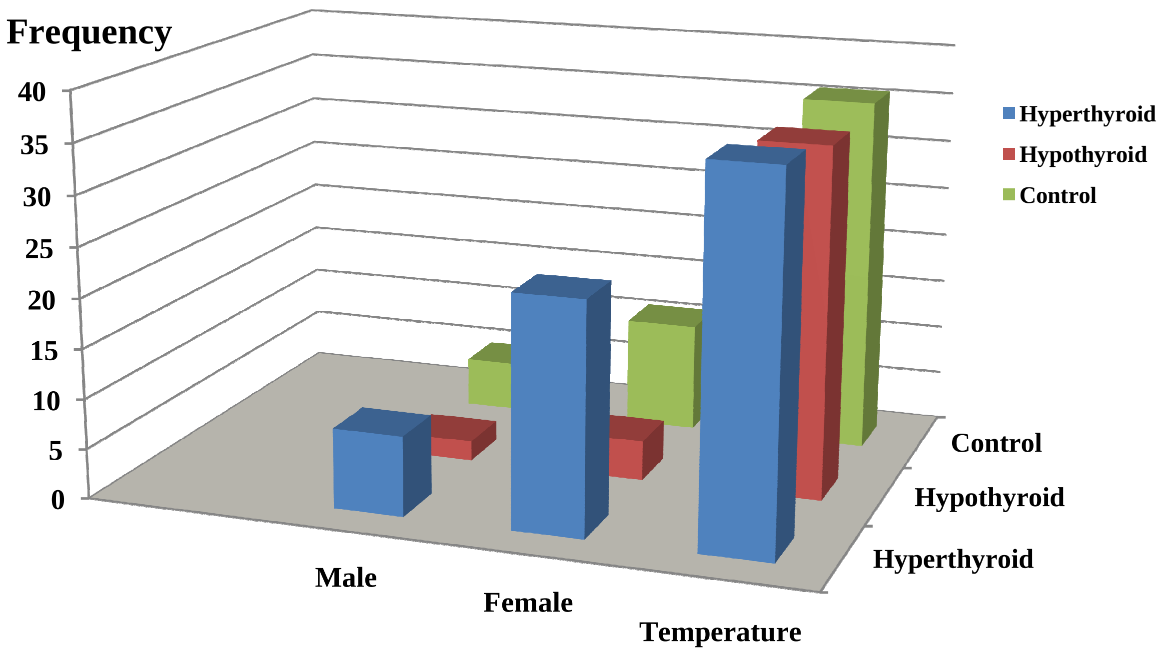

Figure 3: Distribution of mean skin temperature with sex and disease type

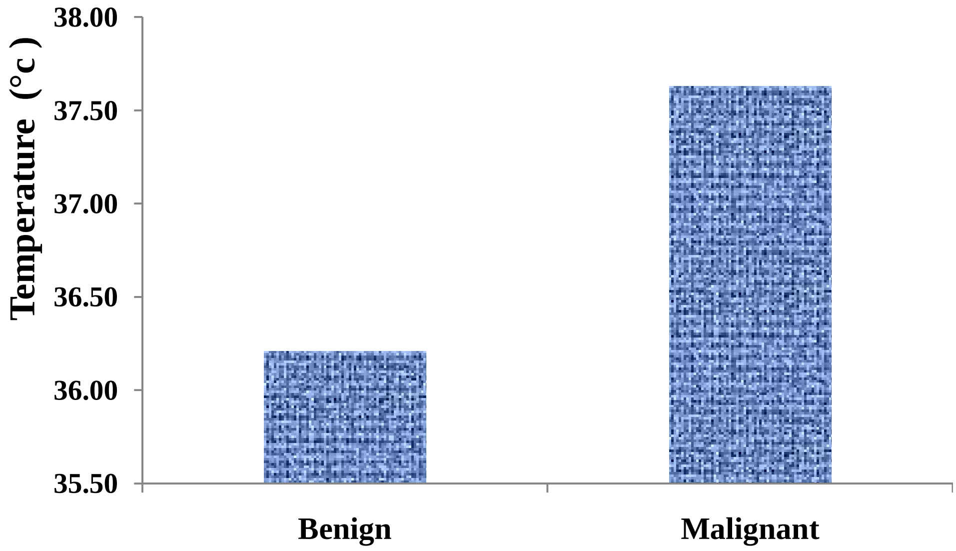

Figure 4: Dependence of disease type with temperature

Table 1. Histological classification of thyroid diseases by sex

Type of disease	No. of Male	No. of Female	Total (Frequency)
Hyperthyroidism	8	23	31
Hypothyroidism	2	4	6
Control	5	11	16

DISCUSSION

The ages of the 37 studied patients with thyroid dysfunction varied from 20 to 80 years with mean of 40.97 ± 08.72. The number of patients was highest within the age groups of 31- 40 years and 41-50 years with 14 (37.8 %) each. 4 patients (10.8 %) were between 21-30 years and 4 others (10.8 %) between (51 - 60) years. No patient (0 %) was found between 61-70 years, while 1 (18 %) was between 71 - 80 years. 27 (73 %) were females and the remaining 10 (27 %) males, giving male to female ratio of 1:2.7. This agrees with similar findings in thyroid diseases analysis statistics by [15 - 17] at Lagos University Teaching Hospital, Nigeria, and also among 13.5 million diagnosed in US, 80 % of all cases of Graves' Disease were females [18]. From the reports on the contribution of fine aspiration cytology to the diagnosis and management of thyroid diseases by Godinho L. et al. [19] and Diagnostic Role of Fine Needle Aspiration Cytology in the Diagnosis of Solitary Thyroid Nodules in Pakistan by Muhammad et al. [20], the male: female ratios were 1:5 and 1:15.6 respectively.

34 patients (91.9 %) showed symptoms of pain, 2 patients (5.4 %) had swelling at right side, 32 (89.2 %) at middle of neck and 2 (5.4 %) had no swelling at all. Ultrasonographic scanning showed 5 patients (13.5 %) had small size of nodule (< 2 x 2 cm) and 10 (27 %) had intermediate size (between 2 x 2 cm and 5 x 4 cm) while 8 (21.6 %) had large size nodules (≥ 5 x 5 cm). Ovoid shaped nodules were observed in 6 patients (16.2 %) while hemispherical shape was noted in 9 (24.3 %). The sonographs showed cystic echo textures in 10 cases (27 %), solid echo texture in 12 (32 %), a mixed echo texture in 14 (39 %), and a coarse echo texture in 1 case (2.7 %). These observations are in close agreement with those of ultrasound diagnosis of thyroid nodules by Muhammad et al. [20].

The clinical report of thyroid tests confirmed only 6 patients (16.2 %) to be hypothyroidic, out of which 2 were male (5.4 %) and 4 female (10.8 %). 31 cases (83 %) were hyperthyroidic, of which 8 were male (21.6 %) while 23 (62.2 %) were female (Table 2). Similarly, the thyroid lesions were classified from cytology results because fine needle aspiration cytology (FNAC) has been a well-established technique for pre-operative investigation of thyroid nodule [21] (Tabaqchal M. A. et al.). The technique is one of the least invasive, cost effective and efficient methods of differentiating benign and malignant thyroid nodules [21 - 22] . In this study, it showed 4 malignant lesions (10.8 %) and 33 benign lesions (89.2 %), similar results of 11.66 % malignant and 88.34 % benign were gotten in a study of thyroid swelling [23]. Out of the malignant cases 3 (8.1 %) were females and 1 male (2.7 %) while 9 (24 %) are males out of benign cases and 24 (64.9 %) are females.

The mean skin temperature compared with the results gotten from thyroid disease types showed evidences of temperature variations. The mean skin temperatures in hypothyroid cases for males and females ± standard deviation were 34.7 ± 0.43 °C and 35.05 ± 0.24 °C respectively. For hyperthyroid cases, the mean skin temperatures were higher for both genders which were 36.55 ± 0.65 °C and 36.66 ± 0.54 °C respectively as shown in Table 1. There were significant differences in these values compared with control: the mean for hyperthyroidic was 36.63 ± 0.56 °C, for hypothyroidic 34.92 ± 0.32 °C while for control, it was 35.76 ± 0.49 °C (figure 3). Comparison of the thermograms of malignant and benign cases also demonstrated differences: the mean skin temperatures were 37.63 ± 0.29 °C and 36.21 ± 0.73 °C respectively (figure 5). Approximately the same mean values were obtained for both males and females among the control group, which were 35.7 ± 0.34 °C and 35.8 ± 0.56 °C respectively.

CONCLUSION

The mean skin temperature around the thyroid gland is approximately the same for both males and females among the control, implying gender independence. There were differences in the mean skin temperatures among the hyperthyroidic and hypothyroidic patients. The mean skin temperatures ± SD for male and female patients and the control were 36.55 ± 0.64 °C, 34.70 ± 0.42 °C; 35.49 ± 0.82 °C; 36.66 ± 0.54 °C, 35.05 ± 0.24 °C and 35.75 ± 0.07 °C respectively. The results show hyperthyroidic patients have higher temperature than control and hypothyroidic have the least. Females are more prone to thyroid diseases than males. The temperature gradient of thermogram can be used to predict thyroid pathologies which ultrasound technique may not. Thermographs demonstrated slightly higher skin temperature in thyroid malignant than benign.

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