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# Screening of Type 2 Diabetes Mellitus and Chronic Sinusitis using Non-Contact Infrared Thermal Imaging

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**Abstract:** Sinusitis is a common disorder that becomes chronic, which paves the way for insulin resistance in the earlier stages of life and that leads to type 2 diabetes with irrecoverable damage to the vital organs of the body. The present study aims to reveal the key factor behind the increased morbidity and mortality rate among type 2 diabetic subjects using non-contact infrared thermography. The total study subjects (N=52) were grouped into control (n=27) and diabetic (n=25) and they underwent blood tests to obtain blood sugar level, C-reactive protein test (CRP) which indicates that only 6% (n=4) of the study subjects are positive. Whereas, the non-contact infrared thermal imaging reveals that more than 50% of the study subjects were suffering from sinus infection which was not screened by the CRP test; whereas, all the four sinus regions namely the frontal ($r=-0.48$, $p<0.01$), ethmoid ($r=-0.561$, $p<0.01$), maxillary ($r=-0.424$, $p<0.01$) and sphenoid ($r=-0.415$, $p<0.01$) regions indicated negative correlation with HbA1c. Further, the independent samples t test indicated statistical significance at the forehead ($p=0.005$), knee ($p<0.001$), tibial ($p<0.002$), sinus regions of frontal ($p=0.002$), ethmoid ($p<0.001$), maxillary ($p<0.007$) and the sphenoid ($p<0.010$) regions. The test results of the study suggest that body immunity decreases due to infection of any kind that enters the human body; furthermore, it causes apoptosis of beta cells to take place in the pancreas which leads to decreased insulin production. These could be avoided by following proper hygiene at the dwelling place, hospitals and other public places. Either Viral or bacterial infection of an individual was considered a pre-disposing factor of type 2 diabetes, which can be predicted in the earlier stage through non-invasive thermal imaging.

**Keywords:** Sinusitis, Diabetes, Infection, Infrared imaging, Apoptosis

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## Introduction

Type 2 diabetes mellitus is a metabolic disorder, where 537 million people all over the globe were affected during the year 2021. It was projected to reach 643 million in the year 2030, and 783 million by 2045. India will have 123.5 million at the same time, according to the International Diabetes Federation (IDF) (IDF Diabetes Atlas, 2021). The root cause for this global burden has to be identified and the preventive measures need to be taken to curb the mortality rate. Developing

countries like India, poor sanitation facilities and lack of hygiene which results in an outbreak of the water and air-borne diseases. Sinusitis is a common illness of the mucosal surface of the paranasal sinuses, which was classified into frontal, ethmoidal, maxillal and sphenoidal regions (Wilson *et al*., 2021). The infection may be caused by either bacteria or viruses that persist in the human body for a longer time and gradually weaken the immune system (Monga *et al*., 2022), the virus enters the human body remains active and gets multiplied all over the body through the circulatory system; when the blood glucose for body metabolism is available from the ingested food, that also circulates along with the virus; thereby, the tissues find it to be a foreign substance altogether and offer resistance to the insulin by which the glucose uptake by the tissue for the process of metabolism was prevented (Ingli, 2022).

Further, the infected beta cells in the pancreas may undergo apoptosis which leads to decreased beta cell count and ultimately results in poor body metabolism (Galeoitte, 2020). The screening for infection was done with the help of C-reactive protein (CRP), a non-specific inflammatory marker produced by the liver that demands exclusive biomarkers for accurate diagnosis (Serbis, 2021). Medical infrared thermography is non-invasive and safe, as the non-ionizing infrared (IR) radiation emitted by the human body is captured passively using thermal camera to detail the physiological changes in the body. It offers high reliability and accuracy with no restriction on the repeatability of the procedure in comparison to computed tomography (CT) that utilizing ionizing X-rays to give anatomical information with poor specificity (Shin, 2020). The present study aims to reveal the key factor behind the increased morbidity and mortality rate among the type 2 diabetic subjects using non-contact infrared thermography.

## Materials and Methods

### *Subject selection*

The study is conducted at the SRM Hospital, Kattankulathur, Tamil Nadu, India. All participants signed an informed consent agreement. The study population (n=52; male n=20, female n=32) aged between 21 and 75 years, the study subjects who had undergone the CRP test did not have any of the confounding complications like cardiovascular, arthritis, thyroid, fever were included in the study from the group of self-interested participants (n=75).

### (A) *Thermal, physical, physiological and bio-chemical measurements*

The subjects were made to relax in a temperature control room (23°C) for 15 min. The selected regions of the body to be imaged were exposed to that temperature. The imaging of the face, arm, leg and foot regions of contralateral body regions was obtained using a FLIR T-400 thermal camera at a distance of nearly 3 feet from the subject. Physical measurements (height, weight, waist and hip circumference), physiological (Systolic and Diastolic blood pressure) measurements and from the blood sample, HbA1c resulted from enzymatic principle and CRP test was carried out using ELISA reader as a qualitative parameter indicating the positive (n=4) or negative (n=48) for the test among the study population. The temperature coefficients were obtained manually using thermal software at the desired region of interest (ROI) (Deruau, 2021). The ROI was selected bilaterally for the various sinus-infected regions based on the anatomical position of the frontal (area just above the eyebrow), ethmoidal (area between the inner canthus of eyes), maxillary and sphenoidal regions The region of interest has been chosen either in the form of a square or a rectangle and the measurements were maintained as uniform for all the subjects.

### (B) *Statistical measures*

The diagnostic criteria (HbA1c ≥6.5%) set by the American Diabetes Association (ADA) followed to segregate the subjects into control (n=27) and diabetic (n=25). The significant level of the study variables between the control and diabetic group was obtained using the indepen-dent samples t

test and the Pearson correlation study was performed to study the correlation using SPSS version 17.0. All the values are expressed as mean±SD.

## Results

The age of the diabetic group indicates that the onset of the disease occurs in the early adult stage (35 years), at which most of them would have undiagnosed the disease. Central obesity seems to be highly significant when compared to the total obesity among the South Indians. Table 1 reveals that the waist ($p=0.018$) and hip circumference ($p<0.010$) indicate better significance when compared with the body mass index ($p<0.042$). Among the body regions considered under study, all of the body regions under the diabetic group indicate decreased skin surface temperature of at least 0.5°C among either the bilateral or contra-lateral body regions. Further, the skin surface temperature at the knee region of a diabetic group indicated significance ($p<0.001$) with decreased skin surface temperature.

The infection, a pre-disposing factor studied from the facial thermogram indicated decreased skin temperature at the frontal, ethmoidal, maxillial and sphenoidal regions. The ethmoidal region indicates better significance ($p<0.001$) with nearly 1°C decrease in skin temperature among the diabetic group. Figure 1 describes the box plot for the sinus-infected regions among the diabetic group, which reveals that the skin temperature at the ethmoidal region was 33.42 ± 0.9°C, which indicates the lowest median temperature with highest deviation among the measured sinus regions.

Table 2 indicates the bivariate correlation of the study population, where the HbA1c indicates a positive correlation with age ($r=0.507$, $p<0.010$, systolic and diastolic blood pressure ($r=0.302$, $p<0.05$, $r=0.304$, $p<0.05$), respectively. Whereas, HbA1c indicates negative correlation with measured skin temperature and the ethmoid region exhibits the highest level of significance ($r=-0.561$, $p<0.01$). Further, the parameter age (years) was found to exhibit highest positive correlation with systolic blood pressure ($r= 0.555$, $p<0.01$) and the highest negative correlation with the frontal sinus region ($r=-0.548$, $p<0.01$).

Figure 2 describes the normal facial thermogram of the control subjects with no sinus indications and the skin temperature at the ethmoid region indicates 34.9°C. Figure 3 describes the facial thermogram of a diabetic subject with the CRP test indicated negative, the thermogram signifies the sub-clinical infection at the ethmoidal region with skin temperature of 32.9°C. Figure 4 describes the facial thermogram of a diabetic subject with the CRP test indicated positive and the blockage of the sinus drain at the left side from the ethmoidal into a maxillary region was observed and the skin temperature at the ethmoid region indicates 30.5°C.

## Discussion

The principal findings of this study are (i) the identification of the most prevalent sinus-infected region among the type 2 diabetic subjects and (ii) the inability of the biomarker, CRP test with a poor sensitivity of 6% when compared with non-contact thermal imaging could serve as a non-invasive marker with prognostic capability. Furthermore, bilateral regions of the sinus drain blockage were diagnosed.

The onset of type 2 diabetes was indicated by the Gold standard biomarker test only when the beta cell mass reduces to nearly 50-65%, which leads to serious complications in the near future. Further, the South Indian population suffers from central obesity; this could be due to sedentary life style. The facial thermogram of most of the pre-diabetic subjects and few of the control subjects indicated ethmoid sinus, this signifies that an infection in an individual could be predicted at the earlier stage of the disorder. When the infection rate transits from the acute state to the chronic,the weakened immune system leads to insulin resistance in the tissues. Further, the apoptosis of the beta cells takes place in the pancreas

Table 1: Characteristics of the study population

| Study variables | Control (n=27) | Diabetic (n=25) | *p* value |
|---|---|---|---|
| | Mean±SD | | |
| Age (Years) | 40±12 | 50±15 | 0.014* |
| $HbA_{1c}$ (%) | 5.7±0.4 | 8.7±1.9 | 0.000** |
| [a]SBP (mmHg) | 124±18 | 130±16 | 0.218 |
| [b]DBP (mmHg) | 80±10 | 84±12 | 0.11 |
| [c]BMI ($Kg/m^2$) | 25±4 | 28±4 | 0.042* |
| [d]WC (cm) | 86±14 | 97±13 | 0.018* |
| [e]HC (cm) | 95±12 | 105±11 | 0.010* |
| **Skin Temperature region ($^oC$)** | | | |
| Forehead | 35.02±0.47 | 34.67±0.41 | 0.005** |
| Palm | 33.53±1.5 | 32.80±1.1 | 0.054 |
| knee | 32.40±0.9 | 31.61±0.6 | 0.001** |
| Tibial | 32.89±0.7 | 32.19±0.8 | 0.002** |
| Toes posterior | 26.43±2.9 | 25.00±1.7 | 0.031* |
| Foot | 28.37±2.3 | 27.28±1.6 | 0.054 |
| Frontal sinus | 35.21±0.6 | 34.70±0.5 | 0.002** |
| Ethmoid sinus | 34.34±1.0 | 33.42±0.9 | 0.001** |
| Maxilliary sinus | 34.76±0.7 | 34.22±0.6 | 0.007** |
| Sphenoid sinus | 34.31±0.6 | 33.86±0.5 | 0.010* |

* Significant correlation at 0.05 level; ** Significant correlation 0.01 level

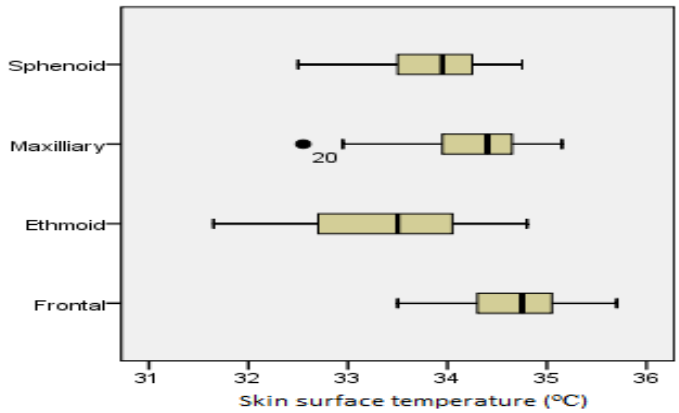


Fig. 1: The box plot representation for the skin surface temperature of the sinus infected regions among the diabetic population.

(Ciardullo *et al*., 2022). The negative correlation of the HbA1c with various body regions indicated that the body metabolism decreases with advancing age, infection rate and increase of insulin resistance (Chauhan, 2021; Vitiello, 2023). The CRP test result could be used as a biomarker of the infection rate among diabetic subjects (Zhou, 2023; Calderwood, 2023, Sahebkar, 2024), although it lacks in specificity. The thermal imaging indicates the infection of the ethmoidal region indicated a decreased temperature of nearly 2°C compared with the control subject; this was an early indication of sinus infection, which the subjects did not disclose in the completed questionnaire or at the time of image capture. When the CRP test result indicated positive, a

Table 2: Pearson correlation for the study subjects (n=52)

| Variables | Age (years) | $HbA_{1c}$ (%) |
|---|---|---|
| Age (years) | 1 | 0.507** |
| $HbA_{1c}$ (%) | 0.507** | 1 |
| [a]SBP (mmHg) | 0.555** | 0.302* |
| [b]DBP (mmHg) | 0.435** | 0.304* |
| [c]BMI (Kg/m2) | 0.314* | |
| [d]WC (cm) | 0.378* | |
| [e]HC (cm) | 0.319* | |
| Forehead (°C) | -0.546** | -0.426** |
| Knee (°C) | | -0.298* |
| Tibial (°C) | | -0.316* |
| Frontal sinus (°C) | -0.548** | -0.480** |
| Ethmoid sinus (°C) | -0.407** | -0.561** |
| Maxilliary sinus (°C) | -0.388** | -0.424** |
| Sphenoid sinus (°C) | -.407** | -0.415** |

[a]Systolic blood pressure; [b]Diastolic blood pressure; [c]Body mass index; [d]Waist circumference; [e] Hip circumference

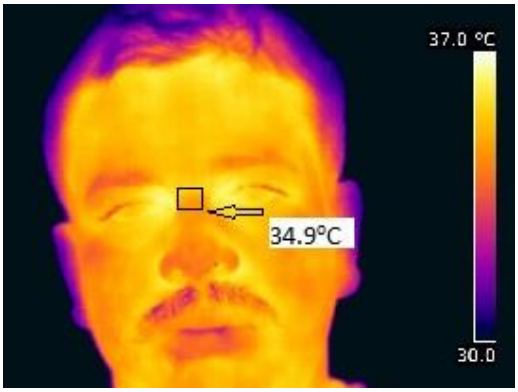


Fig. 2: The facial thermogram describes the normal temperature of a control subject.

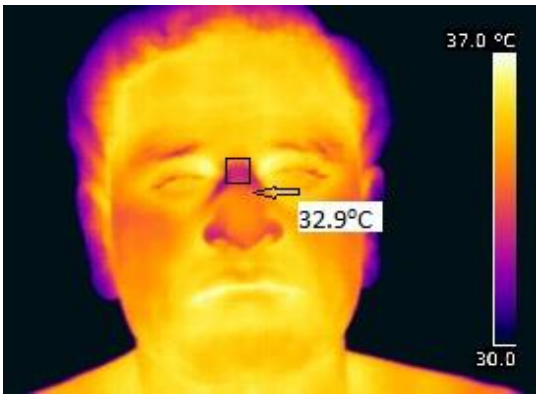


Fig. 3: The facial thermogram indicates the ethmoid sinus in a diabetic subject with CRP test result indicated negative.

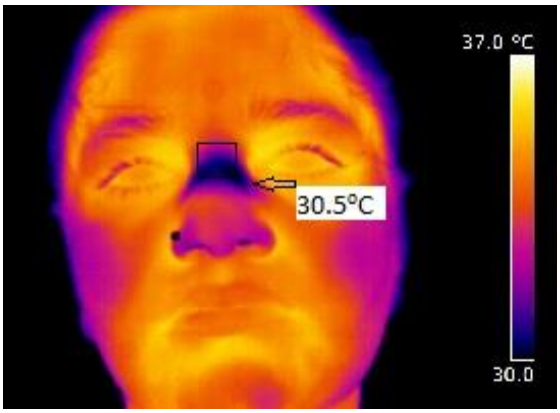


Fig. 4: The facial thermogram of a diabetic subject with the CRP positive indicates severe blockage of sinus drain from ethmoidal into maxillial region.

significant decrease in temperature at the ethmoidal region of 4°C and 2°C was observed among the control and diabetic subjects with CRP negative, respectively. Further, the blockage of the sinus drain from the ethmoidal region into the maxillary region reveals the chronic state of the infection (Coughlan, 2016; Abouzari, 2022; Julka, 2023). Kalaiarasi *et al*. (2013) reported that sinusitis leads to an increase in the skin surface temperature of the face. In our study, it was observed that there was a decrease in temperature in the sinus-infected regions. This result could be due to sinusitis, which leads to inflammation. Thereby, the fluid in the sinus cavity indicates a decrease in the skin surface temperature.

### Conclusion

The study signifies the effect of sinus infection on the HbA1c. The study finds potential merit over X-ray imaging and biopsy tests as the sinus-infected regions were diagnosed using IR thermal imaging with no subject discomfort. Further, when a physician plans surgery, the thermal image could give detailed information about the sinus drainage, deviated septum and the region at which the corrective surgery has to be done. The early indication of sinus infection among the control and pre-diabetic subjects indicated the prognostic capability of this thermal imaging method when the inflammatory bio-marker and the conventional imaging modality were found unsuitable to serve the purpose.

## Ethical Statement

The study was approved by the SRM Hospital IRB.

## Acknowledgements

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## Conflict of Interest

The author declares no conflicts of interest.

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