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Early Diagnosis of Acute wound Infection in Orthopaedic Trauma using CRP and Serial Periwound Skin Temperature Monitoring by Infrared Thermoradiography

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Infrared imaging allows non-contact, non-radiating, non-invasive investigation of biological systems, both in preclinical research settings and in the clinical assessment of patients. Quantitative measurement of periwound skin temperature using a reliable infrared camera can assist the wound care practitioner with early identification of deep or spreading infection, allow for timely intervention, and help to monitor ongoing treatment response.
Aim: To assess the wound healing in orthopaedic trauma using infrared camera as an adjunct in clinical practice.
Methods: Prospective observation study of 40 patients with acute wound managed in a tertiary centre from December 2018 to October 2019. Infrared camera used as an adjunct along with other routine blood investigations to assess the healing of these wounds during the course of hospital stay. All skin temperatures were documented using a handheld infrared camera under consistent

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environmental conditions on the day of dressing. Wound infection was identified using the combination of a serial CRP value and clinical judgement.
Results: Out of 40 patients, 28 cases were post operative wounds and none of them developed any complications. The remaining 12 cases were post traumatic, in which 4 developed infections. These cases were identified by infrared camera in correlation with CRP and other clinical parameters.
Conclusion: Infrared thermography can act as an adjunct in acute post traumatic and post-surgical wound to monitor healing. It cannot replace an experienced clinician's assessment and judgement based on individual patient and wound factors.

Keywords: Infrared camera; acute wounds; peri wound skin temperature; infection.

1. INTRODUCTION

Wound healing is a dynamic and precisely programmed process include haemostasis, inflammation, proliferation and remodelling. "The extent of primary wound contamination is dependent on the mechanism of injury and the environment in which the injury was sustained" [1]. About 70–80% acute traumatic wounds develop primary colonisation of organisms [2].

Increase in vascularity is a hallmark feature of many pathological changes such as inflammation due to increased metabolic activity. This will lead to increase in temperature, which can be detected by using an infrared thermographic camera called as dynamic infrared thermography (DIRT).

Early detection of postoperative wound infection reduces the morbidity. C-reactive protein (CRP) is a useful marker for the early diagnosis of infection. CRP levels starts to increase by 4 to 6 hours post trauma and post-surgery. "Levels peak by 24 to 48 hours and return to baseline by 3rd day. Persistent elevation of CRP levels beyond postoperative or post traumatic day 3 is therefore suggestive of infection" [3].

Infrared imaging is an outstanding technique that allows non-contact, non-radiating, non-invasive investigation of biological systems. Infrared thermography is a digital imaging technique in which a camera detects radiation of the electromagnetic spectrum. "The emitted thermal radiation of a surface is measured and translated into a matrix of temperature measurements and will provide a visual map of skin temperatures in real time. Infrared thermography can allow the immediate assessment of inflammation of the skin because inflammation of the skin or deeper tissue layers cause an increase in skin temperature"[4].

We measured serial periwound skin temperature with a hand-held infrared camera in 40 patients with acute post operative and post traumatic wounds and correlated with CRP values to identify wound infection.

2. MATERIALS AND METHODS

Prospective observation study of 40 patients with acute wound managed in a tertiary centre from December 2018 to October 2019. After getting approval from institute ethics committee informed consent from each patient was taken. Acute traumatic wounds and post operative wounds were included in our study. Infrared thermographic imaging and CRP measurement were done as a baseline on the day of surgery or when patient arrives casualty with an acute wound. During the post operative period all patient were under antibiotics, analgesics and anti-inflammatory drugs. Any discharge from the wound and increase in body temperature were noted. Blood samples were collected from a peripheral vein on postoperative day 4 and 6. Patient follow up done till the day of discharge. A hand-held digital infrared thermographic camera used to monitor the peri wound skin temperature. This is a non-contact, non-invasive, quick, economic and does not impose any pain on the patient. It is a relatively straightforward non-radiographic imaging approach that detects the temperature variation on the human skin surface. It is a dynamic imaging technique which yields 2D images where each pixel represents the temperature value, from which different region of interest can be studied. We used the Therma CAM™ Reporter 2000 Professional software to complete a report. A reference temperature scale in the form of a colour gradient is given adjacent to each infrared image to compare temperature. The blue and blue-green areas represent lowest temperature, yellow-red areas represent higher temperature and red-white areas represent

highest temperature. Increase in temperature is directly proportional to degree of inflammation.

2.1 Criteria of Inclusion (COI)

- Minimum age of 18 years.
- Permission to enrol patient granted by the surgeon who manages the patient.
- Persons with an acute traumatic wound or with injury.

2.2 Criteria of Exclusion (COE)

- Hemodynamic instability, resuscitation/ intensive care requirements as judged by the trauma surgeon
- Patients suffering advanced medical conditions where the severity of the condition was such that the patient was not expected to survive for the follow-up period.
- End-stage peripheral vascular disease, problems which would be expected to progress to amputation.

Student t test (two tailed, paired) was used to find the significance of study parameters on continuous scale within group. Significance is assessed at 5% level of significance ($p < 0.05$). The following assumptions on data are made. Data entered into Microsoft excel and analysed using statistical software IBM SPSS version 22. Microsoft Excel 2010 has been used to generate the master chart, tables and graphs.

2.3 Procedure and Conduct of the Study

40 patients, who were meeting the inclusion criteria, were considered for the present study after getting approval from the institutional ethics committee. When patient arrives at the emergency department, wound cleaning done under adequate analgesia. Infrared thermographic images are taken under optimal conditions from the emergency medicine department itself. Blood samples were collected from a peripheral vein on the day of admission and on postoperative days 1,4 and 6. Photograph of wound was taken with digital infrared camera and temperature is noted. Patients were discharged on 7th day according to the decision of treating surgeon. All patients were undergoing appropriate surgical procedures and complications were managed as per standard treatment protocols.

2.3.1 Case 1

A 38-year-old male patient admitted following a road traffic accident with compound fracture of both bones of leg (Fig. 1). Treated by wound debridement and stabilization of fractures. Serial CRP measurement and periwound temperature monitoring were done (Fig. 2). Elevated CRP and periwound temperature from day 4 to 6 suggestive of infection.

2.3.2 Case 2

A 40-year-old male patient admitted following a road traffic accident with compound fracture of distal end both bones of leg (Fig. 3). Treated by wound debridement and stabilization of fractures. Serial CRP measurement and periwound temperature monitoring were done (Fig. 4). Fall in CRP and periwound temperature from day 4 to 6 suggestive of absence of infection.

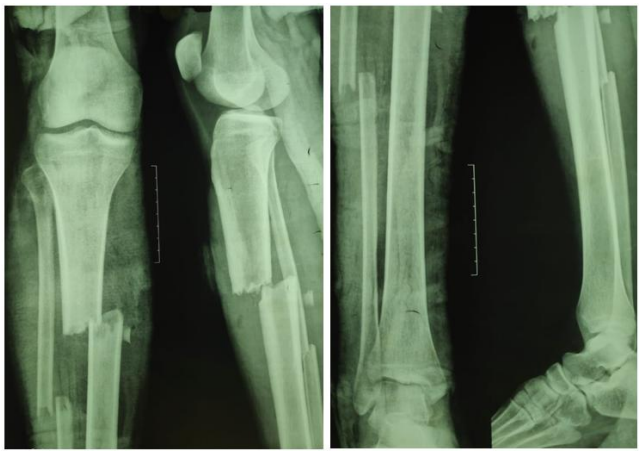

Fig. 1. Xray of case 1 showing compound fracture of both bones of leg

Fig. 2. Infrared thermography images of wound of case 1 showing periwound skin temperature on day 0,1,4 and 6

Fig. 3. Xray of case 2 showing compound fracture of distal end both bones of leg

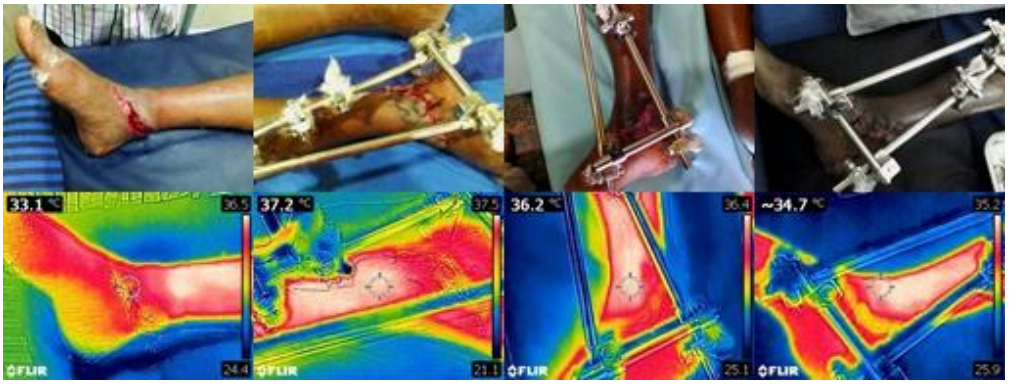

Fig. 4. Infrared thermographic images of case 2 showing periwound skin temperature

3. RESULTS

Out of 40 patients 14 were female and 26 were male patients. 12 patients were admitted following a trauma and 28 patients were post-surgery. Out of 40 patients, 28 cases were post operative wounds and none of them developed any complications. Among 12 cases post traumatic cases, in which 4 developed infections.

Mean value of CRP and peri wound skin temperature among 40 patients on day0,1,4 and 6 were calculated (Fig. 5,6). The linear correlation between these two data shows significant Pearson correlation coefficient on day 1,4 and 6 where the p value is <0.05. On day 0, mean value of CRP and peri wound skin temperature did not show any significant correlation.

Mean value of peri wound skin temperature value shows ascending trend on day 4 and day 6 in infected wounds and descending trends in non-infected wounds (Fig. 7).

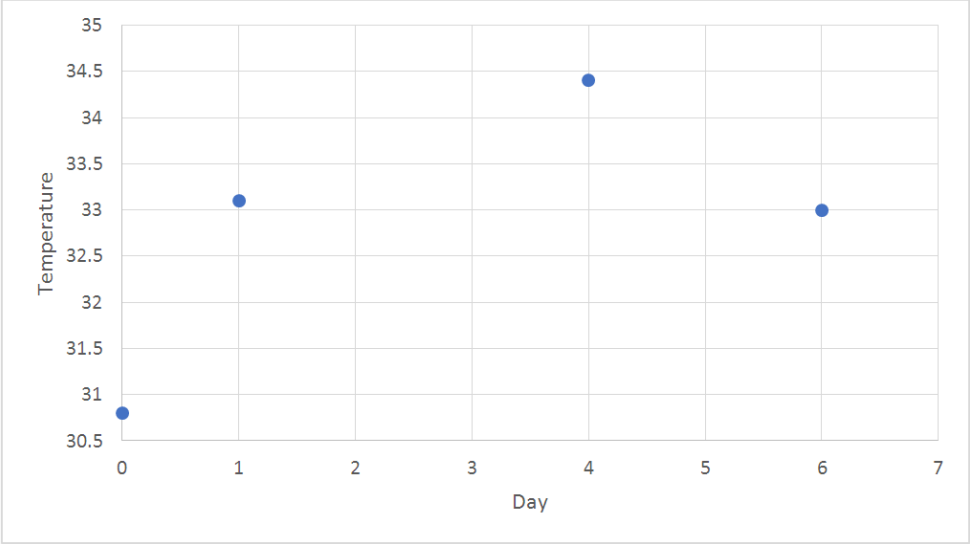

Fig. 5. Mean value of periwound skin temperature of 40 patients on day 0,1,4, and 6

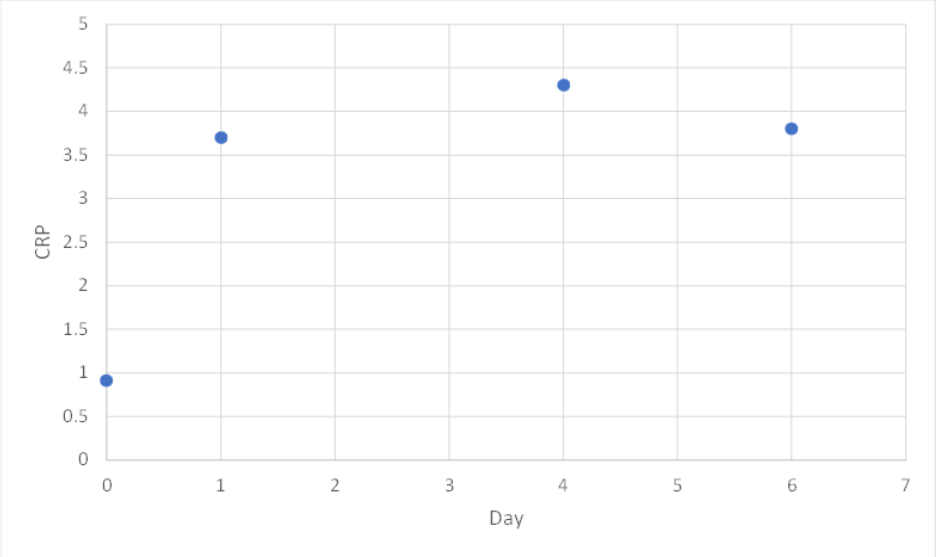

Fig. 6. Mean value of serial CRP measurement of 40 patients on day 0,1,4 and 6

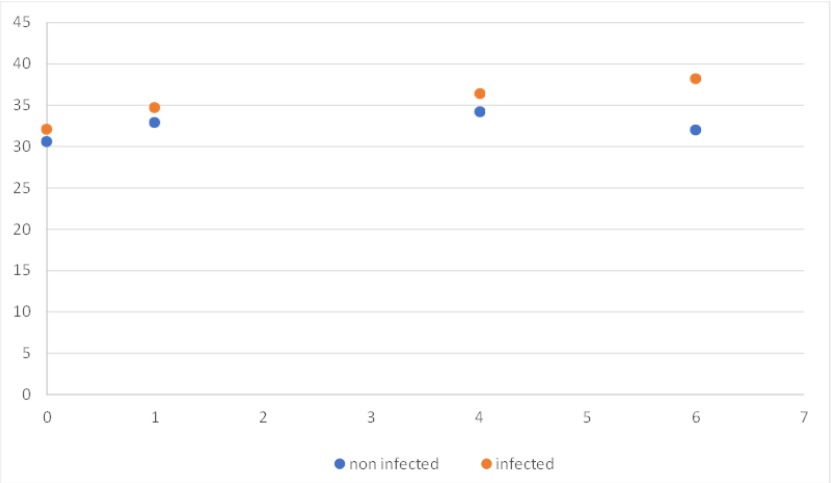

Fig. 7. Mean value of periwound skin temperature on day 0,1,4 and 6 of infected and noninfected cases

4. DISCUSSION

This clinical research study was conducted to quantify the relationship between increased peri wound skin temperature and CRP values in a local wound infection and to validate the use of the handheld infrared camera for early diagnoses of infection in acute wounds.

C-reactive protein is an inflammatory marker, and its levels increase during infection [5]. "The CRP concentration increases on day 2 after elective orthopaedic procedures" [6]. "Studies have reported that CRP levels decline sharply from day 3 in subjects without infection and progressively increase in patients with infection, which is a feature consistent with sepsis" [7,8].

In our study CRP levels were sharply decline after day 4 in wounds without infection. In case of infection CRP levels were persistently elevated after post op day 4.

"The temperature of human body is highly variable and it is comparable to a symmetrical site under normal circumstances" [9]. "Body surface temperatures vary widely between person to person and by body location" [10].

"Horzic et al compared skin temperatures adjacent to healing postsurgical wounds. According to the stage of wound healing increased skin temperature was detected for the first 3 days and gradually decreased between days 4 and 8. Infection and disturbed healing of wound is predicted by persistence of increased skin temperature after the third postoperative day" [11].

"Robicsek et al studied early diagnosis of postoperative sternal wound infection by monitoring periwound skin temperature using infrared thermometer" [12].

In our study we measured skin temperature using a handheld infrared camera in 40 patients. Out of 40 patients, 28 cases were post operative wounds and none of them developed infection. The remaining 12 cases were post traumatic, in which 4 developed infections. Mean value of peri wound skin temperature decreased after day 4 in non-infected wounds. Persistent increased temperature after day4 noted in 4 patients who had infection.

Statistical analysis of skin temperature data and CRP values of participants with wounds demonstrates a strong relationship between these two. In infected acute wounds the quantitative measurement of increased peri wound skin temperature and increased CRP levels shows significant correlation.

4.1 Limitations of this Study

- Co morbidities among patients were not taking into consideration.
- Not considering the treatment modalities and other supportive measures given to the patient.
- Variables such as the surrounding temperature, humidity or airflow can

greatly influence the skin surface temperature.

4.2 Benefits

- Non-contact and non-invasive
- Skin surface temperature screening
- Quick
- Economic
- Does not impose any pain on the patient

4.3 Drawbacks

- Expensive instrument
- Interpretation of the thermal images requires specific training
- Controlled environment

5. CONCLUSION

The ability of a handheld infrared thermal camera to identify and quantify the increased peri wound skin temperature in acute wound infection can be used as a part of routine wound assessment. Quantitative measurement of peri wound skin temperature using a handheld infrared camera can assist the surgeon with early identification of infection. A positive correlation between CRP and peri wound skin temperature suggest that infrared thermography is a useful tool for early detection as well as timely intervention and help to monitor ongoing treatment response. However, the clinician's assessment of wound based on individual patient is unavoidable.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

As per international standard or university standard, patients' written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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