Role of infrared thermography in the assessment of burn wounds treated with and without hyperbaric oxygen therapy

ABSTRACT

Aim: The aim is to study the role of infrared thermography in the assessment of burns wound treated with and without hyperbaric oxygen (HBO) therapy. Burn wound progression is assessed with clinical evaluation and infrared thermography for the patients subjected to HBO therapy with controls.

Materials and Methods: This study was carried out in the plastic surgery department, from November 2018 to February 2019. A total of 21 patients with Burns were subjected to clinical evaluation and thermographic study. All patients were treated according to standard burns treatment protocol, and photographic data of clinical and thermographic imagings were sequentially recorded. These clinical and radiographic images were preserved for analysis. In 10 patients, HBO therapy was used as an adjunct for burns wound management and results were evaluated and rest of the patients was used as control.

Results: Of 21 patients, with all patients' burns patients assessment done clinically and infrared thermography, 10 patients were subjected to hyperbaric therapy in random fashion and 11 patients were not subjected to HBO therapy. The duration of wound healing and wound progression to deeper planes were reduced in the patients subjected to hyperbaric therapy, which was evident both clinically and, by thermographic assessment. No complications were noted in patients subjected to HBO therapy.

Conclusions: Infrared thermography can be used in association with clinical examination to assess the various types of burns wound and could be utilized for understanding the dynamic changes that happen in burns wound due to changes in the treatment protocol with evolving adjunct managements.

Keywords: Burn depth, hyperbaric oxygen therapy, infrared thermography, thermal burn

INTRODUCTION

The assessment of the burn wound remained mostly clinical as the burn wound dynamically changes its course during the treatment. The accuracy of the clinical wounds may vary within a range from 50% to 70%.[1] Adjunct modalities have evolved during the recent years which proved the outcome of burns wound would be improved by carefully applying them in planned manner. Hyperbaric oxygen (HBO) therapy is one such modality to improve the healing of burn wounds when used appropriately.[2] However, there was no objective wound assessment to measure the dynamic changes in burns wound during these adjunctive therapies. Newer technologies have extended the scope of measuring the progress of burns wound depth for comparative analysis with clinical assessment.[3] Agarwal et al.[4] used a handheld infrared thermometer to measure the surface temperature of burn wounds to assess the depth of burn.[4] Infrared
thermography could very well be utilized to estimate the progression of burns wound and could be utilized to check whether the burn wounds are taking the right course during different modes of intervention.

MATERIALS AND METHODS

This study was carried out in the Plastic Surgery and Burns Department, from November 2018 to February 2019 in a tertiary referral center in South India. A total of 21 patients with burns were subjected to clinical evaluation and thermographic study. All patients were treated according to standard burns treatment protocol, and photographic data of clinical and thermographic imagings were sequentially recorded till the wound heals completely. By clinical evaluation, the burn wounds depth was classified clinically into full-thickness, deep partial-thickness, or superficial partial-thickness burns and the progress evaluated till the wound healed. Simultaneously, thermographic images were also obtained during the evaluation. Thermometry was performed using the handheld infrared thermometer (FLIR one camera) at a distance of 30 cm from the skin. The temperature of the burn surface and the temperature of the surrounding normal skin were recorded. All the patients were afebrile during thermographic image recording. These clinical and thermographic images were preserved for analysis with FLIR software (Wilsonville, Oregon, United States). The duration of wound healing, need for debridement, and skin grafting was assessed. In 10 patients, HBO therapy was used as an adjunct for burns wound management, and results were evaluated and rest of the patients were used as control.

RESULTS

A total of 21 patients with burns were included in the study. Of 21 patients, burns wound assessment done clinically and by infrared thermography. Ten patients were subjected to hyperbaric therapy and 11 patients were not subjected to HBO therapy in random fashion. There were 12 males and 9 female patients. A total of 9 pediatric, 1 geriatric and 11 adults were included in the study. The average age was 23.38 years (range 1–78 years). Two out of 21 burns wound on the clinical assessment were thought to be superficial but were predicted deep by thermographic images [Figure 1]. Average healing time for patient treated with HBO in case of hot water spillage was 7.7 days. Average healing time was 14.5 days in patients not subjected to HBO therapy [Tables 1 and 2]. The duration of wound healing and wound progression to deeper planes were reduced in the patients subjected to hyperbaric therapy, which was evident both clinically and by thermographic assessment. No complications were noted in patients subjected to HBO therapy.

CASE REPORTS

Case 1
A 32-year-old male was admitted with 12%–15% TBSA burns involving the face and bilateral hand due to electrical burns with components of flame burns more than electric shock [Figure 2a and b]. He underwent wound debridement on day 1 and assessment was done clinically and with infrared thermography. HBO therapy was administered for 12 sessions at 1.8–2.4 atmospheres absolute (ATA). Superficial and deep Second-degree burn wounds were assessed and compared with clinical, digital photography, and thermographic images sequentially on day 1, 3, 5, 7, and 9. Clinical and thermographic images showed improvement in the wound. Wound healed with these interventions within 8 days.

Case 2
A 3-year-old male was admitted with 30%–35% TBSA burns involving the face and bilateral hand due to scalds [Figure 3]. HBO therapy was administered for 12 sessions at 1.8–2.4 ATA. Superficial and deep Second-degree burn wounds were assessed and compared with clinical, digital photography and thermographic images sequentially on day 1, 4, 6, and 8. Clinical and thermographic images showed improvement in the wound. The wound healed with these interventions within 8 days.
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Table 1: Data of comparison on clinical, infrared thermographic assessment, surgical outcome, and duration of wound healing of patients not subjected to hyperbaric oxygen therapy

| Age/sex  | Type of burns | Clinical assessment | Discrepancy with clinical and thermographic findings | Surgical intervention | Duration of wound healing (days) |
|----------|---------------|---------------------|-----------------------------------------------------|-----------------------|----------------------------------|
| 9/male   | Scalds        | 2* deep and 2* superficial | Nil | Nil | 14 |
| 8/male   | Scalds        | 2* superficial      | Nil | Nil | 12 |
| 6/male   | Scalds        | 2* deep and 2* superficial | Nil | Nil | 12 |
| 27/female | Flame/cracker | 2* deep and 2* superficial | Nil | Nil | 17 |
| 29/male  | Scalds        | 2* deep and 2* superficial | Nil | Nil | 18 |
| 11/male  | Scalds        | 2* superficial      | Nil | Nil | 10 |
| 10/male  | Scalds        | 2* deep and 2* superficial | Nil | Nil | 18 |
| 78/female | Flame        | 2* deep and 3* deep | Appeared deep in thermography | Skin grafting | 30 |
| 55/male  | Scalds        | 2* deep and 2* superficial | Nil | Nil | 19 |
| 48/female | Scalds        | 2* superficial      | Nil | Nil | 12 |
| 1 year/female | Scalds  | 2* superficial | Nil | Nil | 12 |

*Represents: Degree(°)

Table 2: Data of comparison on clinical, infrared thermographic assessment, surgical outcome, and duration of wound healing of patients subjected to hyperbaric oxygen therapy

| Age/sex  | Type of burns | Clinical assessment | Discrepancy with clinical and thermographic findings | Surgical intervention | Duration of wound healing (days) |
|----------|---------------|---------------------|-----------------------------------------------------|-----------------------|----------------------------------|
| 2/female | Scalds        | 2* deep and 2* superficial | Nil | Nil | 4 |
| 10/female | Scalds       | 2* deep and 2* superficial | Nil | Nil | 10 |
| 27/female | Silencer burns | 2* deep and 3* deep | Nil | Skin grafting | 27 |
| 18/female | Flame        | 2* deep and 3* deep | Nil | Skin grafting | 17 |
| 21/female | Kerosene burns | 2* deep and 3* deep | Appeared deep in thermography | Skin grafting | 52 |
| 25/male  | Scalds        | 2* deep and 2* superficial | Nil | Nil | 8 |
| 35/male  | Flame- gas leak | 2* deep and 2* superficial | Nil | Nil | 10 |
| 3/male   | Scalds        | 2* deep and 2* superficial | Nil | Nil | 9 |
| 36/male  | Flame/cracker burst injury | 2* deep and 2* superficial | Nil | Nil | 17 |
| 32/male  | Electrical burns - flame | 2* deep and 2* superficial | Nil | Nil | 8 |

*Represents: Degree(°)

Case 3
A 29-year-old male was admitted with approximately 2%-5% TBSA burns involving the left foot dorsum and plantar aspect due to scalds [Figure 4]. Second-degree superficial and deep burns were assessed and compared with clinical, digital photography, and thermographic images sequentially on day 1, 4, 6, and 11. Clinical and thermographic images showed improvement in the wound. Wound healed with these interventions within 18 days.

Case 4
A 1-year-old female child was admitted with approximately 7%-9% TBSA burns involving the right arm, forearm, and posterior thorax right side due to scalds [Figure 5]. Second-degree superficial and deep burns were assessed and compared with clinical, digital photography, and thermographic images sequentially on day 1, 5, and 11. Clinical and thermographic images showed improvement in the wound. The wound healed with these interventions within 12 days.
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DISCUSSION

Burns wound progression as it depends on multiple factors, a careful continuous assessment of the wound is necessary for a proper outcome. Assessment of the burn wound remained mostly clinical as the burn wound dynamically changes its course during the treatment. The accuracy of the clinical wounds may vary within a range from 50% to 70%.[3] Newer modalities have evolved the scope of measuring the progress of burns wound depth for comparative analysis with clinical assessment.[3] The assessment could be done in terms of wound dimension, functional wound closure, and wound perfusion. Optical imaging and harmonic ultrasound imaging are useful tools for wound dimension assessment. Transepidermal water loss measurement will assess the functional wound closure. Hyperspectral imaging of partial oxygen saturation, fluorescent vascular angiography with indocyanin green, laser speckle contrast imaging of microvessels, ultrasound Doppler imaging may help in the assessment of burn wound perfusion.[3] Most of these investigations, even though not be feasible at present, would be an aid to the burns surgeon in near future. A evidence-based approach is always useful to know the wound progression, so that its helps a plastic surgeon to take appropriate treatment modalities before the disease condition worsens. Burn depth estimation may determine the prognosis of burns wound, which causes hypertrophic scarring in small wounds if not excised early or may result in septicemia in larger wounds. Clinical evaluation, as it considers multiple associated comorbidities remains superior most tools for assessment with these newer modalities as adjunct for wound assessment. Agarwal et al.[4] used a handheld infrared thermometer to measure the surface temperature of burn wounds to assess the depth of burn.[4] Infrared thermometry assesses the burn wound temperature by measuring infrared radiation emitted from wounds. When there is increasing depth of burns, the surface temperature will be reduced as there is less vascular perfusion. Surrounding inflammation can also be observed when there is increase of

Figure 2: (a) Sequential clinical and infrared thermographic images of flame burns involving bilateral hand treated with hyperbaric oxygen therapy. (b) Sequential clinical and infrared thermographic images of flame burns involving face treated with hyperbaric oxygen therapy.
Figure 3: Sequential clinical and infrared thermographic images of flame burns involving face, trunk, and upper extremity treated with hyperbaric oxygen therapy
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Infrared thermometry is considered superior to clinical examination in estimating burn wound depth.\cite{4} Evaporation of water from the burns wound surface, ambient temperature, timing of study, wound with granulation, and variations in vasculature depth in different body locations may lead to ambiguous results.\cite{8,9}

Adjunct modalities have evolved during the recent years which proved the outcome of burns wound would be improved by carefully applying them in planned manner. HBO therapy is one such modality to improve the healing of burn wounds when used appropriately.\cite{2} The first monoplace chamber at the Karolinska was part of the burns unit and began treatments of less critically ill, spontaneously breathing patients in 1991. Local and general inflammatory syndrome sets in burns injury, which results in the deepening of the burn wound during the first 24 h of injury. This results in a 20-fold increase in the oxygen consumption (oxidative burst) and production of free radicals resulting in a vicious circle of inflammation.\cite{10}

The utilization of HBO therapy in early phases of burns trauma reduces the plasma loss by precapillary vasoconstriction into
the injured capillary bed, but still maintaining a sufficient oxygenation for the survival of dermal cellular elements. A lesser degree of dermal destruction was illustrated by means of faster reversal of capillary stasis by HBO therapy. A paradoxical reduction of oxygen-free radicals production after reperfusion of the ischemic burn wound has been demonstrated. To obtain maximal beneficial effect of HBO therapy in burns injury, the therapy should be administered as early (ideally within 6 h). A retrospective study of Cianci and Sato revealed that patients receiving HBO (2.0 ATA, 90 min, twice daily) in the acute phase, resulted in reduction of perfusion volumes required. Integrating HBO into the early treatment protocol illustrates the reduction of incidence of respiratory insufficiency due to reduction in perfusion volumes required.

Hyperbaric oxygenation maintains adequate oxygenation in the burned areas protecting the tissue from colonization or infection by anaerobic organism. In animal studies, it has been demonstrated that the degree of intestinal bacterial translocation after a severe burn wound is significantly reduced when HBO therapy is administered. A significantly lower incidence of sepsis is also found in the HBO treated group. HBO also potentiates the function of certain polymorphonuclear white blood cells and augments the function of certain antibiotics. Angiogenic effect of HBO therapy helps to prepare the wound bed for skin grafting procedure at the earliest and provide sufficient oxygenation of graft by diffusion. Evidence-based tools to evaluate the progression of burns wound subjected to different modalities are need of the hour.

Infrared thermography being noninvasive, could very well be utilized to estimate the progression of burns wound and could be utilized to check whether the burn wounds are taking the right course during different modes of intervention. The objective burn wound assessment helps in both educating the team and the patients regarding burn wound progression and priming them on necessary wound management protocols to be taken up.

CONCLUSIONS

Infrared thermography can be used in association with clinical examination to assess the various types of burns wound and could be utilized for understanding the dynamic changes that happen in burns wound due to changes in the treatment protocol with evolving adjunct managements.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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