ABSTRACT

**Aim:** To identify perfusion differences between the areas of different depths and to evaluate the potential of portable indocyanine green (ICG) perfusion assessment to determine the likelihood of healing in burns compared with visual assessment.

**Materials and Methods:** This interventional study was carried out at the burn unit and plastic surgery department, from April 2017 to September 2017. A total of 20 patients with superficial and partial thickness burns <15% for whom the burn assessment was done with portable ICG perfusion assessment and visual assessment were included in the study. The results regarding the excision of burn wound and burn wound healing were compared.

**Results:** Of 20 patients, 14 patients did not have any discrepancy with the clinical findings and ICG perfusion assessment. The findings of five patients appeared clinically deep, but perfusion was present which did not require surgical intervention. One patient had patchy perfusion and finally required surgical correction.

**Conclusion:** ICG perfusion assessment appeared to be effective in preventing surgical intervention in patients by differentiating deep to superficial second-degree burns. Proper clinical assessment and ICG perfusion assessment as an adjunct can improve the outcome of burn wound.

**Keywords:** Depth analysis, indocyanine green perfusion assessment, second-degree burns, visual assessment

INTRODUCTION

Wound assessment largely relied on clinical findings in burn patients in most of the burn centers in India. Some of the useful noninvasive modalities are available at present to assess burn injury, which guides us to safe surgical intervention in critical burn patients. In patients with burn injury, there is an intense need of understanding the depth of injury, particularly of second-degree burns, which makes our intervention safer.

Sheridan et al. described the use of indocyanine green (ICG) fluorescence. The authors made a clear difference in perfusion in deep burns compared to superficial burns. Later, Still et al. demonstrated with a trial in nine patients.

Due to the limitations of the technology during that period, the authors could only perform a visual assessment of the fluorescein images, and the equipment was cumbersome to use. In the present study, we tried to understand the depth of burn wound by ICG infusion to the patient and evaluated Portable indocyanine green perfusion assessment: An adjunct to visual assessment in burn wound healing in second-degree burns

**Keywords:** Depth analysis, indocyanine green perfusion assessment, second-degree burns, visual assessment

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the burn wound according to the fluorescent video captured through a monochrome industrial camera.

**MATERIALS AND METHODS**

The Ethical Committee of Jubilee Mission Medical College and Research Institute approved this study. Twenty patients with second-degree burns <15% total body surface area (TBSA) were screened for inclusion in the study. Pediatric patients; pregnant patients; and patients with comorbidities such as renal failure, diabetes mellitus, hypertension, and epilepsy were excluded from the study. Informed consent was obtained from the patients participated in the study. Visual assessment and wound care was proceeded as per the standard protocol of the burn unit. After initial debridement, ICG perfusion assessment was performed as follows:

1. The monochrome camera was mounted on a stand and was placed at a distance from the field of view [Figure 1a]
2. The light source (21 lights) was mounted on the same stand and was placed at a distance closer from the field of view [Figure 1b and c]
3. An intravenous dose of 5 mg of ICG was injected (safe doses: up to 50 mg at one setting). Injection is followed by fluorescence imaging and digital videography captured from the burn wound. The lowest effective dose was chosen to ensure patient safety
4. The injection of ICG led to the visualization of perfusion within 1–2 min. The video of the perfusion was visualized, recorded, and clinically correlated [Figure 2a], until the ICG began to washout, a process that is usually complete around 5 min
5. Clinical decisions were made based on standard visual assessment and ICG perfusion measurement as per the usual protocol of our burn unit.

**RESULTS**

Twenty patients of burns were included in the study [Table 1]. The mean age of the patients participated in the study was 43 years. The modes of burns were five scalds, three electrical burns, two firecracker burns, seven flame burns, one kerosene burn, one friction burn, and one contact burn. Seventeen patients were male and three were female. Of 20 patients, 13 patients did not have any discrepancy with the clinical findings and ICG perfusion assessment. The findings of five patients appeared clinically deep, but perfusion was present which did not require surgical intervention. One patient had patchy perfusion and finally required surgical correction. One patient of friction burns showed deep in both visual and perfusion assessment of evaluation, but healed without any intervention.

**Case 1**

A 30-year-old female was admitted with 7% TBSA burns involving the sacral region and bilateral thigh while rescuing her husband from electrical burns on an 11 kV line [Figure 2a and b]. She underwent wound debridement on day 1, and assessment was done clinically and with ICG perfusion visual assessment. Second-degree superficial and deep burns were assessed and compared with ICG perfusion. There was no difficulty while assessing third-degree burns. The photographs and perfusion images are shown in Figure 2c and Video 1.

**Case 2**

A 30-year-old male was admitted with firecracker burns involving the left upper limb, forearm, hand, and left lower limb comprising approximately 12% TBSA. On day 1, the patient posted for wound debridement [Figure 3a-d]. Intraoperatively, there was a sign of impending compartment
syndrome of the hand and forearm, for which fasciotomy was performed. On clinical assessment, the wound on the left forearm and left leg appeared deep second-degree burns. On ICG perfusion visual assessment, videography showed adequate perfusion in the leg wound, representing second-degree superficial in nature [Figure 3e-g]. Left forearm and hand wound showed patchy perfusion in fluorescence imaging, indicating second-degree deep components of burn injury. Leg wounds were managed conservatively, and deep areas of the hand required excision and skin grafting [Figure 3h and Video 2].

**Case 3**
A 34-year-old male admitted to the burn ward with 7% burns involving the right upper limb [Figure 4a and b]. Clinically, involved region appeared to be second-degree deep burns, but ICG perfusion showed adequate perfusion, indicating superficial nature of injury [Figure 4c]. Burn wound healed with a conservative line of management [Video 3].

**DISCUSSION**
Burn wound assessment is largely relied on clinical findings in most of the burn centers in the Indian subcontinent. The need to identify the burn wound depth is crucial in the management of these complicated wounds. Early identification of depth of wound and surgical correction by supplementing skin autograft to the specific region results in decreased morbidity and higher utility of the donor area. Recently, various cutaneous imaging modalities such as optical imaging, harmonic ultrasound technology, laser speckle imaging, fluorescence imaging, and ultrasound Doppler imaging are used to identify the burn wound depth.[10] In the present study, we have used the ICG fluorescent assessment as an adjunct for clinical assessment in twenty burn patients to determine the potential of management in second-degree burn wound.

ICG fluorescence assessment has a potential to differentiate the depth of burn wound several days before it becomes evident to an experienced burn surgeon by visual analysis.[4] Sheridan et al. initially applied the method of analysis with ICG perfusion in burn wound in animal models.[2] Later, Still et al. demonstrated the use in nine patients.[3] In our study, the ICG fluorescence was incorporated into a portable device which was used to visualize the perfusion, following coronary anastomosis. ICG perfusion visual assessment was carried on after the primary debridement following burn admission. We found that, in burn wound without debridement, the skin debris may hinder with the visual analysis of perfusion. Imaging technique was performed at single time point after burn, after initial debridement, and videography was recorded for the future reference. There is a necessary for a dark room for the evaluation for perfusion. Handheld real-time imaging fluorescent systems in a mobile cart are evolving nowadays for the evaluation of tissue perfusion in case of perforator

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**Figure 3:** (a) Firecracker burns involving the volar aspect of the left hand and forearm, (b) lateral aspect of the forearm with fasciotomy to release the compartment syndrome, (c) volar aspects of the left forearm and hand clinically resembling deep second-degree burns postcarpal tunnel release for compartment syndrome, (d) anterior aspect of the left foot and leg resembling deep second-degree burns, (e) indocyanine green perfusion near fasciotomy wound with patchy uptake, (f) indocyanine green perfusion image of the left hand dorsum with patchy perfusion, (g) indocyanine green perfusion in the leg indicating superficial nature of burns, (h) post skin grafting for deep areas in the left hand and forearm.

**Figure 4:** (a) Volar aspect of the right forearm and hand appearing as second-degree deep burns, (b) dorsal aspect of the right forearm and hand appearing as second-degree deep burns, (c) indocyanine green perfusion showing uniform perfusion showing superficial nature of burns.
identification or tumor tissue perfusion. These instruments may also be used for the intraoperative evaluation burn wound. Computer-aided measurement of ICG perfusion and multiple time of assessment of burn wound may facilitate to visualize the dynamic changes occurring in the burn wound during the stay of the burn patient in the hospital. Incorporation of technological advances should necessarily guide us through this evolution process of visual assessment of burn wound. A videography provides a better assessment than a static image analysis because the area involved for the analysis is usually large in many of the patients admitted in our burn unit.

During our analysis in 20 patients, 14 patients did not have any discrepancy with the clinical findings and ICG perfusion visual assessment. The findings of five patients appeared clinically deep, but perfusion was present which did not require surgical intervention. One patient had patchy perfusion and finally required surgical correction. As a guide to understand the depth of the burn wounds, with ICG perfusion, deeper areas had less perfusion when compared to the superficial one. ICG perfusion assessment certainly avoided surgery in superficial areas with providing better utilization of the donor area for confirmed deep burn wounds.

Functional wound closure depends on the barrier function of the epithelized tissue. Even though epithelium is formed and vascularity is visible, the wound may be functionally open. Functionally, open wound is more evident in a burn patient where there is always a deficit in the component tissue. Functionally, open wound could be possibly measured by the assessment of transepidermal water loss or infrared thermography. These technological advances will certainly let us to understand the finer details of behavior of burn wound three dimensionally from above and below the segment of the wound.

However, there are few limitations of utilizing ICG perfusion as a modality of burn wound assessment. The infusion of ICG dye makes the procedure invasive. Even though the toxicity of ICG is low, it is not absolutely free of risk. In rare instances, effects such as anaphylactic shock, dyspnea, tachycardia, hypotension, and urticaria were noted. In our study, we did not experience any of these symptoms to the patient undergoing ICG infusion.

### CONCLUSION

ICG perfusion assessment appeared to be effective in preventing surgical intervention in patients by differentiating deep to superficial second-degree burns. Proper clinical assessment and ICG perfusion assessment as an adjunct can improve the outcome of burn wound.

### 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

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**Table 1: Data of comparison on clinical, indocyanine green perfusion and surgical outcome**

| Age/sex | Type of burns | Clinical assessment | ICG fluorescent image | Discrepancy with clinical findings | Surgical intervention |
|---------|---------------|---------------------|-----------------------|----------------------------------|----------------------|
| 37/male | scald         | 2* superficial      | 2* superficial        | Nil                              | Nil                  |
| 62/male | Flame         | 3*/2* deep          | 3*/2* deep            | Nil                              | Skin grafting        |
| 53/female | Electrical  | 3*/2* deep          | 3*/2* deep            | Nil                              | Skin grafting        |
| 53/male | Electrical | 3*/2* deep          | 3*/2* deep            | Nil                              | Skin grafting, rotation flap, BE amputation |
| 26/female | Kerosene  | 3*/2* deep          | 3*/2* deep            | Nil                              | Skin grafting        |
| 32/male | Flame/cracker | 2* deep - UL      | Patchy 2* deep - UL 2* superficial - LL | Yes                            | Fasciotomy, skin grafting, web space contracture release |
| 30/male | Flame        | 2* deep             | 2* superficial        | Yes                              | Nil                  |
| 25/male | Scalds       | 2* deep             | 2* superficial        | Yes                              | Nil                  |
| 30/male | Flame        | 2* deep             | 2* superficial        | Yes                              | Nil                  |
| 48/male | Steam        | 2* deep             | 2* superficial        | Yes                              | Nil                  |
| 34/male | Flame        | 2* deep             | 2* superficial        | Yes                              | Nil                  |
| 23/male | Friction     | 2* superficial      | 2* superficial        | Nil                              | Nil                  |
| 36/male | Electrical | 3*/2* deep and 2* superficial | 3*/2* deep and 2* superficial | Nil                              | Skin grafting        |
| 25/male | Flame        | 2* superficial      | 2* superficial        | Nil                              | Nil                  |
| 36/male | Flame        | 2* superficial      | 2* superficial        | Nil                              | Nil                  |
| 65/male | Contact burn | 3*/2* deep          | 3*/2* deep            | Nil                              | Skin grafting, PIA flap |
| 64/male | Flame        | 2* superficial      | 2* superficial        | Nil                              | Nil                  |
| 27/male | Scalds       | 2* superficial      | 2* superficial        | Nil                              | Nil                  |
| 23/male | Flame – cracker | 2* superficial    | 2* superficial        | Nil                              | Nil                  |
| 65/female | Scalds     | 2* superficial      | 2* superficial        | Nil                              | Nil                  |

*Represents: Degree(°). ICG: Indocyanine green, PIA: Posterior interosseous artery, UL: Upper limb, LL: Lower limb, BE: Below elbow
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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