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Development of a precise experimental burn model

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ABSTRACT

Background: Porcine wounds closely mimic human wounds and are often used experimentally in burn studies. Multiple burn devices have been reported but they rarely described precise amount of heat transfer and the burn devices generally have low and varying heat capacity resulting in significant and varying temperature drop.
Methods: The authors developed a customized aluminum burn device with cork insulation and high heat capacity. A thermistor probe was embedded in the device to accurately measure the temperature of the aluminum. The burn injury was inflicted by preheating the burn device to 100 °C and pressing on the dorsum of pig skin for different time points ranging from 5 to 30 s using standardized force of 10 N on the device. With the knowledge of the heat capacity of the aluminum block and the temperature drop, the amount of heat transferred can be calculated.
Result: The temperature drop was 0 °C, 1 °C, 2 °C, 3 °C and 5 °C for a wound-device contact time of 5, 10, 15, 20 and 30 s, respectively. The depths of injury at 72 h after burn were 0.46 mm, 0.82 mm, 1.21 mm, 1.61 mm and 1.91 mm at 5, 10, 15, 20 and 30 s respectively. 3.1 mm represented a full thickness burn. The depth of the burn wounds significantly correlated with the heat transferred per cm^2 (correlation coefficient = 0.96, p-value = 0.03).
Conclusion: The authors describe a simple, standardized and reproducible animal burn model using a customized burn device. The high heat capacity ensures minimal temperature drop which minimizes the variability of heat transferred with a large temperature drop. The correlation between the heat transfer and the depth of injury can facilitate standardization of burn depths in future studies.

1. Introduction

Selection of animal models for burn wound healing studies depends on a number of factors such as cost, ease of handling and anatomical/physiological similarity to humans [1]. Rodents are easily available, affordable and simple to handle and house which makes them an attractive option for wound healing research. On the other hand, swine studies can be expensive and difficult to handle. However, the wound healing in rodents is primarily through wound contraction as compared to reepithelialization which is the main mechanism

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of healing in humans and pigs [2]. Human epidermis ranges from 50 to 120 μm as compared to 30–140 μm for pig epidermis [3]. The dermal–epidermal thickness ratio is between 10:1 and 13:1 in both pigs and humans [4]. Both humans and pigs have well developed rete-ridges, dermal papillae and subcutaneous adipose tissue [5,6]. Physiologically, both human and porcine wounds heal primarily through reepithelialization and granulation tissue formation [5,6]. Sullivan et al. demonstrated a concordance rate of 78% between the results in humans and porcine studies [7].

Burn wounds present a significant challenge to the patient and the treating physician [8]. Multiple studies have evaluated the pathophysiology and optimal management of these injuries. Porcine wound healing closely mimics human wound healing and therefore are often used experimentally in burn studies [9]. Many experimental burn models have been described in the literature with different burn depths and sizes [10–17]. These models rarely allow the description of the precise amount of heat transfer and the burn devices generally have low heat capacity resulting in significant temperature drop [10–12]. The precise amount of heat transfer is critical in predicting the depth of burn injury. There is no data available to allow a comparison of depth of injury if the same amount of heat (calories) is delivered at the same temperature or over a wide temperature range (while the temperature of the burning device is dropping).

The goal of this study was threefold: (1) develop a burn model with precise heat transfer that could provide standardized, comparable and reproducible burns across multiple studies, (2) develop a burn model with high heat storage capacity which would result in lower temperature drop, (3) validate the model by determining the correlation between heat transferred and depth of burn injury.

2. Methods

2.1. Burn device

The burn device consists of a cylindrical 5 cm thick aluminum block that is insulated with cork on all sides except the surface, which comes into direct contact with the skin. (Harvard School of Engineering; Cambridge, MA, USA) (Fig. 1A and B). The diameter of the aluminum block is 3 cm and the total diameter of the device including the flanking cork is 10 cm. A thermistor probe containing wire is embedded in the device for precise temperature monitoring. The increase in temperature on heating the device before application and the drop in the temperature upon application to the skin can be precisely monitored when the probe connected with a digital thermometer (VC97+, Aidetek.com, Parlin, NJ) (Fig. 1B). This allows precise calculation of the amount of heat energy transferred for a defined surface area during the burn which can be calculated using the formula:

$$Q = m \times c \times \Delta T$$

$$(Q = \text{heat transferred}, m = \text{mass of the object}, c = \text{specific heat of the object}, \Delta T = \text{change in temperature})$$

To ensure equal force of application among all wounds during the burn creation, a customized spring loaded device calibrated to 10 N of force is used in order to apply the device to the skin with the same force (pressure).

2.2. Animals

All the animal procedures were approved by the Harvard Medical Area Standing Committee on Animals. Female Yorkshire pigs (Parson's Farm, Hadley, Mass) weighing 50–60 kg were used for this study. Pigs were allowed to acclimatize for 72 h before the experiments. Anesthesia was induced with intramuscular administration of 4.4 mg/kg tiletamine and zolazepam (Telazol; Fort Dodge Veterinaria) and 2.5 mg/kg xylazine (Xyla-Ject; Phoenix) per protocol. General anesthesia was maintained with 1–3% isoflurane (Novaplus, Hospira) and oxygen via endo-tracheal intubation. Oxygen saturation and heart rate were routinely measured during the experiment with pulse oximeter ear sensors. In addition, respiratory rate and rectal temperature were monitored throughout the procedure. After the procedure, pigs were transferred back to the pen and monitored during recovery from anesthesia. A transdermal patch releasing 25 μg fentanyl per hour for 72 h (Duralgesic, Janssen) was given for pain management during surgical recovery and buprenorphine 0.005 mg/kg was administered IM immediately after end of the procedure.

2.3. Burn wound creation

The burn injury was inflicted by preheating the burn device to 100 °C on a heating pad and pressing against the dorsum of pig skin for variable duration using standardized force of 10 N. For

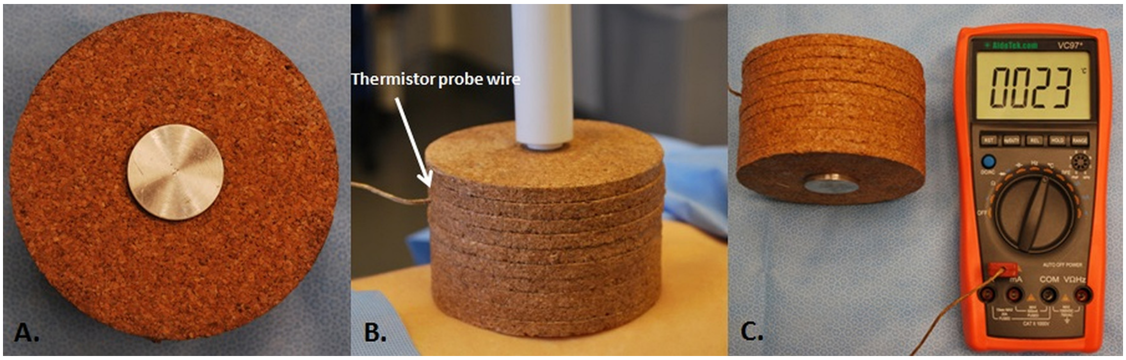

Fig. 1 – (A, B, and C) Customized burn device with thermistor wire probe, spring loaded device and digital thermometer.