Mechanical characterization of burned skin

Burns are one of the common injuries in civilian and combat scenarios. Surgical intervention is recommended for severe burn injuries, i.e., deep partial and full thickness burns. A delay in performing burn care including clinically indicated surgical interventions, or inadequately performed burn care procedures, may cause complications such as muscle necrosis and in severe cases, limb amputation. However, the initial care is often performed outside of a dedicated burn care center due to lack of immediate accessibility and transferability to the centers. Non-expert emergency care providers must be adequately trained to perform burn care, including invasive surgical procedures, as and when the situation demands. Existing medical simulators, however, fall short in providing necessary fidelity for adequate training. They lack the mechanical response and haptic feedback necessary for the trainees to learn prolonged burn care procedures. Hence, to design a high-fidelity simulator for training in burn care related surgeries, there is a need to develop standards for the mechanical properties of the engineered tissue used in the simulator.

Porcine skin is considered a de facto surrogate for human skin for evaluating mechanical characteristics under various thermomechanical loading conditions. However, the mechanical properties of skin tissue change under thermal injury. This study compares the mechanical properties of the full thickness burned human and porcine skin tissues to quantify the statistical similarity between the two. We show that the mechanical characteristics of full thickness burned human skin are different from those of porcine skin. The study relies on five mechanical properties obtained from uniaxial tensile tests at loading rates relevant to surgery: two parameters of the Veronda-Westmann hyperelastic material model, ultimate tensile stress, ultimate tensile strain, and toughness of the skin samples. Univariate statistical analyses show that human and porcine skin properties are dissimilar ($p < 0.01$) for each loading rate. Multivariate classification involving the five mechanical properties using logistic regression can successfully separate the two skin types with a classification accuracy exceeding 95% for each loading rate individually as well as combined. The difference in the mechanical behavior of the full thickness burned human and porcine skin tissues is analyzed based on the structural, compositional, and functional differences between these tissue types.

Other significant results related to mechanical characterization of burned skin tissues and their application in developing standards for high fidelity simulators are also discussed. The findings of this study are expected to guide the development of effective training protocols and high-fidelity simulators to train burn care providers.

Kartik Josyula

Kartik Josyula is a Lecturer with the Department of Mechanical, Aerospace, and Nuclear Engineering at Rensselaer Polytechnic Institute, Troy, NY, USA. He received his Ph.D. in Mechanical Engineering from Rensselaer Polytechnic Institute in 2018. He is an alumnus of IIT Madras and graduated with a Dual degree in Mechanical Engineering in 2009. He worked for 1.5 years in Third Wave Systems, Minneapolis, MN, USA developing constitutive models for the simulation and optimization of metal and composite machining processes. He has over a decade of experience in Computational Materials Modeling. He developed continuum scale and atomistic scale computational models to study the shock-induced phase transformation in energetic molecular crystals. Presently, he advises undergraduate and graduate students in exploring the mechanical characterization of burned skin using novel experimental protocols and data-driven methods. He published 7 journal articles and presented his work in 7 peer-reviewed conferences.