Forces applied to the skin cause a decrease in regional blood flow which can result in tissue necrosis and lead to the formation of deep, penetrating wounds called pressure ulcers. Although surface pressure is known to be a primary risk factor for developing a pressure ulcer, a seated individual rarely experiences pressure alone but rather combined loading which includes pressure as well as shear force on the skin. However, little research has been conducted to quantify the effects of shear forces on blood flow.

Also, deformation of cells in its own right can cause individual cell death leading to tissue necrosis and the formation of a pressure ulcer. It is unclear if ulcers start at the skin level and proceed inwards toward the muscle, or if they start at the muscular level and propagate to the dermal and epidermal regions. Thus, there is a need to study deformation at the deep as well as superficial level to better understand the mode and direction of pressure ulcer propagation.

The goals of this research were to: i) determine the effects of normal and combined loads on arterial and venous blood flow in the forearm; ii) understand the possible mode and direction of tissue necrosis; iii) develop an approach to model arterial to venous blood flow in order to better understand the effects of forces on blood flow; iv) determine the relation of soft tissue thickness and local skin temperature with blood flow at varied load conditions.

To address the first goal, human participants were tested in a MRI scanner under no load, normal load, and a combination of normal and shear loads. Arterial and venous blood flow changes in the forearm were measured using phase-contrast imaging. Results showed that blood flow decreased due to normal loads, and decreased further with combined loads.

To address the second goal, a subject-specific 3D model of the forearm section was developed from MR images, and the effects of normal and shear forces were evaluated through FE analysis. Results showed that combined forces caused increased stresses and strains in skin and muscle when compared to normal forces alone.

The third goal was addressed by creating three models based on deformation geometry and simulating arterial to venous blood flow by assuming muscle tissue to be permeable to blood flow. Results showed that muscle permeability decreased with the application of normal loads, and decreased further with the addition of shear loads.

Finally, the relation between soft tissue thickness and blood flow under varied loads as well as the relation between local skin temperature and skin perfusion under varied loads were explored. Results showed that a smaller magnitude of soft tissue thickness was related to reduced blood flow under combined loading. Increased skin temperatures were also more detrimental to blood flow under combined loading. Thus, shear force is an important factor to consider in relation to tissue necrosis and hence to pressure ulcer formation, and future prevention approaches should address shear loads.