Influence of the calcaneus morphology on the risk of posterior heel ulcer creation

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Abstract: Forty percent of the reanimation or geriatric patients develop a pressure ulcer, of which 40 % are posterior heel ulcers. The main suspected causes are the excessive pressure intensity (leading to internal strains above 50 % for about 10 minutes) and prolonged compression (leading to internal strains above 20 % for about two hours) [1]. Prevention based on daily clinical examination lacks efficiency because deep tissue injuries result from internal strains and when visual symptoms appear it is often too late for treatment. It is consequently important to monitor the internal strains on a patient-specific basis as the shape of the calcaneus in the lying patient might affect the outcome. Based on our previous foot model [2], we study the influence of the calcaneus shape on internal strains. The Finite Element (FE) model used here represents the soft tissues of the lower leg and is composed of four different sub-domains each modelled using a Neo Hookean material with Young moduli and Poisson ratios of 200 kPa and 0.495 for the skin, 30 kPa and 0.49 for the fat, 1 GPa and 0.495 for the tendon, and 60 kPa and 0.495 for the muscles [3], see figure. Bones are modelled as rigid solids. This leg model rests on a FE model of a cushion with three compartments of varying stiffness: under the calf, the Achilles tendon, and the heel back. Simulations carried out on 18 models each implementing a different calcaneus demonstrate the influence of this bone's morphology on the magnitude of internal strains with a standard deviation (STD) of the Von Mises strains of 19.3 percentage points. Additionally, the model was used to identify the supporting cushions' stiffness combination that minimizes the ulceration risk for each individual. The pressure magnitudes below the different sections of the lower leg can be related to the speed of the pressure ulcer creation: higher cushion stiffness below the heel lead to a mean internal strain of 56.9 % with a STD of 13.2 % and could result in ulcers in less than 10 minutes, while mild cushion stiffness maintain the internal strains between 20 and 50 % (with a mean internal strain of 27.7 % with a STD of 2.0 %) and the risk of ulcer creation around two hours [1]. Additionally, the maximal strains are located at the interface between the calcaneus and the fat layer when the cushion is more inflated under the heel, therefore increasing the risk of pressure ulcer when maintained for a long time.

References

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Figure