Various Mathematical Approaches to Mechanical Simulations in Wound Healing Processes (PARTICLES 2021)

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ABSTRACT

Deep tissue injury often results in contraction of skin due to mechanical pulling forces exerted by skin cells in the dermal layer. If contractions are morbid, then they are referred to as contractures. Contractures cause disabilities to the patients, by, for instance, loss of mobility of a joint. By the use of modeling, we aim at understanding the mechanisms behind the formation of a contracture and at predicting which wound is likely to develop a contracture and which treatments can be employed to minimize the likelihood of a contracture. Since the cells are much smaller than the domain of computation, we used the immerse boundary approach based on a superposition of Dirac Delta functions to describe the forces exerted by individual skin cells. The use of this superposition of Delta functions results in a numerical solution that is not in H1. Hence, other alternative approaches are developed to avoid it.

In particular, to describe contractions during wound healing, the forces exerted by cells are actually applied on a continuous curve. Therefore, the region covered by the cell is modeled as a hole in the domain, then the surface forces at the cell are formulated by means of a force boundary condition. The last-mentioned approach shows consistency with the immersed boundary approach, which is proved both analytically and numerically. All the simulations and results will eventually contribute to modeling the contractions of the wound.

On the other hand, we are hunting for the approaches in a general perspective which entail smoothed Dirac Delta distributions. Additionally, we also analyzed a homogenization approach based on Green's fundamental functions. A Gaussian regularization is widely used as a replacement of Dirac Delta distribution. In this approach the selection of the variance has a significant influence on the solution. For one dimension, it is relatively straightforward to demonstrate convergence of the Gaussian distribution approach to the solution using Dirac Delta distribution as the variance is decreasing.

REFERENCES

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