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Modeling contraction in linearly elastic tissue using point sources

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We focus on the contractive forces exerted by fibroblast cells during dermal wound healing. To capture these effects, we construct and analyze two modeling approaches under the assumption of linearized elasticity. The first approach introduces a collection of point forces on the boundary of each fibroblast cell and uses a superimposition principle. The resulting partial differential equation is analyzed rigorously using a sum of radially weighted Sobolev spaces and we propose two discretization approaches. The first is a direct application of the finite element method, which is expected to suffer from sub-optimal convergence. Therefore, a second approach is proposed in which the known singularity is subtracted from the solution and a smooth correction field is sought.

The second modeling approach employs an isotropic stress point source in the cell center. By identifying this model as a limiting case of the point force model, we analyze the model using appropriately weighted Sobolev spaces. By identifying the behavior of the solution, the singularity removal method is shown to be applicable here as well. Moreover, we show that the introduction of the solid pressure leads to a locking-free discretization method using familiar Stokes-compatible finite elements.

The validity of both modeling approaches is confirmed by numerical experiments in two and three dimensions. Moreover, we demonstrate that the rates of convergence of the numerical methods agree with those predicted by the theory.

Participation

In-Person

References

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