Force generation and contraction of random actomyosin ring

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Abstract

Cytokinetic rings and stress fibers generate effective contraction, but how organized respective actomyosin arrays are, and how semi-random actomyosin bundles generate contraction is not clear.

We investigate computationally the self-organization and contraction of actomyosin ring that is completely disorganized initially. To this end, we formulate a detailed agent-based model for a 1D chain of cross-linked actin filaments forming a closed ring interspersed with myosin-II motor proteins.

The result of our numerical experiments is that in order to contract, 1) actin filaments in the ring have to turn over, 2) myosin motors have to be processive, and 3) filaments have to be sufficiently crosslinked. We find that contractile force and rate scale with myosin density and have a complex dependence on the actin density. The simulations indicate that the ring consisting of short filaments contracts rapidly but exerts little force, while the long filament ring generates significant force but contracts slowly. Our simulations predict, in agreement with experimental observations, that the rate of contraction is constant and the time of contraction is invariant with respect to the original ring size. Finally, the model demonstrates that with time, a pattern formation takes place in the ring worsening the contractile process. The more random actin dynamics are and the longer actomyosin ring stays disorganized the higher contractile force and rate it generates.