Molecular motors from a 3D perspective: motion and torque generation of kinesins

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Kinesin motor proteins organize the mitotic spindle by cross-linking and sliding microtubules, which orchestrates the complex process of cell division. Some kinesins, such as kinesin-5 and kinesin-14, not only move straight along a microtubule, but exhibit a lateral stepping component. This results in a sideward motion, which has not been fully investigated so far due to technical limitations. Here we explore how kinesin-5 and kinesin-14 slide microtubules and estimate the rotational forces (torques), that the motors produce. Using a 3D motility assay, we show that both kinesin-5 and kinesin-14 drive the rotation of short microtubules around long, suspended microtubules along helical trajectories. Further, we develop a microtubule coiling assay in which sliding by kineisn-5 and kinesin-14 twists microtubules, indicative of torque generation. A theoretical simulation allows the quantification of the torque from the observed microtubule bending. These results reveal that kinesin-5 and kinesin-14 both rotate microtubules around each other and generate torque. We hypothesize that this behavior serves to organize spindle fibers, to circumnavigate roadblocks and to break symmetry through chirality of the mitotic spindle.