Left-right Asymmetry in Cell Mechanics

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Mechanical force is pervasive in regulating cell physiology and morphogenesis. For example, cell contractility is known positively correlated with the density of actin stress fibers and the size of focal adhesions, and directly associated with cell viability and differentiation. Recently, a variety of cell mechanics was reported with left-right (LR) asymmetry, e.g. rightward-biased cell migration [1]. Such biased mechanics suggests a cell-level mechanism of how LR asymmetry in tissue architectural is formed [2]. Interestingly, because actomyosin cytoskeleton was found important for both expression of LR asymmetry and generation of cellular forces, it predicts a type of cellular force that mediates the LR-biased mechanics and eventually coordinates the formation of LR asymmetry in tissue architecture. To address this, we report a nanowire magnetoscope that reveals a rotating force – torque – exerted by cells [3]. Ferromagnetic nanowires were deposited into cell culture and spontaneously internalized by cells. With a uniform and horizontal magnetic field around the cell culture, nanowires inside the cell were first aligned with the magnetic field and subsequently rotated in clockwise (CW) or counterclockwise (CCW) direction due to the cellular torque (Fig. 1). Importantly, this torque was found with LR bias depending on cell types. While NIH 3T3 fibroblasts and human vascular endothelial cells (hVECs) exhibited CCW torques, C2C12 mouse myoblast cells showed a CW-biased torque (Fig. 2). Moreover, using the quantitatively measured torque and the analysis of subcellular actin distribution, we found that an actin ring composed of transverse arc and radial fibers is the key factor determining the LR bias of cellular torque (Fig. 3 and Fig. 4). Together, our finding of LR biased cellular torque measured by the nanowire magnetoscope offers a new approach for characterizing cell's rotational force and a fundamental framework explaining single cell's LR asymmetry. Furthermore, we will discuss how LR asymmetry was regulated by microenvironment cues, i.e. stiffness [4], and how it was utilized in controlling cell orientation and formation of tissue-like architecture, paving the way for rebuilding artificial tissue constructs with inherent LR asymmetry in the future.

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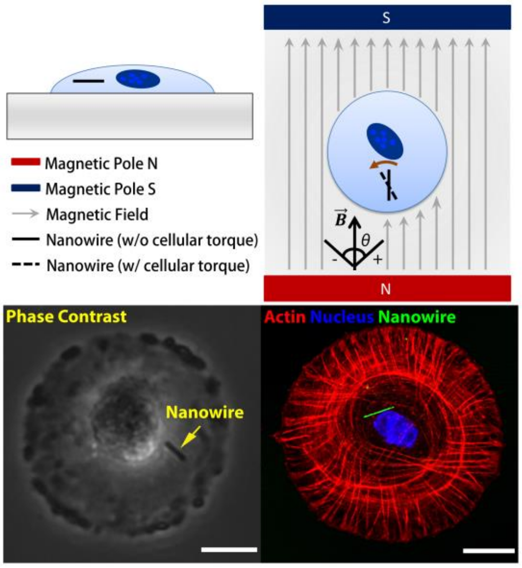

Fig.1 Schematic of the measurement of cellular torque via rotation of ferromagnetic nanowires in micropatterned cells. Scale bar: 10μm.

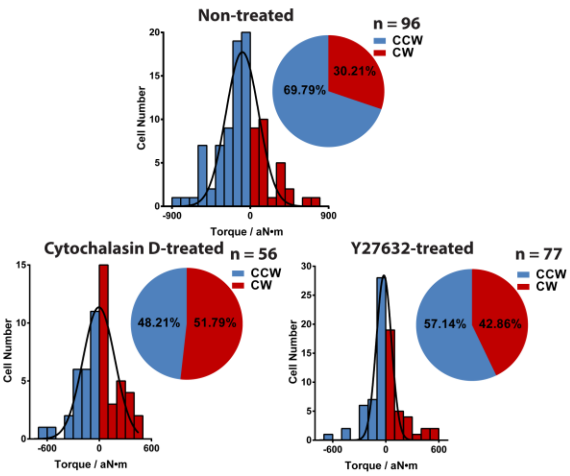

Fig. 2 Gaussian distribution and relative pie chart reveals the LR-biased torque of cells with different treatment. CW: clockwise; CCW: counterclockwise.

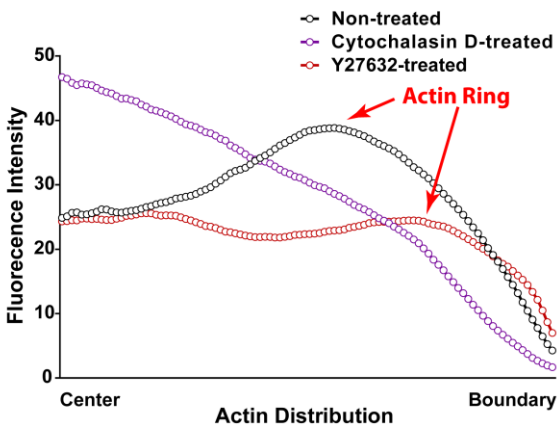

Fig. 4 The actin distribution with respect to the radial axis of cells.

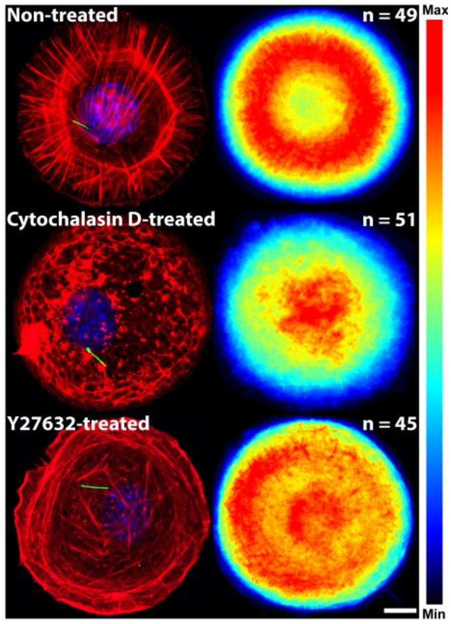

Fig. 3 Confocal microscopy images showing the actin distribution in cells with different treatment (left), and the stacked images of actin stress fibers (right). Scale bar: 10 μm.

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