Nanomechanics of Soft Biological Tissues Probed with Atomic Force Microscopy

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Abstract

Cell biomechanics mediates critical cell functions including proliferation, differentiation, gene expression, contraction, and migration. Moreover, cells sense and actively respond to the mechanical features of their microenvironment. Therefore, a precise characterization of the mechanical properties of cells and extracellular matrix (ECM) is needed to further our understanding of the cell-microenvironment interplay. We use atomic force microscopy (AFM) to study nanomechanical properties of cells and EMC of lung and heart tissues [1-4]. The Young's modulus (E) is computed by fitting the tip-sample contact model to force-indentation curves recorded on sample. The complex shear modulus (G*) is measured by placing the tip at an operating indentation of ~500 nm and superimposing small amplitude (~75 nm) multifrequency oscillations composed of sine waves (0.1-11.45 Hz). G* is computed in the frequency domain from the complex ratio between oscillatory force and indentation signals. Both cells and ECM exhibit a viscoelastic behavior with a complex shear modulus that increases with frequency as a two power law composed of a weak power law (exponent ~0.05), accounting for a viscoelastic solid regime dominant at physiological frequencies, and a second power law with an exponent of 3/4, accounting for a viscoelastic liquid regime at high frequencies. Our AFM measurements define intrinsic mechanical properties of the ECM at the length scale in which cells sense and probe their microenvironment. Regional changes in mechanical properties of the ECM could provide differential mechanical cues to regulate the spatial distribution, differentiation and function of lung and heart cells.

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References

[1] Alcaraz J, Buscemi L, Grabulosa M, Trepat X, Fabry B, Farré R, Navajas D. Microrheology of human lung epithelial cells measured by atomic force microscopy. *Biophys J* 2003; 84: 2071-9.
[2] Luque T, Melo E, Garreta E, Cortiella J, Nichols J, Farré R, Navajas D. Local micromechanical properties of decellularized lung scaffolds measured with atomic force microscopy. *Acta Biomater* 2013; 9:6852-9.
[3] Andreu I, Luque T, Sancho A, Pelacho B, Iglesias-García O, Melo E, Farré R, Prósper F, Elizalde MR, Navajas D. Heterogeneous micromechanical properties of the extracellular matrix in healthy and infarcted hearts. *Acta Biomater* 2014; 10:3235-42.
[4] Ignasi