Cite this as: Ying ZHU, Yi ZHENG, Yuan-yuan SHEN, Xin CHEN, Xin-yu ZHANG, Hao-ming LIN, Yan-rong GUO, Tian-fu WANG, Si-ping CHEN, 2014. Analyzing and modeling rheological behavior of liver fibrosis in rats using shear viscoelastic moduli . *Journal of Zhejiang University-SCIENCE B (Biomedicine & Biotechnology),* **15**(4):375-381. [doi:10.1631/jzus.B1300121]

Analyzing and modeling rheological behavior of liver fibrosis in rats using shear viscoelastic moduli

利用剪切黏弹性模量对大鼠肝纤维化流变特性进行分析和建模

Key words: Biological mechanics, Rheological properties, Liver fibrosis, Viscoelasticity, Shear modulus, Elasticity, Viscosity, Zener model, Voigt model

关键词：生物力学，流变属性，肝纤维化，黏弹性，剪切模量，弹性，黏性，Zener模型，Voigt模型

- The process of liver fibrosis changes the rheological properties of liver tissue. This study characterizes and compares liver fibrosis stages from F0 to F4 in rats in terms of shear viscoelastic moduli. Here two viscoelastic models, the Zener model and Voigt model, were applied to experimental data of rheometer tests and then values of elasticity and viscosity were estimated for each fibrosis stage.

- The results demonstrate that moderate fibrosis (≤F2) has a good correlation with liver viscoelasticity. The mean Zener elasticity E_1 increases from (0.452±0.094) kPa (F0) to (1.311±0.717) kPa (F2), while the mean Voigt elasticity E increases from (0.618±0.089) kPa (F0) to (1.701±0.844) kPa (F2).The mean Zener viscosity increases from (3.499±0.186) Pa·s (F0) to (4.947±1.811) Pa·s (F2) and the mean Voigt viscosity increases from (3.379±0.316) Pa·s (F0) to (4.625±1.296) Pa·s (F2).

- Compared with viscosity, the elasticity shows smaller variations at stages F1 and F2 no matter what viscoelastic model is used. Therefore, the estimated elasticity is more effective than viscosity for differentiating the fibrosis stages from F0 to F2.

Table Mean viscoelastic parameters of each fibrosis stage according to two rheological models

Stage	Zener model			Voigt model	
	E_1 (kPa)	E_2 (kPa)	η (Pa·s)	E (kPa)	η (Pa·s)
F0 (*n*=6)	0.452±0.094	1.507±1.446	3.499±0.186	0.618±0.089	3.379±0.316
F1 (*n*=5)	0.688±0.264	0.921±0.906	4.212±1.468	0.991±0.555	4.023±1.165
F2 (*n*=9)	1.311±0.717	0.561±0.221	4.947±1.811	1.701±0.844	4.625±1.296
F3 (*n*=5)	1.284±0.674	0.962±1.105	4.829±0.922	1.616±0.587	4.443±0.329
F4 (*n*=2)	1.605±0.809	3.404±1.475	4.972±1.757	1.644±0.824	4.060±0.813

Data are expressed as mean±standard deviation (SD)