VISCOSITY AND NONLINEAR ELASTOGRAPHY WILL BE THE NEXT GENERATION BIOMARKERS IN CLINICAL DIAGNOSIS

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RESUMEN

Los últimos cambios en un tejido se asocian con un amplio espectro de patologías, que se derivan de la microestructura, la histología y la bioquímica del tejido. Esta presentación tiene como objetivo dilucidar el potencial de los parámetros elásticos viscosos y no lineales como biomarcadores mecánicos de diagnóstico concebibles. En primer lugar, proporcionando información sobre el papel de la microestructura de los tejidos blandos en la elasticidad lineal; segundo, al comprender cómo la viscosidad y la no linealidad podrían mejorar el diagnóstico actual en elastografía; y finalmente, combinando investigaciones preliminares de esos parámetros de elastografía dentro de diferentes tecnologías.

La caracterización por elastografía ultrasónica y la comprensión de los tejidos blandos se están desarrollando recientemente como una herramienta de diagnóstico clínico. Las nuevas tecnologías de sensores de elastografía, desde hardware hasta algoritmos, están destinadas a dotar de una nueva clase de biomarcadores que cuantifican la funcionalidad mecánica y las anomalías en la arquitectura estructural de los tejidos blandos están íntimamente relacionadas con una amplia gama de patologías, incluidos tumores, aterosclerosis, envejecimiento, hígado. fibrosis o síndromes osteoarticulares, por citar algunos. Estos parámetros mecánicos de orden superior pueden convertirse en biomarcadores discriminatorios clave ya que: (1) la física de la propagación de ondas explica cómo la dispersión es una expresión compuesta de la dispersión reológica, poroelástica y microestructural y (2) la hiperelasticidad extrema que exhiben los tejidos blandos se manifiesta claramente como generación armónica cuantificable.

ABSTRACT

Elastic changes in a tissue are associated with a broad spectrum of pathologies, which stems from the tissue microstructure, histology and biochemistry. This presentation aims to elucidate the potential of viscous and nonlinear elastic parameters as conceivable diagnostic mechanical biomarkers. First, by providing an insight into the role of soft tissue microstructure in linear elasticity; second, by understanding how viscosity and nonlinearity could enhance the current diagnosis in elastography; and finally, by compounding preliminary investigations of those elastography parameters within different technologies.

Ultrasonic elastography characterization and understanding of soft tissue is recently being developed as a clinical diagnostic tool. New elastography sensor technologies, from hardware to algorithms, are bound to endow a new class of biomarkers that quantify the mechanical functionality and abnormalities in the structural architecture of soft tissues are intimately linked to a broad range of pathologies including tumors, atherosclerosis, ageing, liver fibrosis or osteoarticular syndromes, to name a few. These higher order

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mechanical parameters may become key discriminating biomarkers since: (1) the physics of wave propagation is explaining how dispersion is a compound expression of the rheological, poroelastic, and microstructural scattering and (2) the extreme hyperelasticity that soft tissue exhibits clearly manifests as quantifiable harmonic generation.

Palabras Clave— Ultrasonidos. Elastografía. Mecánica tisular.

1. INTRODUCTION

Ultrasonic elastography characterization and understanding of soft tissue has been developed as a clinical diagnostic tool over the last two decades and evolved through different technologies: quasi-static, dynamic elastography, based acoustic radiation force: ARFI, vibroacoustography or pSWE, or on direct excitation: sonoelastography and the emerging torsional wave principle. New elastography sensor technologies to characterize soft tissue biomechanics, from hardware to algorithms, are bound to endow a new class of biomarkers that quantify the mechanical functionality and abnormalities in the structural architecture of soft tissues are intimately linked to a broad range of pathologies including tumors, atherosclerosis, brain ageing, gestational disorders, liver fibrosis or osteoarticular syndromes, to name a few. These higher order mechanical parameters may become key discriminating biomarkers since: (1) the physics of wave propagation is explaining how dispersion is a compound expression of the rheological, poroelastic, and microstructural scattering phenomena governed by the complex fibrous multiscale microarchitecture of the stroma, which undergoes characteristic changes during pathologies; and (2) the extreme hyperelasticity that soft tissue exhibits clearly manifests as quantifiable harmonic generation, hypothesized to strongly depend on the unfolding of its collagen fibres, which again controls the tissue´s mechanical functionality.

2. RECENT ADVANCES

Existing ultrasonic techniques are restricted to map first order tissue stiffness. In contrast, recent advances covering:

a) new mechanical wave-based sensing technologies ranging magnetic resonance elastography, ultrasonic shear wave elastography or torsional wave elastography,

b) wave propagation models and multiscale interaction with michroarchitectural changes, and

c) patient testing, are allowing to quantify the mechanical functionality through relevant parameters beyond linear: dispersive and nonlinear.

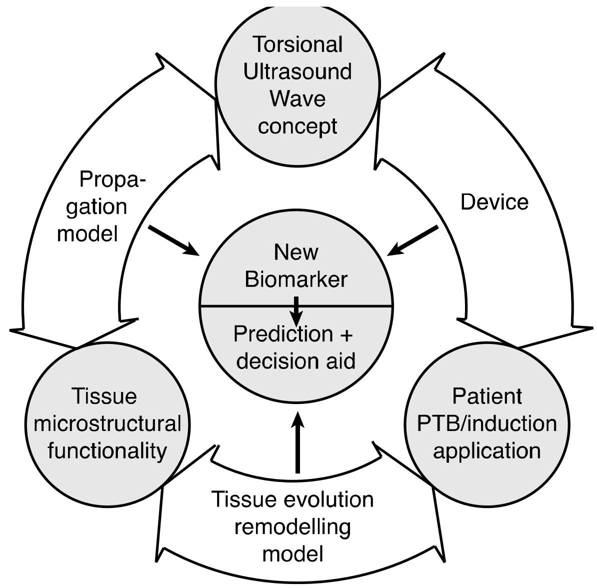

Figure 1. Dimensions of the problems to be addressed to generate a solid scientific backgound**.**

3. FUTURE DIRECTIONS

a) To understand how structural architecture of soft tissue is intimately linked and controls a broad range of pathologies, which underpins the foundation of a new diagnostic technology.

b) To develop new sensor technologies capable of effectively sensing tissue elasticity, and yield simple and robust diagnostic tests and instruments.

c) To ground a new generation of biomarkers of physical nature based on the mechanical micro- architecture and properties of the tissue.

4. CONCLUSIONS

In conclusion, evidence of the diagnostic capability of elastic parameters beyond linear stiffness is gaining momentum as a result of the technological and imaging developments in the field of biomechanics. The unexplored nature and applicability span of viscous and nonlinear mechanical biomarkers endow a foundational diagnostic technology.

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