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Editorial

Analysis of Collagen Fiber Arrangement by Fluid Mechanics Technique

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EDITORIAL

Collagen fiber spatial arrangement has been employed as a biomarker to measure damage and disease progression. Quantifying this organization for complex systems, on the other hand, is difficult. Collagen is the main structural protein in connective tissue and the extracellular matrix. Collagenous fiber organization might be employed as a biomarker to detect structural abnormalities, illness diagnosis and progression, aging, tissue development, and injury. When fibrillar collagen interacts with light, its non-centrosymmetric molecular structure causes a nonlinear optical response in which two input photons make an output photon with twice the frequency, a process known as Second-Harmonic Generation (SHG). SHG microscopy can thus produce high-contrast pictures of collagenous fibers without the need for exogenous dye. Various quantitative SHG imaging approaches have been utilized to help researchers better understand how collagen microstructure affects biological function. Texture analysis techniques have been used to objectively characterize SHG pictures of normal and malignant human pancreatic tissues, for example. Curvelet, wavelet, and Fourier transforms have also been employed to measure the morphological characteristics of collagen fibers. In the latter scenario, as in the case of tendon tissues, Fourier Transform-Second Harmonic Generation (FT-SHG) imaging analysis was utilized to assess the orientation and spatial dispersion of uniformly organized collagen fibers.

A grid-based technique is frequently employed for disordered collagen fibers, in which Fourier-transform analysis is performed in small homogeneous zones, and the relative contributions of all regions are recorded in a histogram of orientations. To identify well-aligned fibers from wavy fibers in two dimensions (2D), the Circular Variance (CV) and Standard Deviation (SD) of fibers orientation distribution have been employed. Although the FT-SHG may reveal the many types of morphology inside an image, the CV or SD alone cannot catch quick changes in local characteristics. In this research, we present a technique for analyzing SHG collagen pictures as pseudo-VFs and using fluid mechanics-based assessment metrics. Using FT-SHG analysis, we first generate a 2D quadrilateral mesh that incorporates pseudo unit vectors in each cell. The velocity map of a fluid flow is equivalent to the collection of these vectors. Then there are fluid-mechanics measures like enstrophy E and tortuosity τ, and vitality U These VFs are described using are utilized to characterize them. E is used to evaluate circularly structured collagen fibers and is related to the vorticity of a fluid flow τ corresponds with the fiber straightness, and U records the VFs' changes in orientation.

It illustrates how fluid mechanics measures for assessing fluid flow may be applied to complicated collagen fiber structures. SHG pictures of collagenous tissue for straight, wavy, and circular fiber architectures are used as examples. While existing FT methods record individual fiber orientation, FT methods alone are unable to quantify the complexity of collagen topologies. Fiber orientation may be evaluated as part of a unified system of vectors similar to fluid flow using an analytical technique based on fluid mechanics. E as well as U assist in quantifying this flow, and τ. The waviness of streamlines is captured. Even though this approach does not offer any new spatial information, collective assessment of fiber orientation does provide fresh insight into overall collagen-fiber architecture in complex tissues. The collagen fiber arrangement of the bovine tendon, porcine cortical bone, and rat vaginal tissue was studied using fluid mechanics analysis. We discovered that collagen fiber orientation may be represented as pseudo vectors of unit length. We also showed that E, U as well as τ capture and differentiate different collagen structures numerically. This approach was used to assess fibers that were straight, wavy, and organized in a circular pattern.

It was discovered that straight fibers produce a distribution with a short-range, but values that cluster around. It has been demonstrated that the range of τ The waviness of collagen strands is reflected in the scales. As U captures fast fiber orientation changes and E We have demonstrated how, depending on the fiber topology, these values bifurcate from low to high values. Modeling fiber organization as a VF and using fluid mechanics measurements to characterize collagen architecture, we hope, will help us better understand the significance of the collagen microstructure in biological function. This might lead to a better understanding of disease-related mechanical characteristics, ECM remodeling, and aging. Finally, if desired, the method might benefit from using multiphase fluid flow analysis to isolate fibers for further investigation. We also looked at SHG imaging in a single plane, but we're now looking into adapting to three-dimensional picture stacks.

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