6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11-15 June 2018, Glasgow, UK

Benign enlargement of the prostate with age mechanically restricts the growth of prostatic tumors

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Keywords: *Mathematical Oncology, Prostate Cancer, Isogeometric Analysis*

Prostate cancer (PCa) and benign prostatic hyperplasia (BPH) are common urogenital diseases in ageing men. BPH consists of the pathological enlargement of the organ, which may eventually cause bothersome lower urinary tract symptoms. Recent studies on extensive series of surgical prostate specimens have shown that tumors originating in larger prostates present favorable pathological features, hence suggesting that large prostates may exert a protective effect against PCa [1]. This phenomenon could result from BPH contributing to the mechanical stress fields that build up as tumors grow, which are known to slow down their dynamics. To explore this, we extend our model of PCa growth [2] to include the equations of mechanical equilibrium and define the coupling terms between them and tumor dynamics.

We leverage the phase-field method to account for the coupled dynamics of healthy and tumoral tissue and reaction-diffusion equations to describe the dynamics of a generic nutrient and a PCa biomarker. Following previous mechanically-coupled approaches [3], we assume that the deformation of the prostate is a quasistatic phenomenon and we model prostatic tissue as a linear elastic, heterogeneous, isotropic material. The confinement of the prostate in the pelvic region is modeled with Winkler boundary conditions. BPH and PCa are modeled as pressure terms in the constitutive equation of the prostatic tissue. The inhibitory effect of the mechanical stress fields is estimated with a global factor that slows down tumor dynamics. We leverage isogeometric analysis to handle the nonlinearity of our set of equations, as well as the complex anatomy of the prostate and the intricate tumoral morphologies.

Our simulations confirm that a history of BPH creates mechanical stress fields in the prostate that hamper PCa growth and limit its invasiveness. The technology presented herein may also assist physicians in the management of prostate cancer, especially in patients with larger prostates.

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