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Relationship between QUS parameters and a cellular model- based estimation of bone strength

Guillaume Haiat[a], Frederic Padilla[b] and Pascal Laugier[b]
[a]CNRS, Laboratoire de Recherches Orthopédiques, 10, Avenue de Verdun, 75010 Paris, France
[b]Université Paris 6, Laboratoire d'Imagerie Paramétrique, 15, rue de l'Ecole de Médecine, 75006 Paris, France

The final goal of quantitative ultrasound (QUS) techniques is to assess bone strength. However, the translation of QUS results into bone strength remains elusive because the physical principles of ultrasonic propagation in bone are not fully understood yet. Here, the sensitivity of Broadband Ultrasonic Attenuation and Speed of Sound to variations of bone strength is derived. Therefore, a cellular model is combined to a multiple regression analysis resulting from the analysis of finite-difference time domain (FDTD) simulations coupled with imaging techniques. The variation of QUS variables induced by a variation of strength of 10%, realized either by a change in material properties or a change in bone volume fraction (BV/TV) is investigated. Except when BV/TV is high, the variations of BUA in response to a variation in strength realized by a pure change of BV/TV is higher than the technique imprecision and thus can be detected. When the variation of strength is realized by changes of elastic properties, the response in QUS properties is dominated by the variation in C11 over C44. The interpretation of these data, however, is not straightforward due to sparse description of elastic properties at the tissue level, which is a limitation of the cellular model.