Quantitative molecular imaging in the era of precision medicine

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Summary

Early diagnosis and therapy increasingly operate at the cellular, molecular or even at the genetic level. As diagnostic techniques transition from the systems to the molecular level, the role of multimodality molecular imaging becomes increasingly important. Positron emission tomography (PET), x-ray computed tomography (CT) and magnetic resonance imaging (MRI) and their combinations (PET/CT and PET/MRI) provide powerful multimodality techniques for *in vivo* imaging. Quantitative image analysis has deep roots in the usage of molecular imaging in clinical and research settings to address a wide variety of diseases. It has been extensively employed to assess molecular and physiological biomarkers *in vivo* in healthy and disease states, in oncology, cardiology, neurology, and psychiatry. This talk reflects the tremendous increase in multimodality molecular imaging as both clinical and research imaging modalities in the past decade. An overview of advanced medial image instrumentation technologies and PET image quantification and related image processing issues with special emphasis on radiomics analysis will be presented. This talk aims to bring the medical physics community a review on the state-of-the-art algorithms used and under development for accurate quantitative analysis in multimodality and multiparametric molecular imaging and their validation mainly from the developer's perspective. It will inform the audience about a series of advanced development carried out recently at the PET instrumentation & Neuroimaging Lab of Geneva University Hospital and other active research groups. Current and prospective future applications of quantitative molecular imaging are also addressed especially its use prior to therapy for dose distribution modeling and optimization of treatment volumes in external radiation therapy and patient-specific 3D dosimetry in targeted therapy towards the concept of image-guided radiation therapy. In this regard, the promising role of artificial intelligence (AI), in particular deep learning approaches, will be emphasized. To this end, example applications of deep learning in five generic fields of multimodality medical image analysis, including imaging instrumentation design, image denoising (low-dose imaging), image reconstruction quantification and segmentation, radiation dosimetry and computer-aided diagnosis and outcome prediction will be discussed. Future opportunities and the challenges facing the adoption of quantitative imaging biomarkers in the clinic and their role in basic research will also be addressed.