Learning Deep Representation of X-ray Image by Decomposition into Projections of Bone-segmented Quantitative Computed Tomography for End-to-end Estimation of Bone Mineral Density*

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Abstract

Osteoporosis is a prevalent bone disease causing bone fracture, which leads to a decline in activity of daily living. Dual-energy X-ray absorptiometry (DXA) and quantitative computed tomography provide high accuracy in diagnosing osteoporosis; however, these modalities require special equipment and scan protocols. To frequently monitor bone health, low-cost, low-radiation doses and ubiquitously available diagnosis methods are highly anticipated. This study aims for bone mineral density (BMD) estimation from a plain x-ray image for an opportunistic screening, potentially useful for early diagnosis. The previous methods used a multi-stage approach consisting of ROI extraction and a simple regression of BMD, which lack efficiency and require a large number of training datasets to achieve high accuracy. Therefore, we propose an end-to-end method that learns a deep representation of the x-ray image through a bone-isolated virtual x-ray image for estimating BMD. The proposed method was validated on a three-hundred-fifteen-cases dataset with five-fold cross-validation, that demonstrated the improved average BMD prediction error from 0.091 (mg/cm^2) to 0.055 (mg/cm^2) compared to a previous method and the intra-class correlation between

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the DXA-measured BMD and predicted BMD from 0.609 to 0.848. The representation learning by training model with decomposition allows us to achieve a high performance to estimate BMD in an end-to-end manner under a limited dataset, for whom direct regression training failed to predict. To our knowledge, this study is the first to achieve an end-to-end estimation of BMD from an x-ray image. Furthermore, we performed a multi-center experiment, where the model was first trained with a dataset from one institute and evaluated on datasets from five different institutes, showing a Pearson correlation coefficient of 0.890. The proposed methods showed high performance on BMD estimation, outperforming conventional methods significantly.

Keywords:

representation learning, radiography, bone mineral density (BMD), generative adversarial network (GAN)