Opportunistic Screening for Osteoporosis Using CT Scans of the Knee: A Pilot Study

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Abstract. Knee CT scans are used for planning for total knee arthroplasties in patients who are often simultaneously at risk for frailty fractures due to low bone mineral density. We retrospectively identified 200 patients (85.5% female) with concurrent CT scans of the knee and Dual energy x-ray absorptiometry (DXA). The mean CT attenuation of the distal femur, proximal tibia and fibula, and patella, were calculated using volumetric 3-dimensional segmentation using 3D Slicer. Data were split randomly into training 80% and test 20% datasets. The optimal CT attenuation threshold for the proximal fibula was obtained in the training dataset and evaluated in the test dataset. A support vector machine (SVM) with radial basis function (RBF) using C-classification was trained and tuned using 5-fold cross-validation in the training dataset and then evaluated in the test dataset. The SVM had a higher area-under-the curve (AUC) of 0.937 and better performance to detect osteoporosis/osteopenia than the CT attenuation of the fibula (AUC of 0.717) (P=0.015). Opportunistic screening for osteoporosis/osteopenia could be accomplished using CT scans of the knee.

Keywords. Osteoporosis, computed tomography, Knee, Machine learning, Artificial Intelligence, Screening, Bone mineral density.

1. Introduction

We begin to lose bone mineral density in the third to fourth decades of life [1]. This is a pernicious process that eventually may lead to the development of low bone mineral density (BMD) [1]. Low BMD increases future fracture risk [2]. Hip fractures are associated with increased morbidity and approximately 33% mortality within 3 years after the hip fracture [1]. Dual energy X-ray absorptiometry (DXA) is the gold-standard for measuring BMD [1]. The World Health Organization (WHO) guidelines consider patients with lowest BMD T-score less than or equal to -2.5 as osteoporotic; patients with lowest BMD T-score between -2.5 and -1 as osteopenic; and patients with lowest BMD T-score greater than or equal to -1 as normal [1]. Although there are screening guidelines for low BMD using DXA, several eligible patients remain unscreened so there is a need for opportunistic screening using other methods [1]. Recent studies have shown that the computed tomography (CT) attenuation of trabecular bones, including the hand and wrist can be used to screen for low BMD [1]. We hypothesize that knee CT scans performed

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as part of routine clinical practice including knee arthroplasty [2] could be used to screen for low BMD, and we hypothesize that machine learning techniques [1] [3] utilizing the CT attenuation from several bones would be better than using the CT attenuation at a single bone.

2. Materials and Methods

This is a retrospective study of patients evaluated between 01/01/2013 and 12/31/2021 at a tertiary care academic center who had knee CT and DXA scans performed within 12 months of each other. Patients were excluded if they already had knee arthroplasties or fractures. 3D Slicer was used to segment the epiphysis/metaphysis of the distal femur, proximal tibia, and proximal fibula; and the patella to obtain the CT attenuation of these bones. The dataset was randomly split into training/validation (80%) and test (20%). First, the optimal threshold CT attenuation of the fibula to predict whether a patient had osteoporosis or osteopenia was identified in the training dataset and evaluated in the test dataset. Next, we used a support vector machine (SVM) with radial basis function and C-classifier to predict whether a patient had osteoporosis or osteopenia because this model was effective in a prior paper [1]. Tuning was done with 5-fold cross-validation, using epsilon ranging from 0 to 1 in increments of 0.1, and cost of 1 to 8 in unit increments. The performance of the optimal tuned SVM was evaluated in the test dataset. DeLong's test was used to compare the area under the curve (AUC) of the SVM to the CT attenuation of the fibula in the test dataset. Statistics were two-sided with alpha set at 0.05. Statistics were performed using Rv4.04.

3. Results and Conclusions

A total of 200 patients were identified, 171 (85.5%) women and mean age (standard deviation) of 67 (8.0) years. A threshold CT attenuation of the fibula of 45.8 Hounsfield Units (HU) had a sensitivity of 0.733, specificity of 0.700, and AUC of 0.717, while the SVM had a sensitivity of 0.833, specificity of 1.00, and AUC of 0.937 to predict osteoporosis or osteopenia in the test dataset. The SVM classifier had superior performance to the single CT attenuation measurement at the fibula ($P=0.015$).
Opportunistic screening for osteoporosis and osteopenia can be performed from CT scans of the knee. Future research is required to evaluate how fracture risk can be estimated from CT scans of the knee.

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