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Improved Osteoporosis Prediction in Breast Cancer Patients Using a Novel Semi-Foundational Deep Learning Model

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Introduction/Background

Small cohorts of certain disease states are common especially in medical imaging. Despite the growing culture of data sharing, information safety often precludes open sharing of these datasets for creating generalizable machine learning models. To overcome this barrier and maintain proper health information protection, foundational models are rapidly evolving to provide deep learning solutions that have been pretrained on the native feature spaces of the data. Although this has been optimized in Large Language Models (LLMs), there is still a sparsity of foundational models for computer vision tasks.

Methods/Intervention

It is in this space that we provide an investigation into pretraining a Visual Geometry Group (VGG)-16 on an unrelated dataset of 8,500 chest CTs which was subsequently fine-tuned to classify bone mineral density (BMD) in 200 breast cancer patients using the L1 vertebra on CT.

Results/Outcome

This semi-foundational model showed significant improved ternary classification into mild, moderate, and severe demineralization in comparison to ground truth Hounsfield Unit (HU) measurements in trabecular bone. For the 20% holdout testing set, the AUC was 0.92 (p-value < 0.05, ANOVA versus no pretraining versus ImageNet transfer learning) and F1-score 0.84 (p-value < 0.05).

Conclusion

In this study, the use of a semi-foundational model trained on the native feature space of CT provided improved classification in a completely disparate disease state with different window levels.

Statement of Impact

Future implementation with these models may provide better generalization despite smaller numbers of a disease state to be classified.

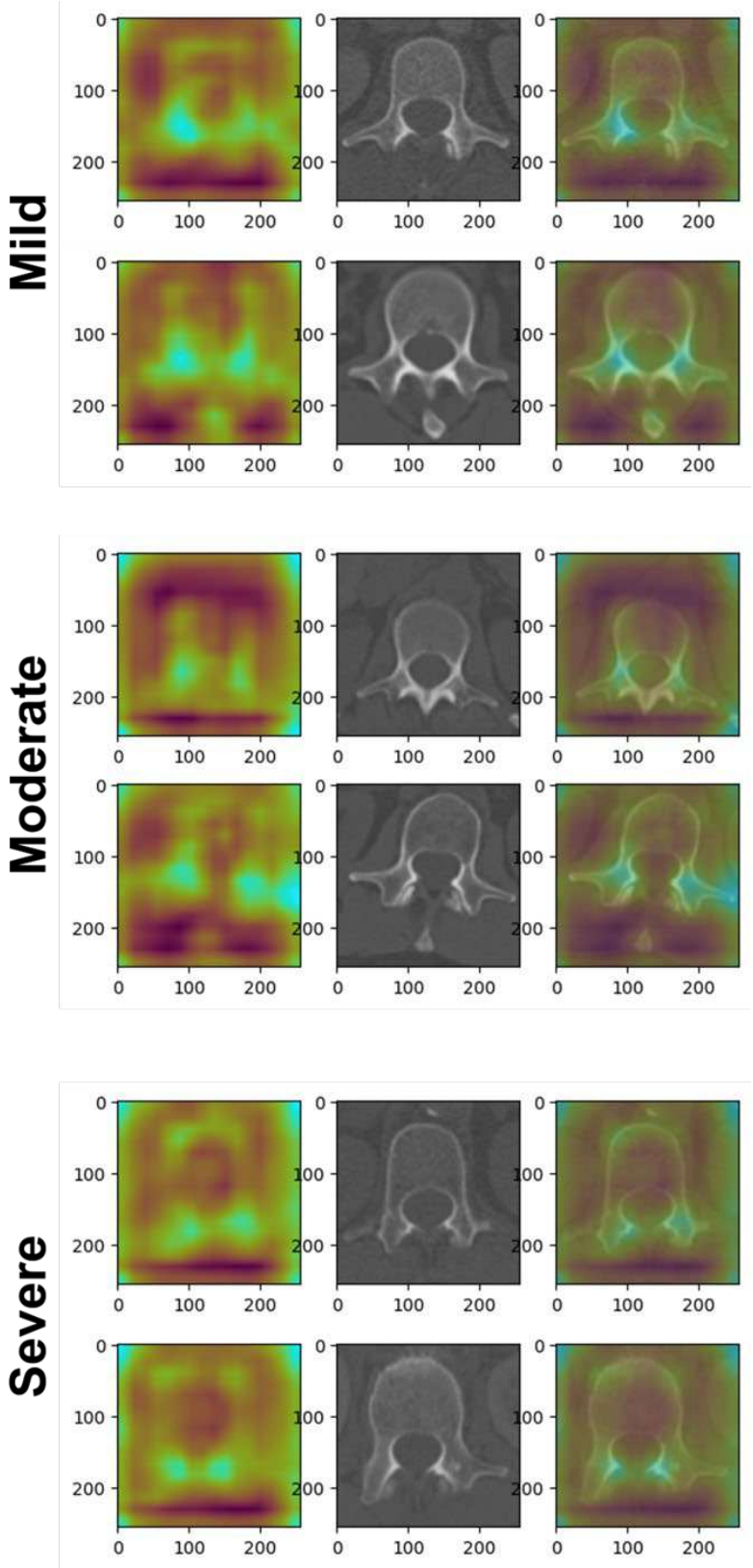

Figure 1. Class Activation Maps (CAMs) of Predicted Classes of Demineralization. The gradients from the last convolutional layer of the semi-foundational VGG16 are graphed (left) with comparison to the original cropped image (center) and final combined overlay (right). Of note, the model demonstrated the greatest attention to the cortical bone, especially in the pedicles. This is counterintuitive to current practices of determining bone mineral density (BMD) where measurements are typically made on cancellous/trabecular bone.

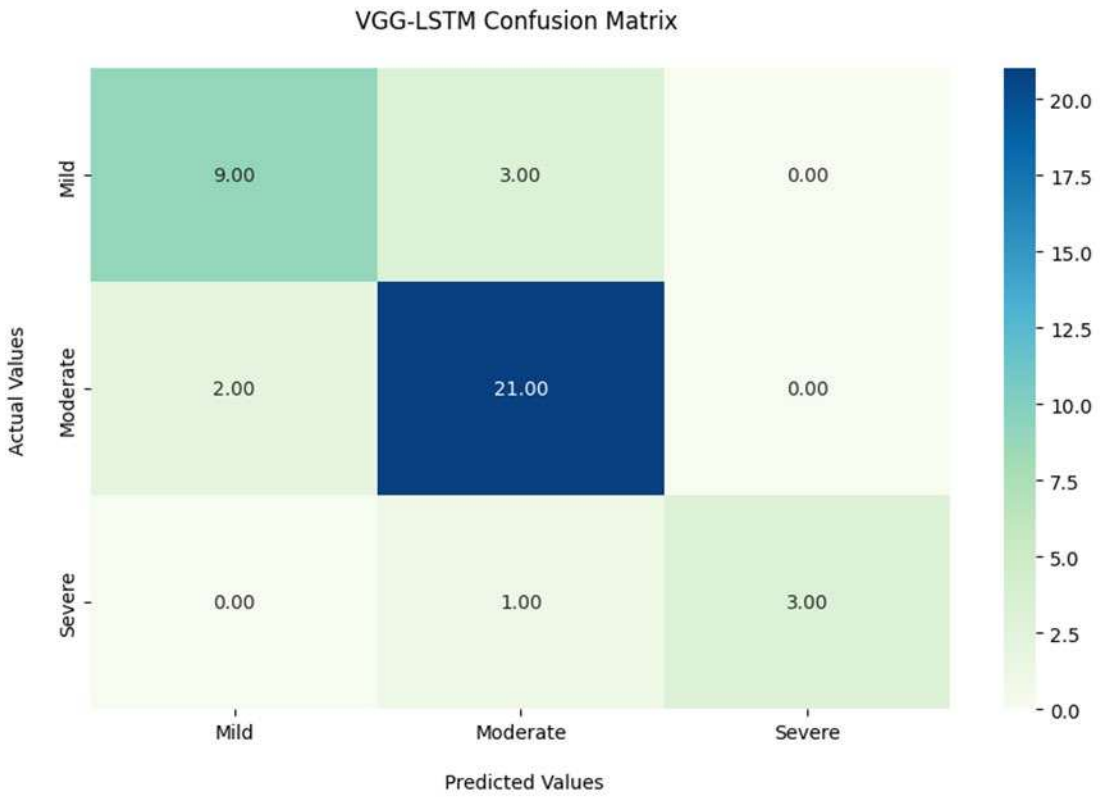

Figure 2. Confusion Matrix of Hold-out Ternary Classification of Demineralization. For the 40 holdout testing samples, there was minor error in classification of mild and moderate classes.

Keywords

Foundational Models; Machine Learning; Artificial Intelligence; Osteoporosis; Computed Tomography; Breast Cancer