# Coronary Artery Calcium Identification on Non-Gated Sim CT Using a Convolutional Neural Network

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## INTRODUCTION

Coronary artery calcium (CAC) is one of the strongest predictors of future cardiovascular disease (CVD) events [1]. Although CAC is routinely quantified on dedicated ECG-gated cardiac CT, it can also be identified on non-gated chest CT scans and help identify patients who would benefit from cholesterol lowering therapy (e.g. statins) [2].

Patients undergoing radiation therapy (RT) routinely receive non-gated planning CT scans that are rarely evaluated for CAC, despite the potential increased risk of radiation-associated CVD [3]. Automated CAC detection on these scans could enable opportunistic cardiovascular screening without additional imaging.

We developed a convolutional neural network (CNN) trained on ECG-gated cardiac CT with preprocessing that requires only a heart contour. The model was evaluated on ECG-gated CT and multiple non-gated acquisition types, including RT planning CTs, without contrast. We also investigated how incorporating non-gated CT scans into training improves robustness and generalization, demonstrating comparable CAC detection performance regardless of whether non-gated data is included during training.

## METHODS AND MATERIALS

Training, validation, and testing data were obtained from multiple institutions (Stanford, WashU) and clinical imaging cohorts (chest CT, cardiac CT, breast cancer , lung cancer) and scored for CAC using established methods. Images were cropped and masked to the heart contour, and then a threshold of 100-700 HU was applied to isolate CAC.

The Densenet121 CNN architecture was used for all models. To investigate how ECG-gated vs non-gated acquisitions affect the robustness and generalization of a CAC detection model, a model was trained using ECG-gated data only and then several additional models were trained using a combination of ECG-gated and non-gated data.

All models were compared on a test set consisting of 262 CT images (80 gated, 182 non-gated, excluding CAC scores [1-10]).

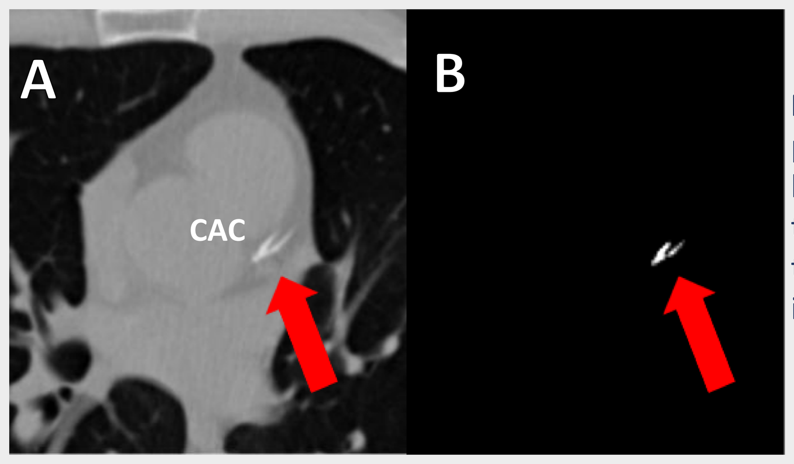


**Figure 1.** Axial slice of preprocessed heart before (A) and after (B) thresholding, showing the reduction in image information.

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| Dataset | Total | Poor contours | CAC score 1-10 | Post-Prep | Calcium | None | Train/val | Testing |
|---|---|---|---|---|---|---|---|---|
| Stanford G | 789 | 182 | 57 | 550 | 292 | 258 | 470 | 80 |
| Stanford NG | 214 | 6 | 17 | 191 | 102 | 89 | 111 | 80 |
| WashU L.C. | 71 | 2 | 3 | 66 | 42 | 24 | 36 | 30 |
| WashU B.C. | 84 | 9 | 3 | 72 | 45 | 27 | 0 | 72 |
| **Total** | **1158** | **199** | **80** | **879** | **481** | **398** | **617** | **262** |

**Table 1.** Summary of data sources used for training, validation, and testing. The post-prep column excludes scans with poor contours or CAC score in the range 1-10. The calcium and none columns show the distribution of post prep data between the two classes. The split of the post-prep data for training/validation and testing is shown on the right. Datasets in descending order: Stanford Gated, Stanford Non-Gated, WashU Lung Cancer, WashU Breast Cancer.

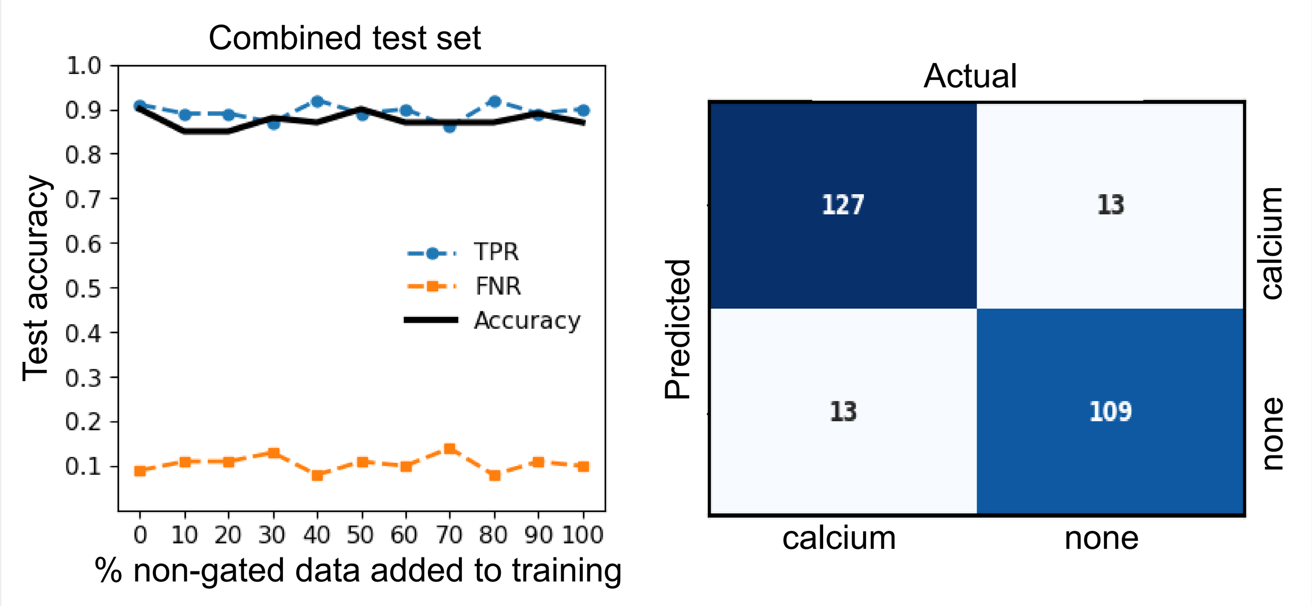


**Figure 2.** (Left) Comparison of models on the full testing set (n=262) showing true positive rate (TPR), false negative rate (FNR) and accuracy.
(Right) Confusion matrix for the model trained with only gated data on the same testing set. Calcium refers to CAC score > 10 and none refers to a CAC score of 0.


**Figure 3.** Examples of model confidence (model trained with only gated data) for non-gated (top) and gated (bottom) CT images containing CAC. Green border indicates true positive and red border indicates false negative. Lower confidence can be seen in cases with artifacts (E), low CAC (C), and unusual CAC location (F). Images with confidence above 0.5 are assigned as containing calcium by the model. The CAC scores and arrows indicating the location of CAC are for reference, not output from the model.

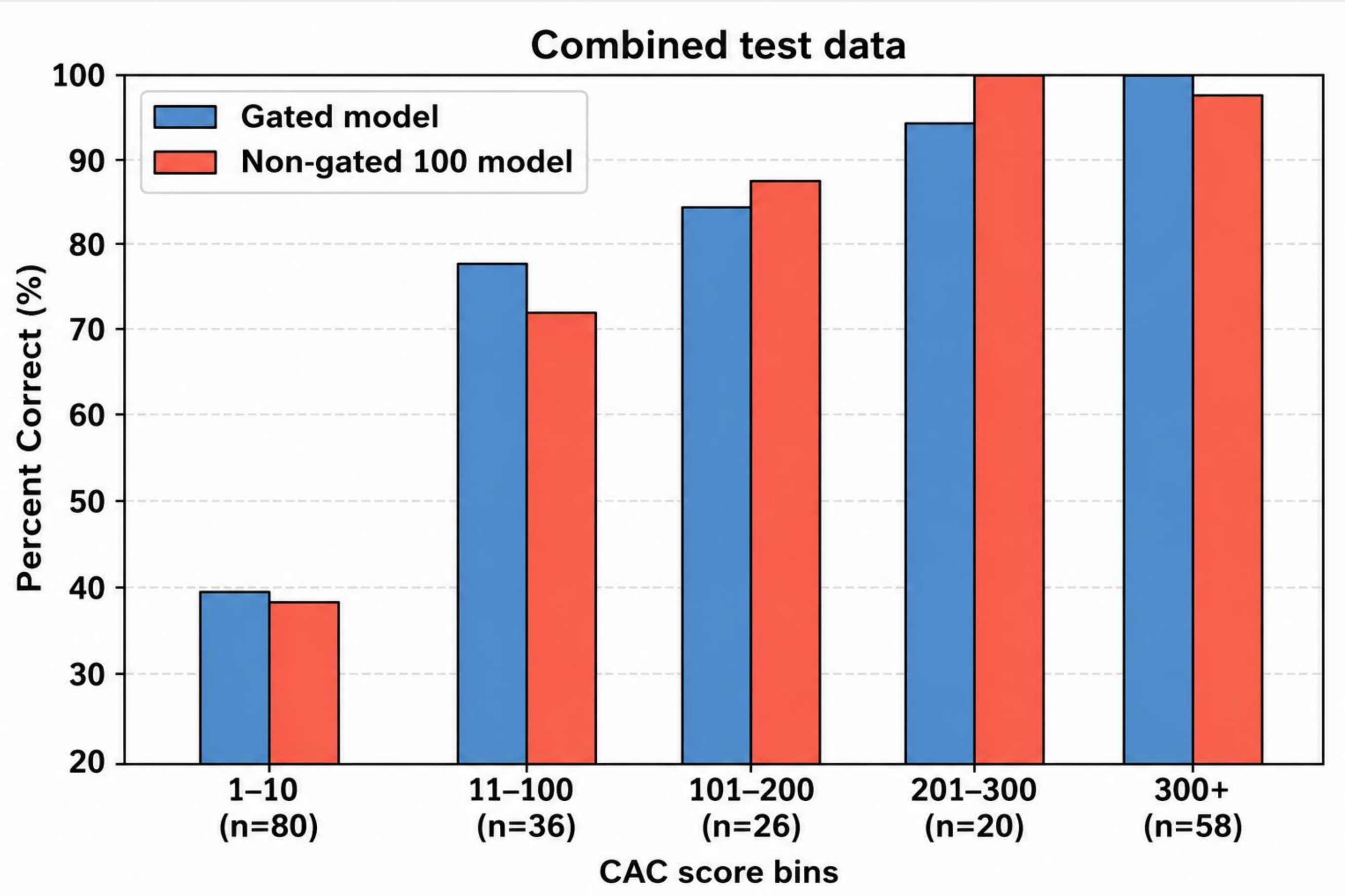


**Figure 4.** Classification accuracy for different CAC score bins of the gated model (trained with only gated data) and non-gated 100 model (gated and 100% non-gated data added to training) on the combined test set. "n" indicates the number of cases within each bin. Scans with CAC scores in the range 1-10 are also included for completeness.

## RESULTS

Models trained using only ECG-gated CT and those trained with increasing amounts of non-gated data demonstrated comparable performance across the combined test set (Figure 2). Accuracy, true positive rate (TPR), false negative rate (FNR), and true negative rate (TNR) had mean ± SD of 0.87 ± 0.02, 0.90 ± 0.02, 0.10 ± 0.02, and 0.85 ± 0.04, respectively. Performance was slightly higher on ECG-gated scans, likely due to reduced motion artifact.

The ECG-gated model demonstrated robust performance across diverse non-gated acquisition types, including scans with motion artifact, high-density artifact, and variable CAC distributions. Confidence scores were generally lower for scans with minimal CAC, severe artifacts, or atypical CAC locations (Figure 3).

Detection performance improved with increasing CAC burden (Figure 4). Lower sensitivity for CAC scores 1–10 was expected, as these cases were excluded during training to prioritize clinically significant disease. The gated model detected 96% of cases with CAC scores >100 and 99% of cases with CAC scores >200.

## DISCUSSION

Patients with moderate CAC (score 100-400) and severe CAC (score >400) are most at risk for CVD and most likely to be prescribed statin therapy, and our high detection rates on these CAC score ranges achieve our goal of developing a model that can flag high CAC on non-gated RT planning CT.

To improve model sensitivity for patients with higher CAC scores, scans with CAC scores of 1–10 were excluded from training. For patients with a CAC score 1-10, the absolute risk of CVD events is low, and previous studies have not demonstrated a benefit from statin therapy [2,4]. 74% (17/23) of non-gated scans with CAC scores of 1–10 were classified as having no calcium, consistent with our goal of flagging only clinically significant CAC.

## CONCLUSIONS

A CNN was trained to detect CAC on both gated and non-gated CT scans with high accuracy. Models trained using gated data demonstrated comparable performance to those trained with mixed gated and non-gated data, suggesting that appropriate preprocessing and thresholding can enable robust CAC detection on non-gated CT scans without including non-gated data during training.

## REFERENCES

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