Automated Assessment of Acute Aortic Dissection on Thoracic CT Using Deep Learning

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Purpose

To assess the efficacy of deep convolutional neural networks (DCNNs) in differentiating acute aortic dissections from non-dissected aortas on thoracic CT

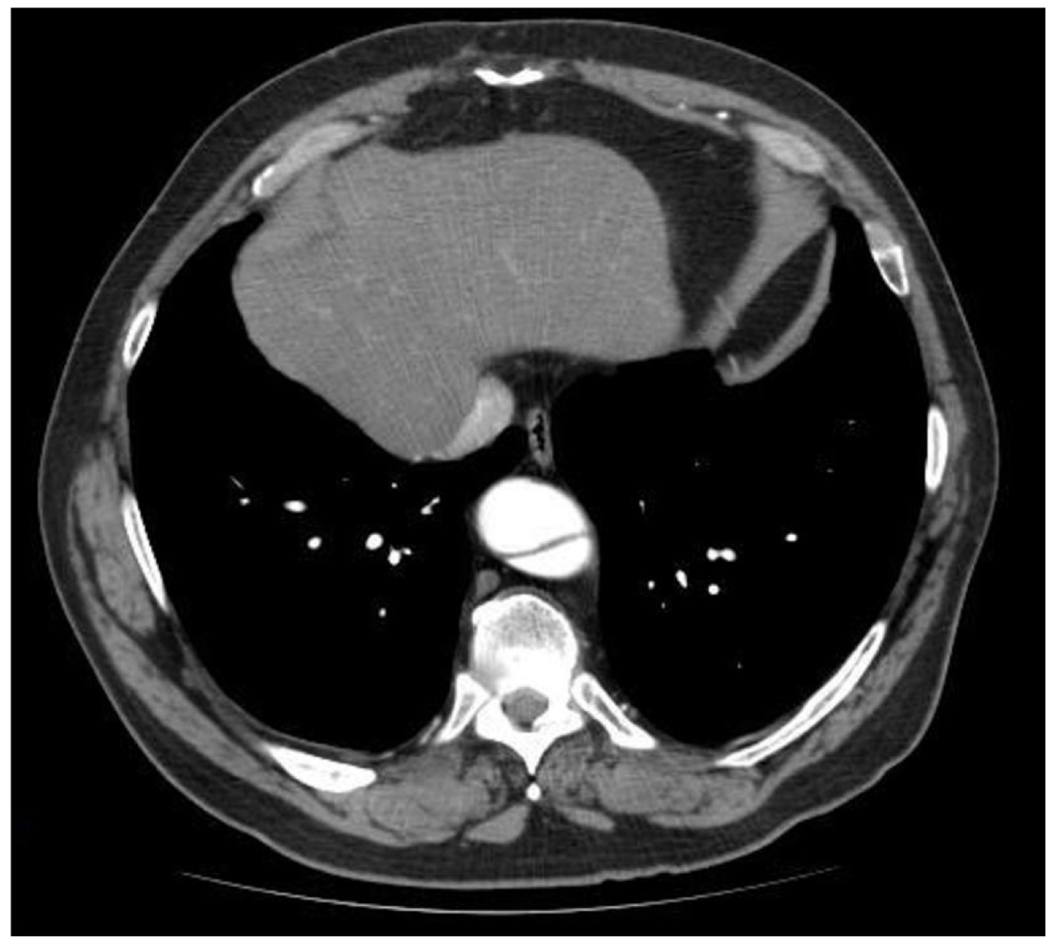

Figure 1 Axial section of CTA demonstrating Stanford Type B aortic dissection[5]

Introduction

- Acute thoracic aortic dissection represents the deadliest iteration of the acute aortic syndrome, with an estimated annual global incidence of 30 million cases per year and a 90% mortality rate without emergent treatment[1]
    - Lethal complications of cardiac tamponade, aortic rupture, congestive heart failure, stroke, and myocardial infarction[2]
    - Malperfusion syndrome complications of paraplegia, acute renal failure, and mesenteric ischemia[2]
- Stanford Type A dissections represent 61% of cases and emerge proximally to the left subclavian artery[3]
- Stanford Type B dissections represent 39% of cases and occur distally to the left subclavian artery[3]
- Aortic dissections must be managed emergently with aggressive blood pressure stabilization, open surgical repair, or thoracic aortic endograft placement[4]
- Thoracic CTA is the most frequent modality employed in the primary diagnosis of aortic dissection, and is utilized in 69% of all cases[6]
- Prior semi-automated solutions for detection algorithms on CTA achieved modest success
    - Semi-automated algorithm to detect healthy, non-dissected ascending aortas with an accuracy of 97%, with no information regarding presence of aortic pathology[8]
    - Wavelet analysis and probabilistic model segmenting true and false lumens in Stanford Type A aortic dissections, with modest results of a sensitivity 0.7 and a specificity of 0.8[9]
    - Proposed CAD solution specifically designed to segment dissected aortas on 3D CTA with no real world performance data[10]
- Deep convolutional neural networks (DCNNs) have already demonstrated success with regard to image classification solutions on CTA
    - Successful classification and segmentation of coronary arteries on CTA with plaque burden scoring[13]
    - Bicuspid aortopathy classification on CTA[14]
    - Successfully prediction of 30-day mortality following interventions for Stanford Type A dissections[15]
- Radiologists are responsible for the emergent diagnosis of aortic dissections on thoracic CTA to ensure timely treatment and intervention
- A computer-aided detection (CAD) system that could automate instantaneous detection of critical aortic dissections to triage patient care appropriately would therefore be invaluable.

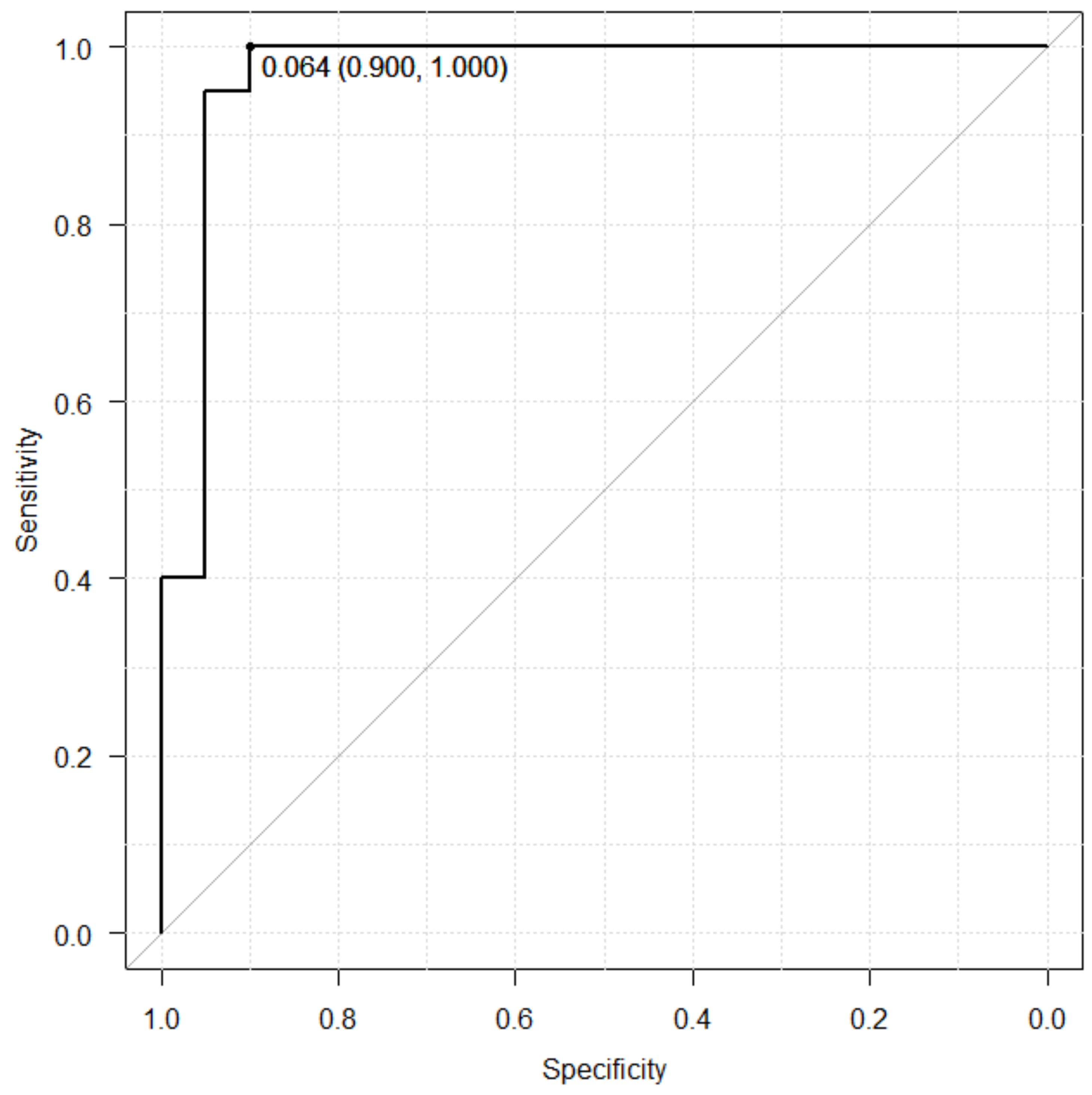

Figure 2 ROC Curve: Inception V3 DCNN

Methods

- 80 de-identified HIPAA compliant CT chest examinations were obtained on unique patients
    - 50% of studies demonstrated acute aortic dissection (40/80)
    - 50% of studies comprised control studies without dissection (40/80)
- Studies were verified by two board-certified radiologists
- The Inception V3 DCNN was used using the Tensorflow framework, pretrained on 1.2 million everyday color images
- Real-time data-augmentation was performed
    - Colorization, rotations, translation, shearing, and zoom
- Six window-level settings were used for each slice.
- Data were split into the following datasets:
    - Training: 30 patients, 15 with and 15 without dissection; 4235 images
    - Validation: 10 patients, 5 with and 5 without dissection; 1295 images
    - Test: 40 patients, 20 with and 20 without dissection; 3423 images
- A 2D network was used that analyzed three slices at a time
- Receiver operating characteristic (ROC), area-under-the-curves (AUC) on the test data, and sensitivity and specificity of the algorithms were performed

Results

- Test dataset results for binary algorithm distinguishing aortic dissection from controls:
    - Patient-level AUC of 0.97 (95% CI: 0.91-1.00)
    - Sensitivity of 100.0% (20/20)
- Two false positive cases with eccentric mural thrombus and endovascular stent

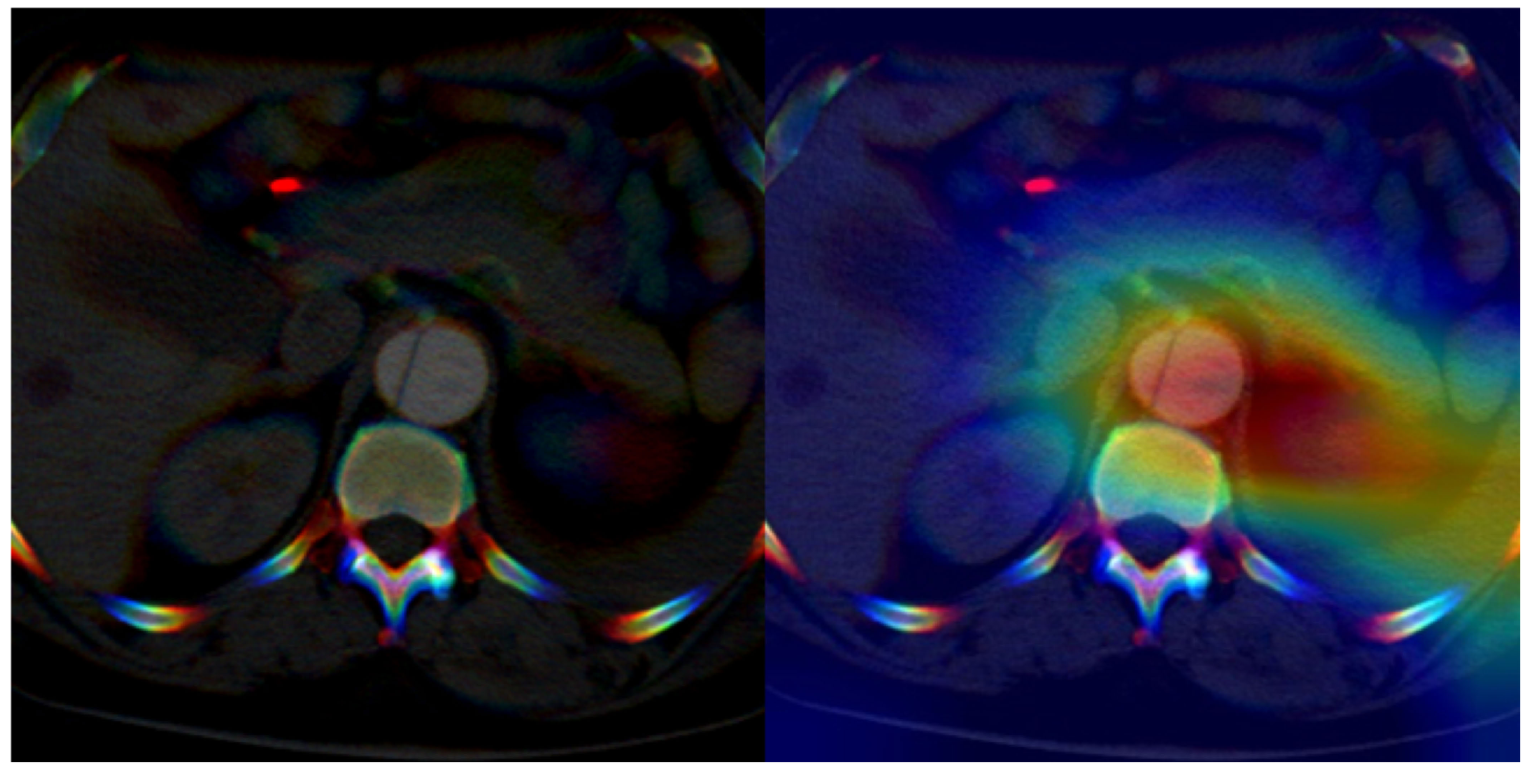

Figure 3 Stanford Type B aortic dissection axial CTA with colorized augmentation (left) and corresponding Class Activation Map[16] (CAM) (right)

Conclusion

- DCNNs demonstrate success in the classification of acute aortic dissection from non-dissected aortas on thoracic CTA with an AUC of 0.97
- Automated, instantaneous classification of critical aortic dissections could allow radiologists to expediently diagnose aortic dissections and ensure timely intervention

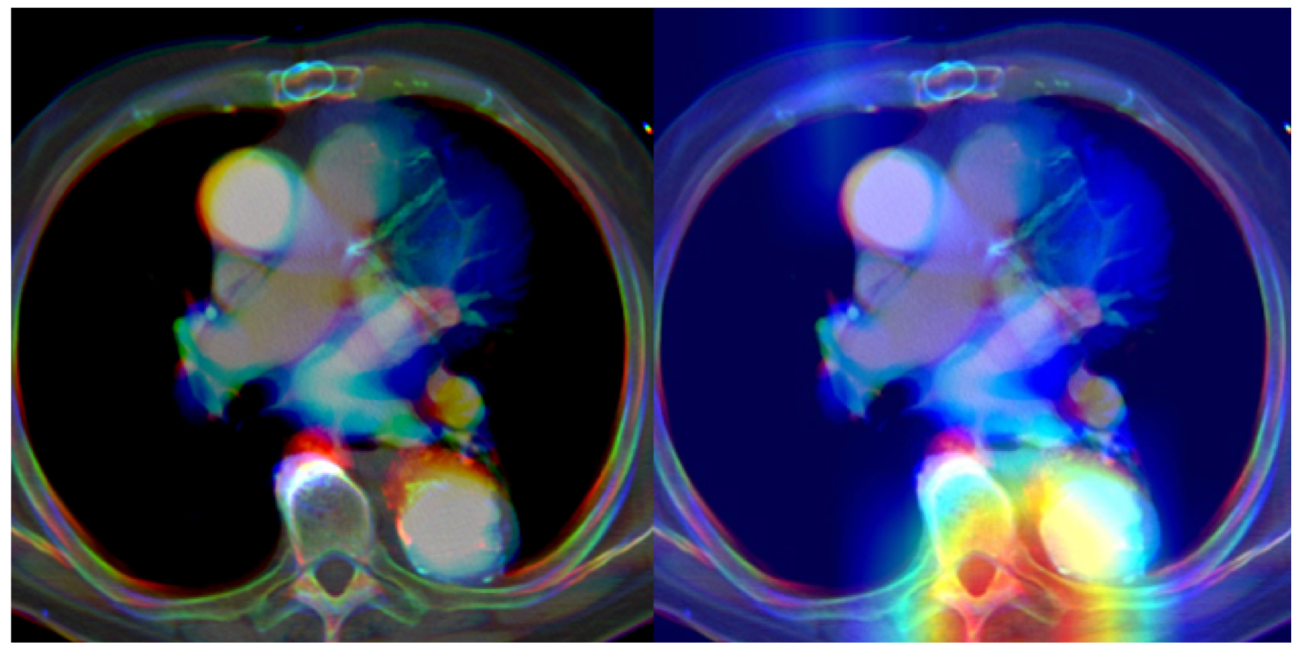

Figure 4 False positive: Eccentric thrombus axial CTA with colorized image (left) and corresponding CAM (right)

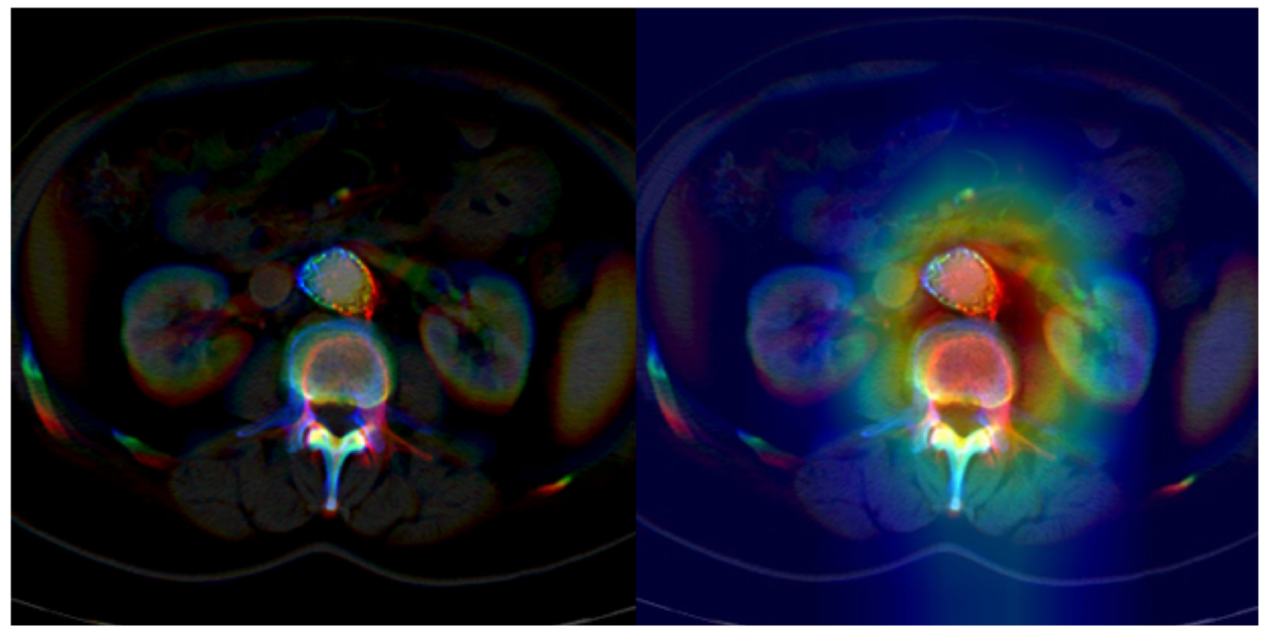

Figure 5 False positive: Endovascular stent axial CTA with colorized image (left) and corresponding CAM (right)

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