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Deep Multiclass Multiple-instance Learning For DSA Classification

Reza Moein Taghavi, Medical Student, UC Davis School of Medicine; Roger Goldman, MD, PhD

Introduction

Anatomic localization is a critical requirement for interpretation of angiography. Many images in digital subtraction angiography (DSA) sequences lack information for localization due to insufficient radiopaque contrast within the vessels, presenting a significant challenge in automated interpretation. The purpose of our study was to evaluate a deep multiclass Multiple Instance Learning (MIL) algorithm for anatomic localization in DSA sequences.

Hypothesis

We hypothesize that MIL model can accurately identify standard anatomic locations in abdominopelvic angiographic sequences.

Methods

We performed a retrospective review of the institutional PACS to identify 689 DSA sequences performed with contrast administration via the aorta, left external iliac artery, right external iliac artery, celiac artery, superior mesenteric artery, and inferior mesenteric artery. Individual images within each DSA sequence were designated as “key” if contrast opacified the identified artery at the location of contrast administration and a first order downstream vessel. Data were divided into 482 sequences for training and validation and 207 sequences for testing. A deep multiclass MIL model was developed using the MONAI Python library to classify DSA sequences from these anatomical locations. The model was trained with inputs of 50 images from each angiographic sequence. To ensure uniformity, all sequences were padded to 50 images with copies of the final image. Classification performance was quantified using accuracy, precision, recall, and F1. MIL model assigned attention weights to each image reflecting contribution to the final classification. Images corresponding to the algorithmically generated top five attention weights were compared with manually-labeled “key” images for overlap. The overlap was quantified as the ratio of the number of images in common to the number of key images.

Results

The deep multiclass MIL algorithm achieved an accuracy of 92.75% (95% CI: 89.22 - 96.28), Precision: 93.99% ± 3.24, Recall: 92.75% ± 3.53, and F1 of 88% ± 4.43 on the held-out test data. The algorithm performance for each anatomical location is provided in table 1. Figure 1 depicts an example of a DSA image sequence, manually-labeled “key” images, and the attention weights. We found an average overlap of 54.8%. In 93.24% of cases, at least one algorithm-chosen image matched an image in the manually-labeled “key” selections.

Conclusion

Deep multiclass MIL is feasible for accurate anatomic localization in DSA imaging.

Statement of Impact

This study demonstrates the potential of deep learning with attention mechanisms for automatically classifying the anatomical locations in time-series DSA data, a critical task in the interpretation of imaging during and after image-guided endovascular procedures.

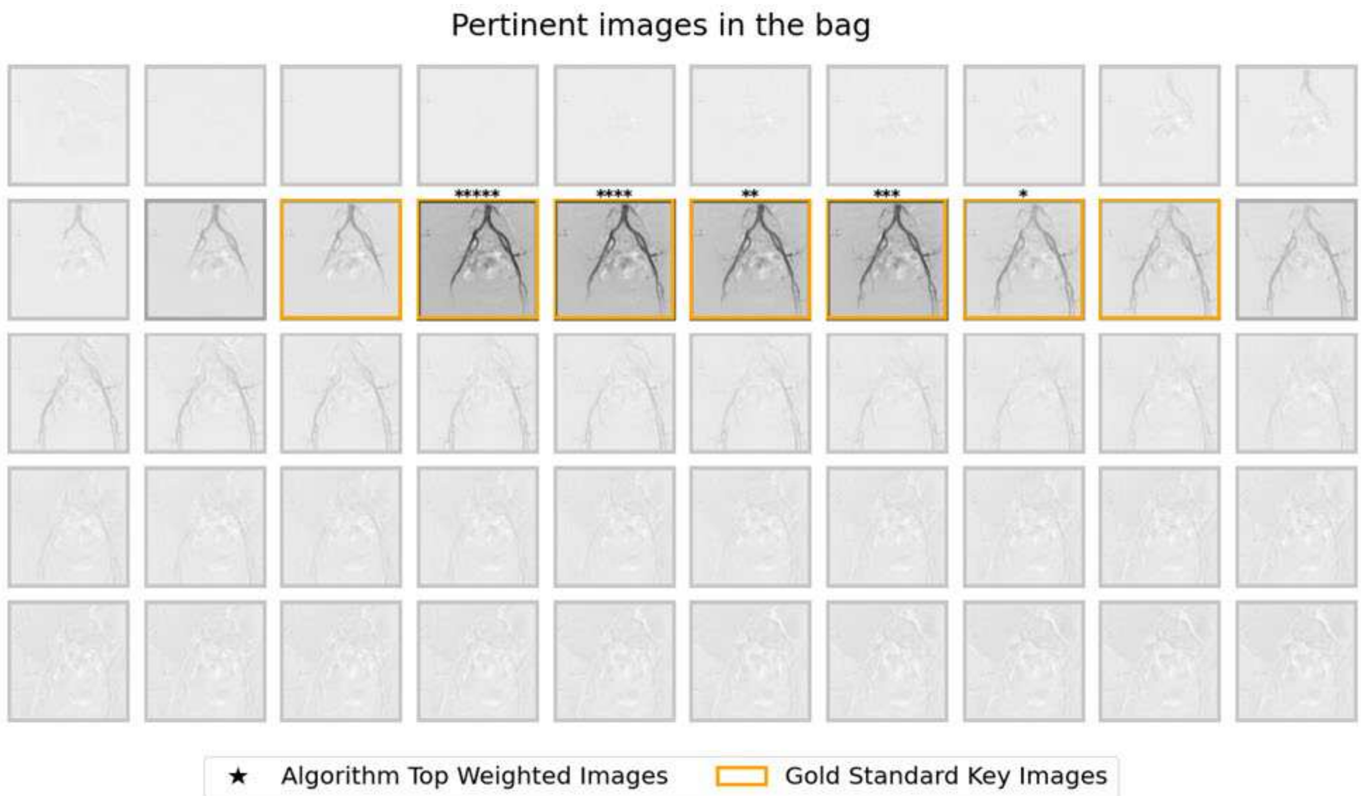

Figure 1: Sample DSA sequence from the testing dataset with an overlay of algorithm-selected images and manually labeled diagnostic “key” images are shown. Images with stars represent the top five weighted images by the algorithm, with the star count correlating to the assigned weight. Similarly, the opacity of the images correlates to algorithm generated weights: the greater the opacity, the larger the weight. Conversely, more transparent images have smaller weights. Images outlined in yellow rectangles represent the diagnostic “key” images.
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Anatomic location	Number of samples	Precision	Sensitivity (Recall)	F1
Aorta	27	100	96.3	98.12
CA	66	95.59	98.48	97.01
EIA/R	68	88.16	98.53	93.06
EIA/L	13	100	69.23	81.82
SMA	28	88	78.57	83.02
IMA	5	100	60	75

Table 1 : Performance of the algorithm on the test dataset, stratified by anatomical location: aorta (AO), left external iliac artery (LEIA), right external iliac artery (REIA), celiac artery (CA), superior mesenteric artery (SMA), and inferior mesenteric (IMA).

Keywords
MIL; Deep Learning; DSA