Strategy to develop convolutional neural network-based classifier for diagnosis of whole-body FDG PET images

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Backgrounds

- As the number of PET-CT scanners increases and FDG PET-CT becomes a common study in oncology, the physicians' burden of interpreting images is increased.
- Recently, image analysis using the convolutional neural network (CNN) is rapidly becoming popular in medical imaging.

Backgrounds

- CNN is one of the deep learning techniques and is known to be feasible to image classification by recognizing complex visual patterns in a similar way to human perceptions.
- The demand on AI is rapidly growing in order to the relative decrease of radiologists/nuclear medicine physicians and to prevent human oversight/misdiagnosis.

Objectives

- We aimed to develop a CNN-based diagnosis system that classifies whole-body FDG PET-CT images into 1) normal, 2) abnormal, 3) equivocal.

Patient population

- We investigated sequential 1,053 studies of FDG PET-CT at our institute.
- A nuclear medicine physician classified all the cases into the following 3 categories:

(1) No malignant uptake

N=302

(2) Malignant uptake

N=146

(3) Equivocal

N=605

Methods; Image acquisition and reconstruction

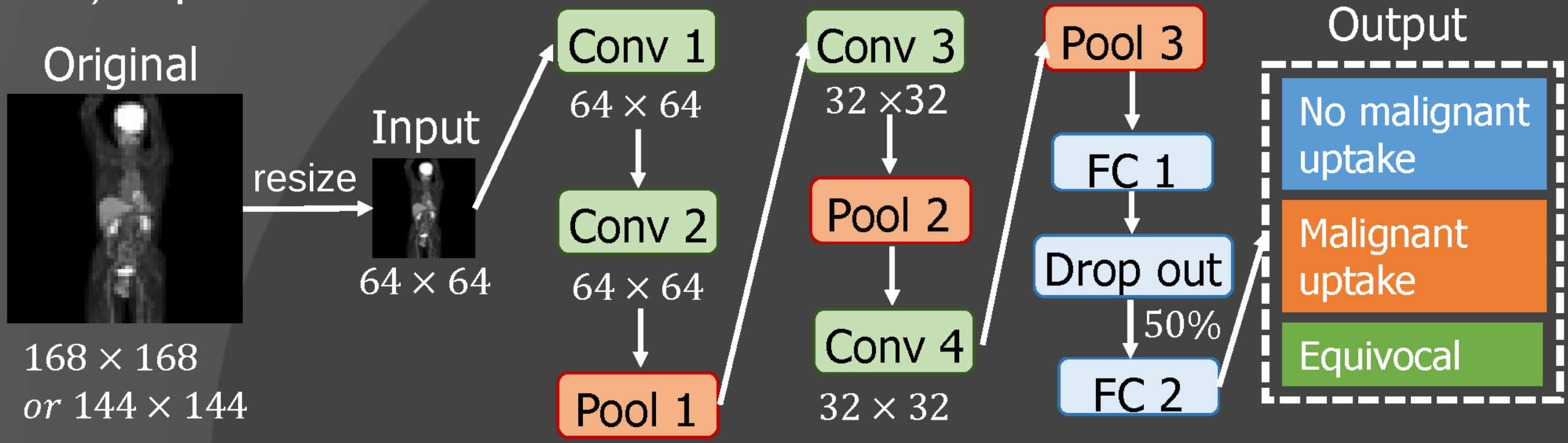
Scanner	Biograph 64 (Siemens, N = 4,794)	GEMINI-TF 64 (Philips, N = 1,641)
Reconstruction method	TrueX (OSEM)	3D-RAMLA (OSEM)
Time of flight	No	Yes
Point spread function	Yes	No
Matrix size	168×168	144×144

Methods; Image acquisition and reconstruction

- Maximum intensity projection (MIP) images (matrix size, 168 × 168 or 144 × 144) were generated on each scanner's workstation at various angles.
- In the current study, CT images were used only for attenuation correction but not for classification.

Methods; Architectures

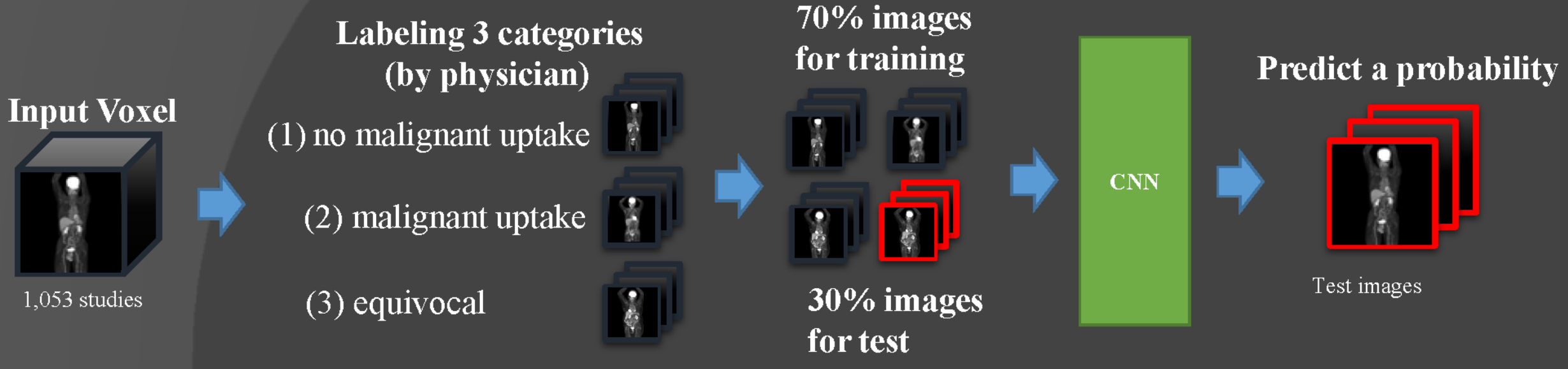
- We constructed a CNN to classify whole-body FDG PET-CT images into 1) No malignant uptake, 2) Malignant uptake, 3) Equivocal.



· Conv = Convolutional Layer · Pool = Max Pooling Layer · FC = Fully Connected Layer

Methods; Model training and test

- We trained the CNN using data from the FDG PET images.
- CNN was trained and validated using the randomly selected 70% images while the data of the remaining 30% images were used for test purpose. The process was repeated 5 times to calculate the accuracy.



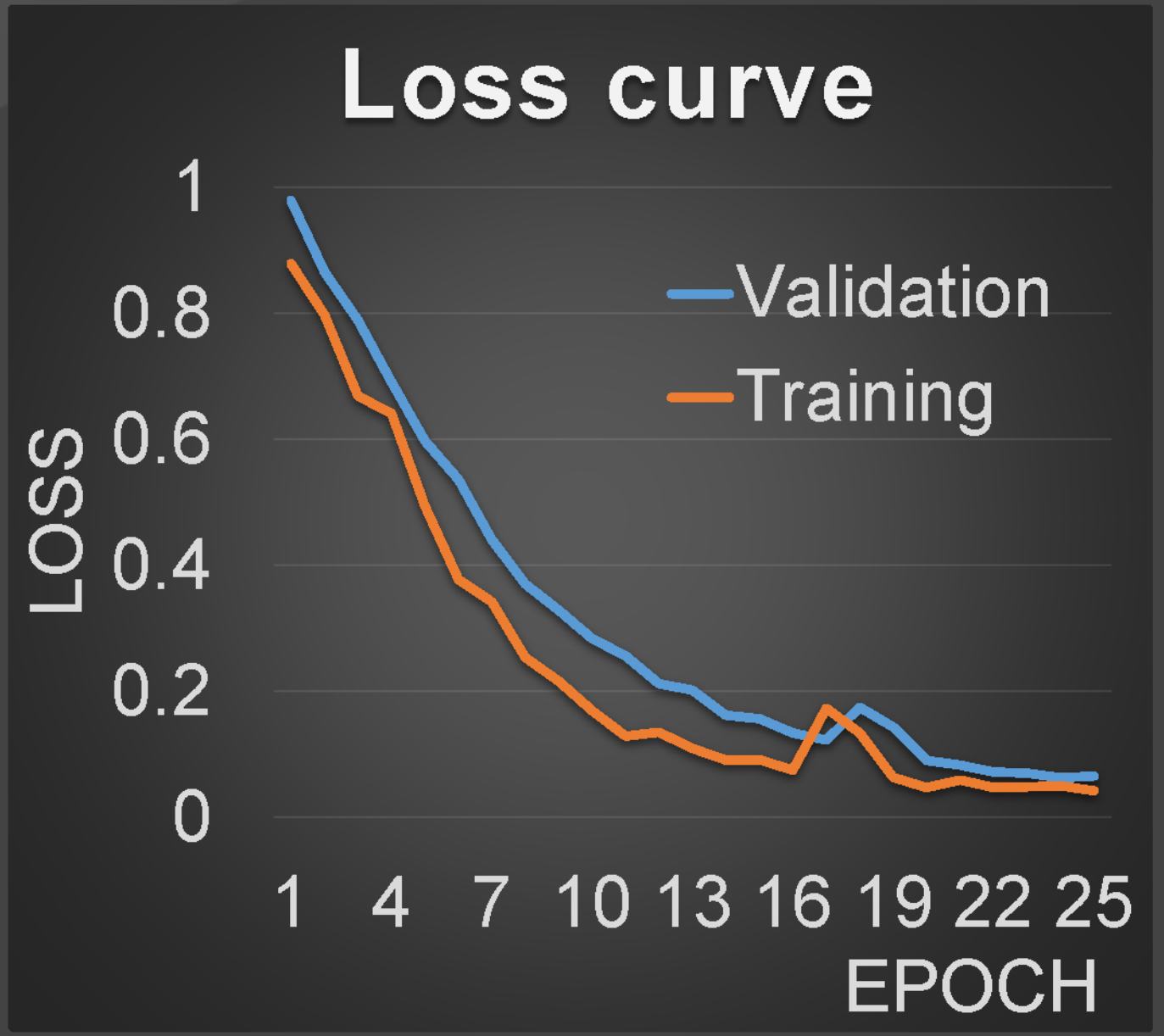
Methods; Hardware and software environments

- These experiments were performed the following environment:

OS	Windows 10 pro 64 bit
CPU	intel Core i7-6700K
GPU	2 × NVIDIA GeForce GTX 1060 6GB
Framework	Keras 2.0.2 and TensorFlow 1.3.0
Language	Python 3.5.2

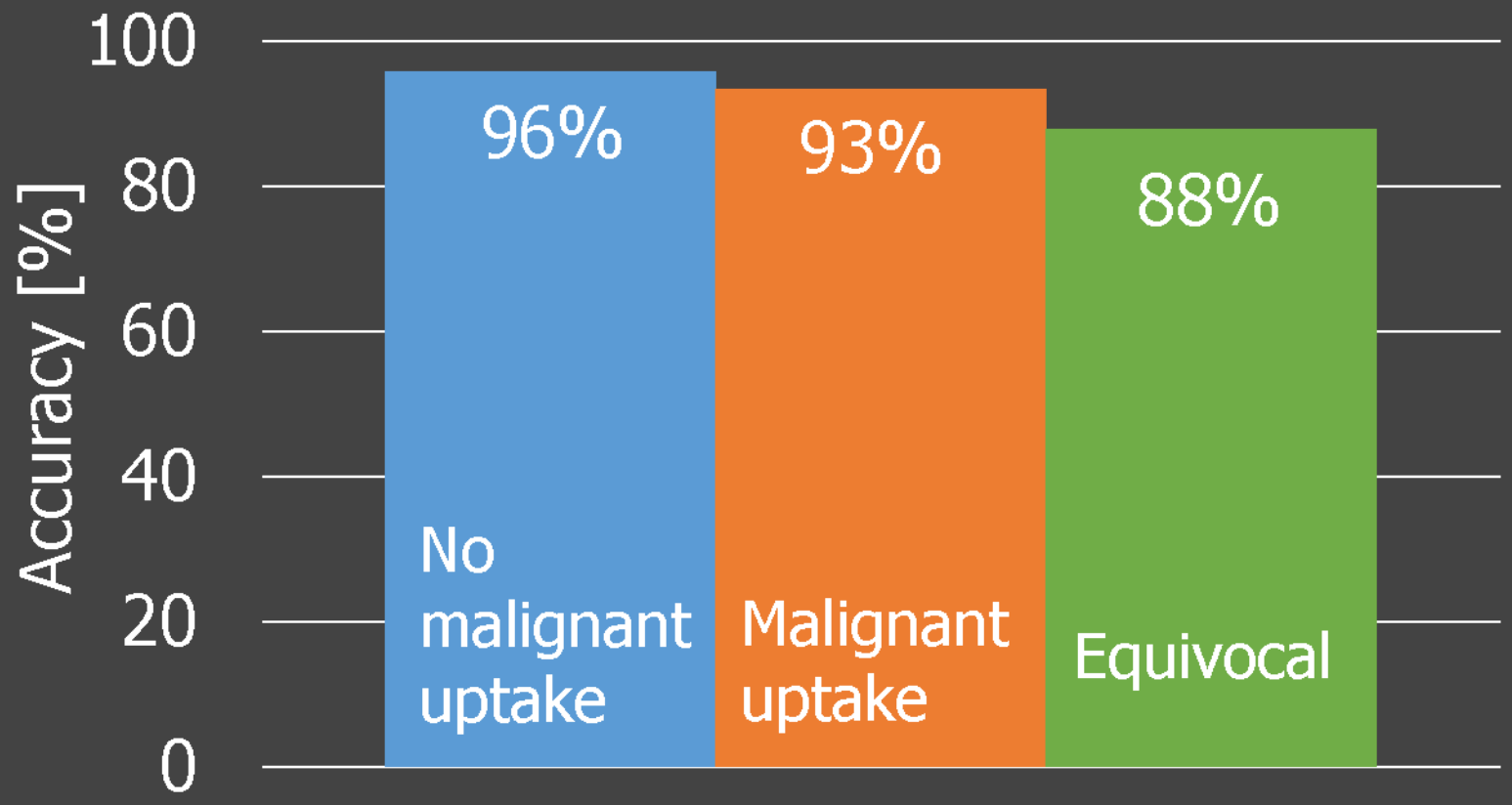
Results

- The model was trained for 25 epochs.
- The CNN process spent 15 minutes for training each fold dataset and <0.1 second / patient for prediction.



Results

- When images of no malignant uptake were given to the learned model, the accuracy was 96%.
- Similarly, the accuracy for images of malignant uptake and images of equivocal were 93% and 88% respectively.



Results - Detailed results -

- For no malignant uptake case, 96% cases were correctly predicted as no malignant uptake.

Prediction	Correct Label		
	(1) no malignant uptake	(2) malignant uptake	(3) equivocal
(1)	96%	4%	8%
(2)	1%	93%	4%
(3)	3%	3%	88%

Results - AI failed to predict -

- This case was "No malignant uptake " by physician’s diagnosis.
- However, the prediction of AI was "Malignant uptake".
- In this case, physiological accumulation of head and neck was high, possibly mimicking malignancy.

Summary

- In this research using CNN, for classification, FDG PET-CT images were classified into 3 categories.
- The overall accuracy was around 90%.

Discussions

- The overall accuracy of 90% was not enough to reduce physicians' burden.
- Especially, the accuracy was lower for "equivocal" than for other categories, possibly because "equivocal" group contained both malignant and non-malignant images and thus was difficult for AI to define; in other words "heterogenous group".

Discussion

- There is still room for improvement. As shown in the table, the percentage of false negatives is high.

Prediction	Correct Label: (1) no malignant uptake	(2) malignant uptake	(3) equivocal
(1)	96%	4%	8%
(2)	1%	93%	4%
(3)	3%	3%	88%

Discussion

- Future studies will make false negatives as small as possible.
- Such an automated diagnosis system will

  - select cases where radiologist further inspection is not necessary.
  - be effective for medical checkup.

Conclusion

- We developed and tested a convolutional neural network-based system to classify FDG-PET images into 1) normal, 2) abnormal, 3) equivocal.
- Although further improvement is needed, such a system will contribute to reducing physicians' burden and preventing oversight.