

Convolutional Neural Network for the Diagnosis of Pediatric Developmental Dysplasia of the Hip on Conventional Radiography

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- ***Developmental Dysplasia Of the Hip (DDH):***

The most common orthopedic disorder in newborns

Incidence: 1.5 in 1,000

Spectrum of structural abnormalities

(mild acetabular dysplasia ~ dislocation of the femoral head)

- ***Diagnosis and Treatment:***

- Modality of choice: Conventional radiography and Ultrasound
- Ossification center of femoral head: 4-6 month of age
- US: < 4-6 months of age
- Conventional radiography: > 4-6 month of age
- Articulation of the femoral head and acetabulum → normal development
- Early diagnosis and treatment are important

Siegel MJ. Pediatric sonography: Lippincott Williams & Wilkins; 2011.

Starr V . Et al. AJR. 2014;203(6):1324-35.

- ***Convolutional Neural Network***

: tremendous progress; considered to be an emerging technique for the classification of images

: potential of deep learning in the field of lesion detection, classification and image improvement in radiologic image

- To evaluate the **diagnostic performance** of a **deep learning algorithm for DDH** using conventional radiography.

- **Inclusion**

- Younger than 12 months of age who were suspected of DDH and were undergoing hip AP conventional radiography
- SNUH: between January 2011 and June 2018
- SNUBH & PNUYH: between January 2016 and June 2018

- **Exclusion**

- Inappropriate images for reading
- Images taken with not proper position
- Postoperative images

• Dataset

- 2,601 Hip radiographs → 5,202 hip joints images
- Exclusion: 126 inappropriate images
- 5,076 hip joint images → Dataset (Training 80% / Validation 10% / Test 10%)

Hospitals	Total	Training Set		Validation Set		Test Set	
		Normal	DDH	Normal	DDH	Normal	DDH
SNUH	3433	2406	341	300	43	300	43
SNUBH	1036	800	32	97	5	97	5
PNUYH	607	452	19	65	3	66	2
Total	5076	4050		513		513	

• Labeling

- Image Review and Labeling: By two pediatric radiologists in consensus
- Binary Classification: Normal and DDH
- Diagnosis of DDH
 - 1) high acetabular index (> 30 degree)
 - 2) abnormal acetabular morphology and delayed femoral head
 - 3) abnormal femoral head location; out of inferior medial quadrant of acetabulum
 - 4) disruption of Shenton line

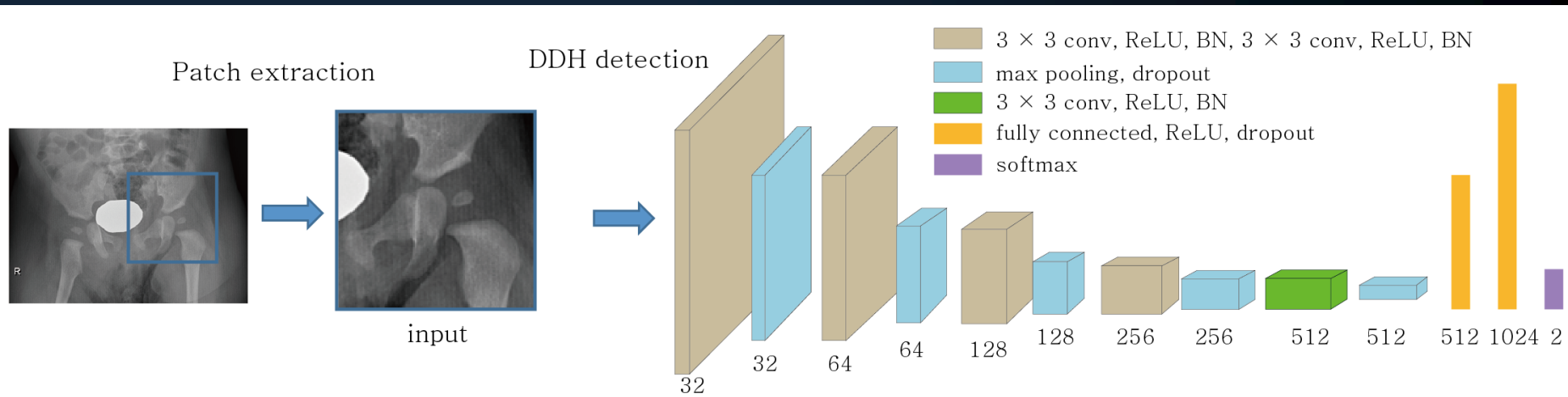


- **Image Processing**

- Manually cropping: include single hip joint with the femoral head in the center of the cropped image
- To avoid overfitting, the training datasets were augmented (x 10 in DDH, x4 in normal)
- 3,920 DDH and 14,632 normal patches were used for training.
- Training was performed after resizing patch size from 414×414 to 128×128

• Deep Learning Algorithm

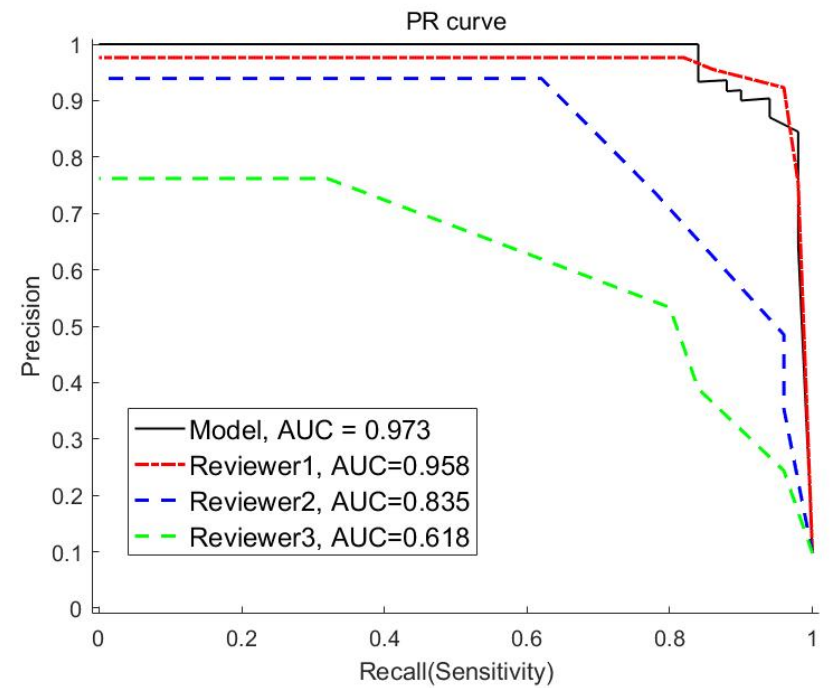
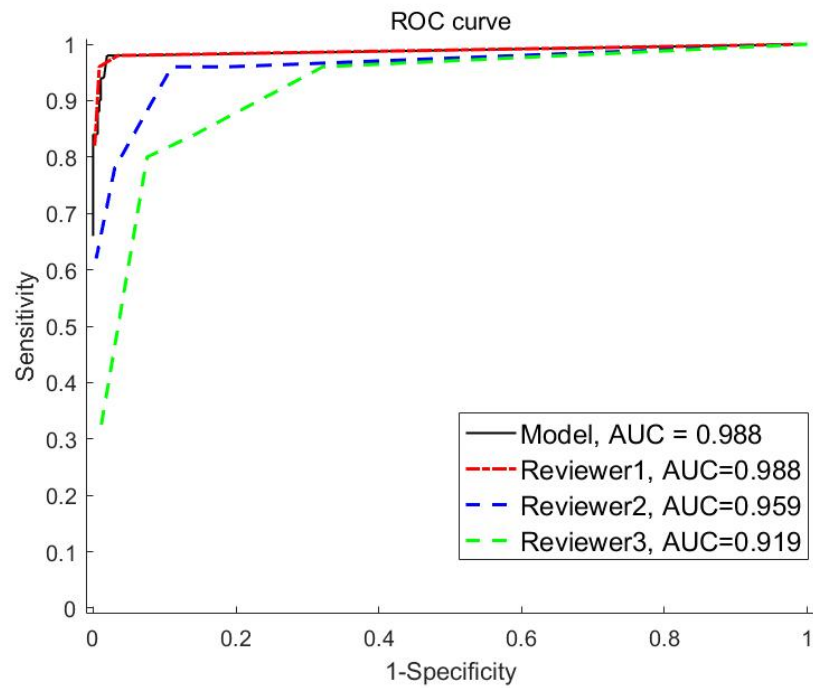
- Tensorflow
- GPU (NVIDIA, Titan Xp. 12GB) system
- Network minimization: using the Adam optimizer
- Learning rate: 0.0001
- Mini-batch size: 16
- Epoch: 100

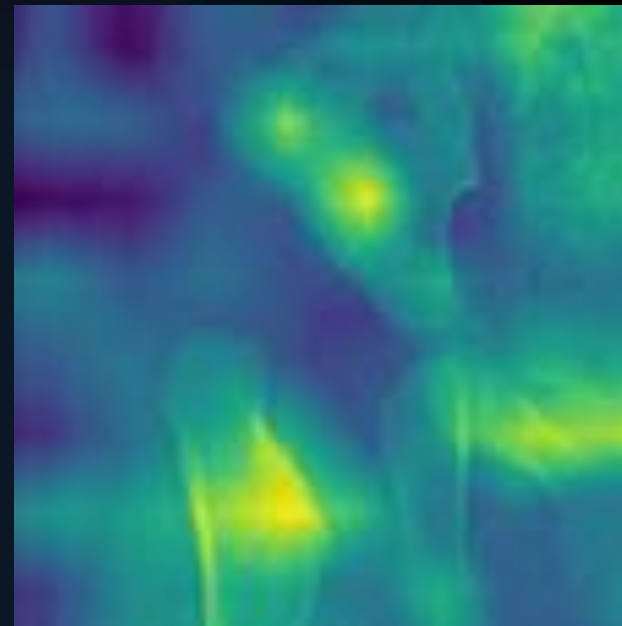
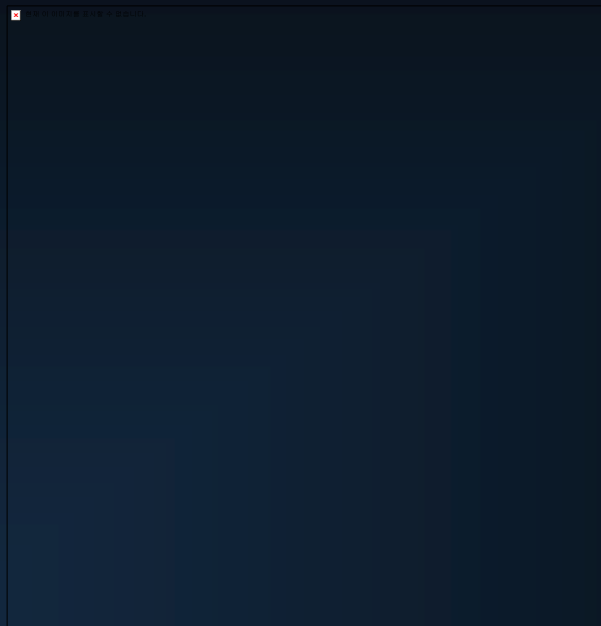
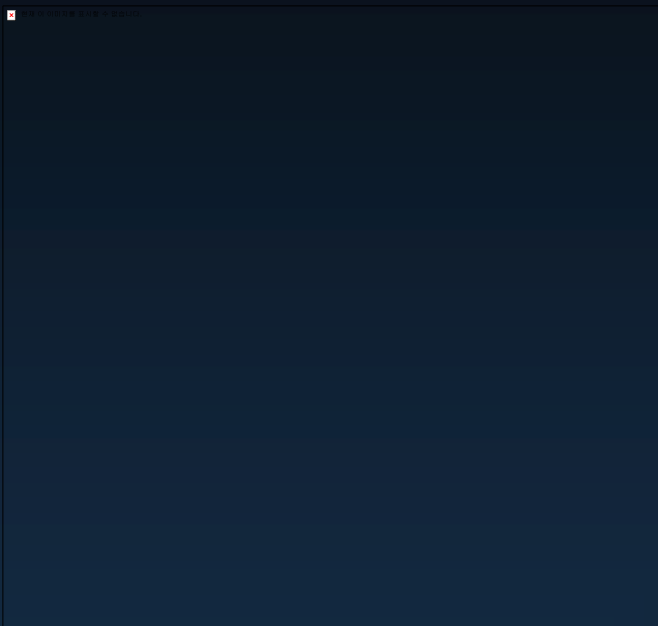


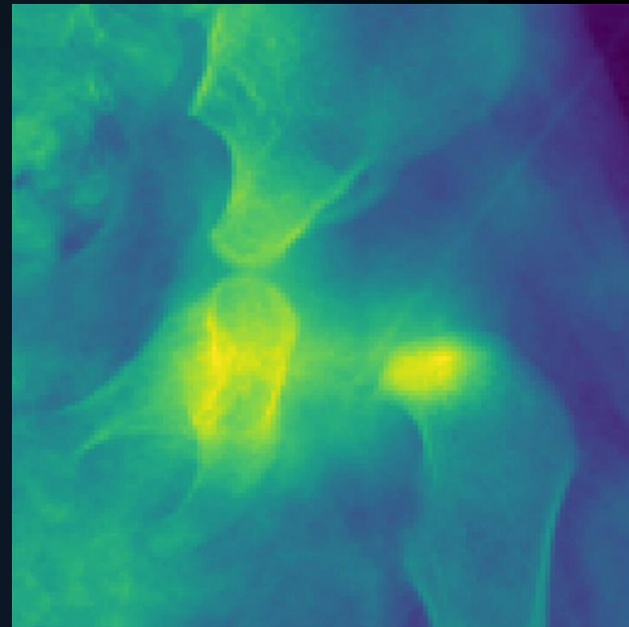
- **Human Readout**
- **Three invited radiologists performed image review**
 - Reviewer 1: pediatric experts
 - Reviewer 2: experienced radiologist without experience in pediatric radiology
 - Reviewer 3: inexperienced radiologist without experience in pediatric radiology
- **No clinical information, No contralateral Hip image**
- **Labeling: 5-point scale**
 - 1, definitely normal; 2, probably normal; 3, indeterminate; 4, probable DDH; and 5, definite DDH

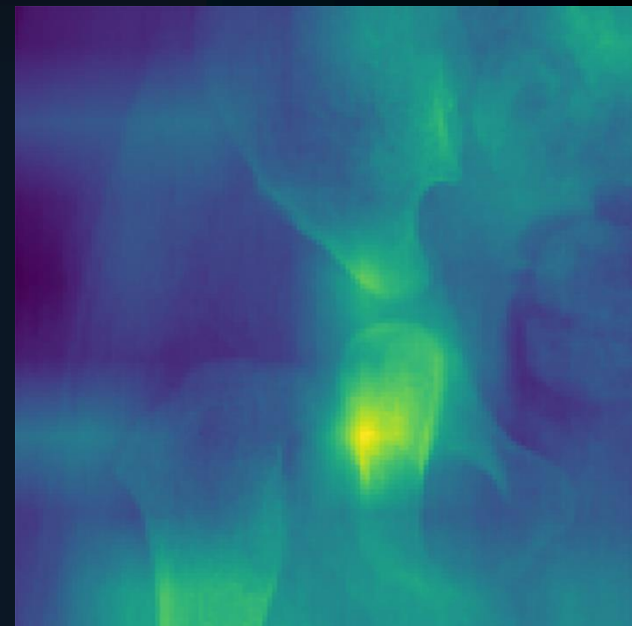
- **Statistical analysis**
- **Diagnostic Performance of the deep learning algorithm**
 - construction of 2x2 table
 - calculation of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV)
 - construction of receiver an operating curve (ROC) plot and a precision-recall (PRC) plot → calculate area under the curve (AUC)
- **Comparison with Human Readout**
 - 5-point scale → dichotomization into normal (1, 2) and D \varnothing (3, 4, 5)
 - calculation of sensitivity, specificity, PPV and NPV
 - McNemar`s test
 - AUC of ROC and PRC plot comparison (algorithm vs. human readout)

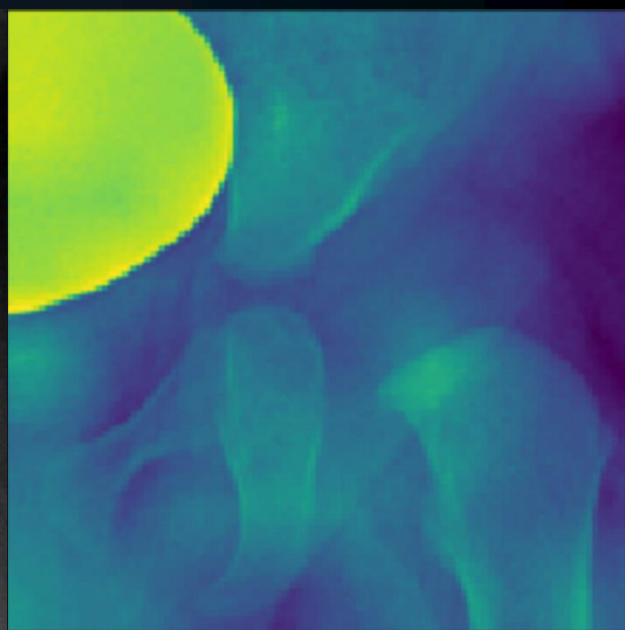
	Sensitivity	Specificity	PPV	NPV	AUC of ROC plot	AUC of PRC plot
Deep learning algorithm	94.0 (83.5-98.7)	98.9 (97.5-99.6)	90.4 (79.7-95.8)	99.4 (98.1-99.8)	0.988 (0.974-0.995)	0.979
Radiologist 1 (p= 1.000)	96.0 (86.3-99.5)	99.1 (97.8-99.8)	92.3 (81.9-97.0)	99.6 (98.3-99.9)	0.988 (0.974-0.995)	0.958
Radiologist 2 (p<0.001)	96.0 (86.3-99.5)	89.0 (85.8-91.7)	48.5 (41.9-55.1)	99.5 (98.1-99.9)	0.959 (0.939-0.975)	0.835
Radiologist 3 (p<0.001)	84.0 (70.9-92.8)	85.8 (82.2-88.8)	38.9 (33.0-45.1)	98.0 (96.3-98.9)	0.919 (0.892-0.941)	0.618

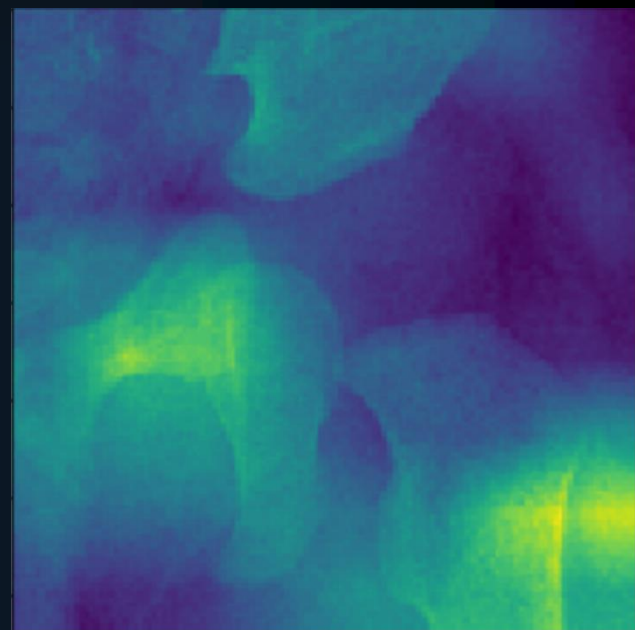












Conclusion

- The proposed **deep learning algorithm** provided an accurate diagnosis of **developmental dysplasia of the hip** on hip AP conventional radiographs, which was **comparable to an experienced radiologist**.

Thank you for your attentions