An algorithm for using deep learning convolutional neural networks with three dimensional depth sensor imaging in scoliosis detection - In order to avoid the detection of extremely mild patients and false positive cases -

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INTRODUCTION:

Adolescent idiopathic scoliosis (AIS) is the most ordinary pediatric spinal disease. Timely intervention in growing individuals, such as brace treatment, relies on early detection of AIS. We developed a system consisting of a three-dimensional (3D) depth sensor and an algorithm installed in a laptop computer. In this system, the correlation between the actual Cobb angle and the predicted Cobb angle calculated from the asymmetry index was 0.85 ($P < 0.01$). However, it could be excessive to detect patients with Cobb angle of 10˚ to 15˚ in school screening, who aren't indicated for brace treatment, because they would be exposed to unnecessary radiation. In addition, healthcare resources could be strained due to the examinations for extremely mild AIS patient and false positive cases.

The purpose of this study is to create a deep learning algorithm (DLA) to identify moderate or severe AIS patients requiring the secondary screening using data of subjects detected in the school screening.

METHODS: This study was conducted retrospectively. Three hundred and thirty-four subjects detected using the 3D depth sensor system in school screening from April 2021 to March 2023 were included. The 3D images from the 3D depth sensor system were used as input data for the DLA with Convolutional neural networks. We randomly separated the 334 subjects into an internal validation data of 250 and an external validation data of 84. To avoid the imbalanced dataset in the internal validation, binary classification was performed as 0 for images with Cobb angle of < 12˚ and 1 for images with Cobb angle of ≥ 12˚ based on the average actual Cobb angle of 12.0 ˚. Five-fold cross validation was conducted to evaluate the probability for Cobb angle of ≥ 12˚. The minimum predicted probability in subjects with Cobb angle of ≥ 15˚ was configured as the cut-off value to detect the second screening targets. In the external validation, 84 images were evaluated utilizing trained DLA in the internal validation, and decide to require secondary screening, based on the cu-off value.

RESULTS: The range of Cobb angle was 0˚ to 34˚ in the internal validation and 0˚ to 32˚ in the external validation, respectively. In the internal validation, the number of subjects with Cobb angle of ≤ 12˚ and > 12˚ were 132 and 118, respectively. The five-fold cross validation showed that the dataset 3 had the highest predicted performance (Table 1 and Figure 1). The minimum predicted probability in subjects with Cobb angle of ≥ 15˚ was 0.47 in dataset 3. In the external validation, the number of subjects with Cobb angle of < 10˚ and < 15˚ were 36 and 62, respectively. Based on a cut-off value of 0.47, 39 (63%) subjects with Cobb angle of < 15˚ were judged as unnecessary for the second screening. The false positive cases with Cobb angle of < 10˚ reduced by 24 cases (67%). There was only one false negative case with Cobb angle of 19˚

DISCUSSION AND CONCLUSION: This DLA reduced the number of extremely mild AIS patient and false positive cases in the external validation, indicating that this DLA can reduce the unnecessary medical care expenditures and the unnecessary radiation exposure for children and adolescents. It is believed that a high accurate AIS screening can be achieved through the combination of this DLA for identifying AIS patients requiring the secondary screening and the asymmetry index calculated from the above original algorithm.

Figure 2. ROC curves for detecting scoliosis with a curve ≥ 15˚ in five-fold cross validation

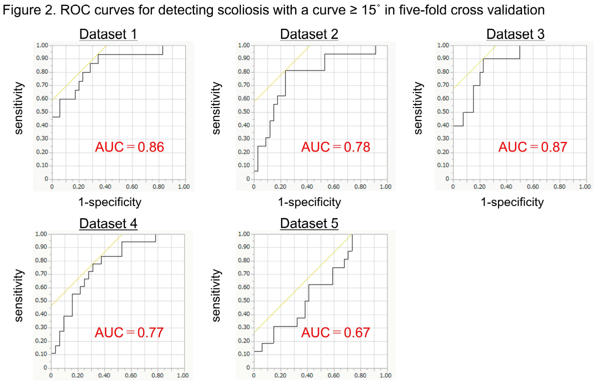

Table 1. Experimental indicators for detecting scoliosis with a curve ≥15° in each dataset

Dataset	Sensitivity	Specificity	PPV	NPV	Accuracy	PLR	NLR
1	0.93	0.66	0.54	0.96	0.74	2.72	0.10
2	0.81	0.77	0.62	0.90	0.78	3.45	0.25
3	0.90	0.78	0.50	0.97	0.80	4.00	0.13
4	0.78	0.69	0.58	0.85	0.72	2.49	0.32
5	1.00	0.27	0.39	1.00	0.50	1.36	0.00

PPV= positive predictive value, NPV= negative predictive value,
PLR= positive likelihood ratio, NLR= negative likelihood ratio