BP-05

Deep learning model for automatic diagnosis of CVJ abnormalities using X-ray images

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Background: Non-traumatic atlantoaxial dislocation (AAD), which includes both anterior and posterior AAD, is often associated with abnormalities in the craniovertebral junction (CVJ), such as basilar invagination, os odontoideum, occipitalization of the atlas, and C2-3 nonsegmentation (a subtype of Klippel-Feil syndrome). Early detection and timely intervention of these abnormalities are critical to preventing high cervical spinal cord injury caused by disease progression, which can lead to irreversible severe outcomes. X-ray imaging, being the most accessible and cost-effective method in primary healthcare, is commonly used. However, due to the insufficient diagnostic experience of primary care physicians, and the overlapping anatomical structures in X-ray images, CVJ abnormalities are often missed or misdiagnosed.

Research question: To develop a deep learning model that can diagnose these CVJ abnormalities.

Design: Model development and validation.

Methods: A total of 1208 X-ray images of the cervical spine were collected and annotated with six binary classification labels: anterior AAD, posterior AAD, basilar invagination, os odontoideum, occipitalization of the atlas, and C2-3 nonsegmentation. Annotations included both classification labels and bounding box selections. The dataset was randomly divided into training and validation sets in an 8:2 ratio. The baseline models for image feature extraction were ResNet50, VGG16, DenseNet121, and ViT. The model's performance was evaluated using the F1-score and sensitivity.

Results: The highest F1-scores achieved for diagnosing anterior AAD, posterior AAD, basilar invagination, os odontoideum, occipitalization of the atlas, and C2-3 nonsegmentation were 0.93, 0.93, 0.7, 0.9, 0.73, and 0.98, respectively (fig.1). The highest sensitivity rates for each condition were 0.93, 0.93, 0.72, 0.9, 0.73, and 1(fig.2).

Discussion: A diagnostic model for the identification of CVJ deformity was developed and validated.

Fig. 1

	ResNet50	VGG16	DenseNet121	ViT
Anterior AAD	0.92	**0.93**	0.91	0.91
Posterior AAD	**0.93**	0.91	**0.93**	**0.93**
Basilar invagination	0.59	0.68	**0.70**	0.63
Os odontoideum	**0.90**	0.88	0.86	0.88
Occipitalization of the atlas	0.69	0.71	**0.73**	0.70
C2-3 nonsegmentation	0.97	0.95	**0.98**	0.97

Fig. 2

	ResNet50	VGG16	DenseNet121	ViT
Anterior AAD	0.91	**0.93**	0.90	0.90
Posterior AAD	**0.93**	0.89	**0.93**	0.86
Basilar invagination	0.58	0.70	**0.72**	0.59
Os odontoideum	**0.90**	**0.90**	0.85	0.88
Occipitalization of the atlas	0.69	0.67	0.72	**0.73**
C2-3 nonsegmentation	0.98	0.98	**1.00**	0.98