Advanced Deep Learning Algorithm for Acute Ischemic Stroke Classification Based on Brain MR

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임상조교수 이대인
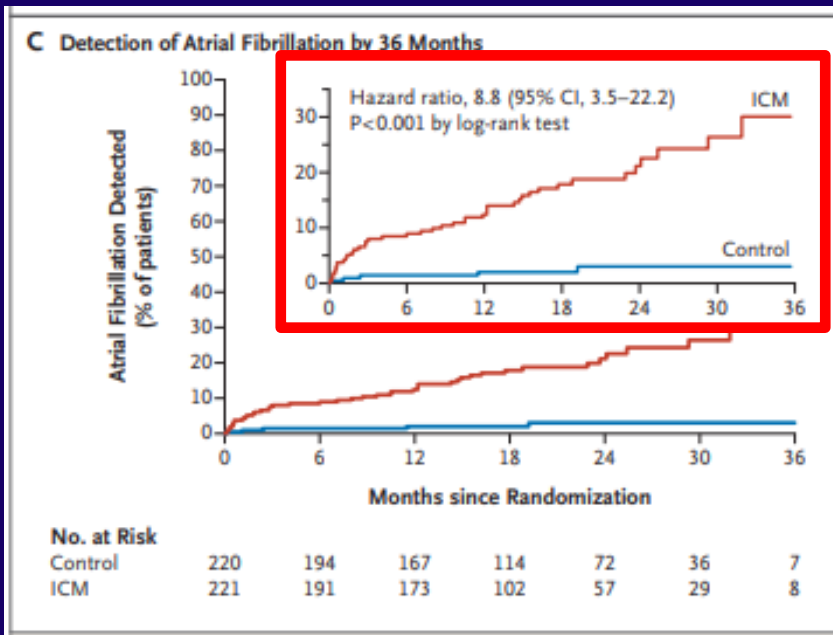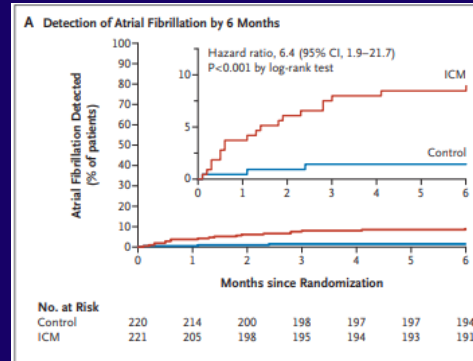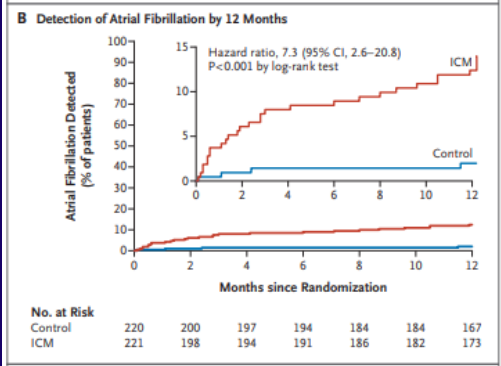
CHUNGBUK NATIONAL UNIVERSITY HOSPITAL

Crystal AF: 30% of Cryptogenic stroke (ESUS) have AF

Guideline of National Health Inusrance Service (NHIS)

나725-3 이식형 사건 기록기(Implantable Loop Recorder, ILR) 검사는 다른 검사로 원인이 진단되지 않는 다음의 경우에 요양급여함.

- 다 음 -

가. 재발성 실신. 다만, 구조적 심장질환을 가진 환자의 경우에는 실신이 1회 발생한 경우에도 요양급여함.

나. 재발성 두근거림(Palpitations)

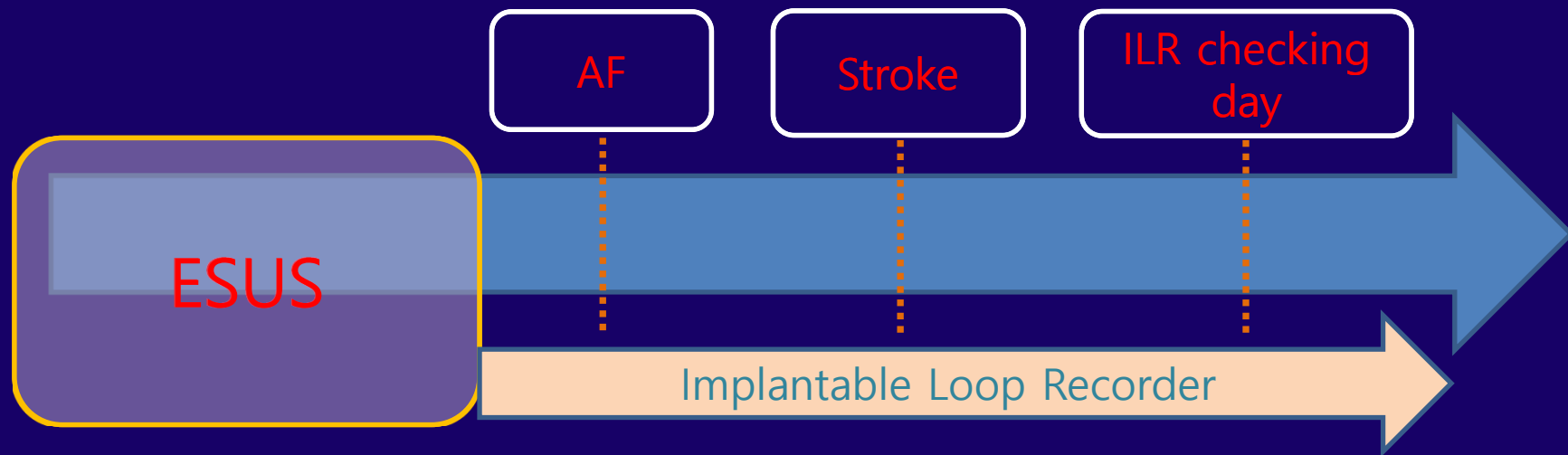다. 심방세동이 의심되는 원인불명의 뇌졸중(Cryptogenic Stroke)으로 아래의 1)~4)를 모두 만족하는 경우

- 아 래 -

1) 비열공성 뇌경색

2) 심전도 검사와 24시간 홀터기록 등의 비침습적 심전도 검사를 통해 심방세동이 발견되지 않은 경우

3) 뇌혈관의 뇌경색을 유발할 수 있는 의미있는 협착이나 폐색이 없는 경우

4) 신경과(또는 신경외과) 전문의의 진료 소견에 따라 기타 색전성 뇌경색의 원인이 없는 경우

TIME LAG OF AF RECURRENCE OR STROKE RECURRENCE

ESUS

AF

Stroke

ILR checking day

Implantable Loop Recorder

CLINICAL SCIENCES

Antithrombotic Treatment of Embolic Stroke of Undetermined Source

RE-SPECT ESUS Elderly and Renally Impaired Subgroups

Dabigatran Etexilate Versus Aspirin
in Patients With Embolic Stroke of Undetermined Source (ESUS)

The trial did not demonstrate superiority of dabigatran versus aspirin for prevention of recurrent stroke in patients with ESUS. There was no statistically significant difference for major bleeding.[7] RE-SPECT ESUS was the first Phase III trial in which the dabigatran dose was

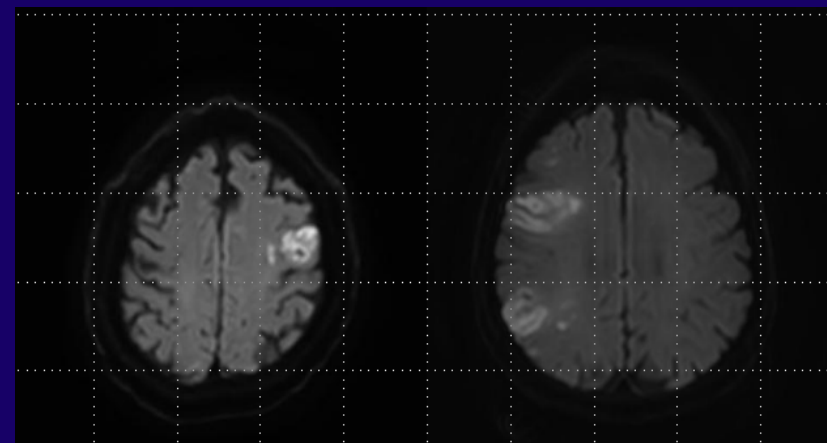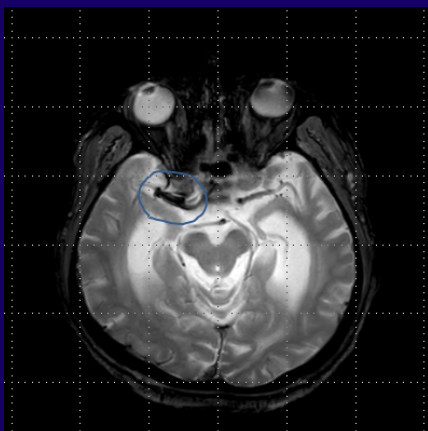# Basement of Intuition, consuming AF as cause of stroke based on brain MR
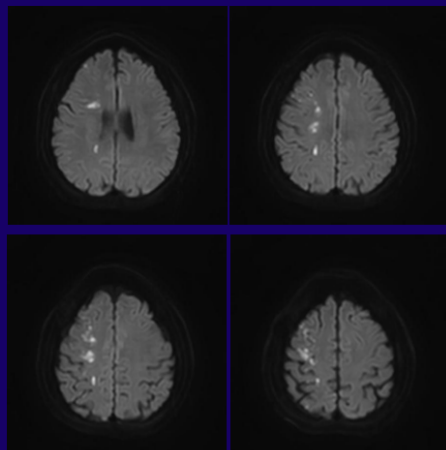
Multifocal infarction
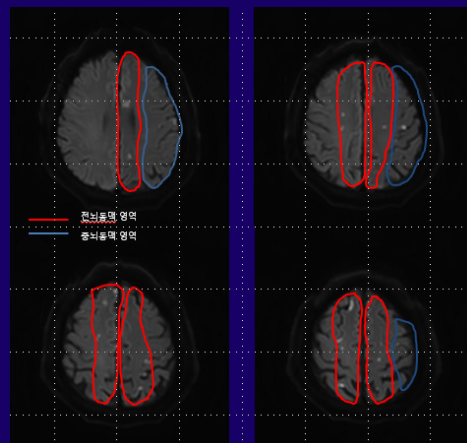
Different vessel involvement

Cortical lesions

Blooming pattern
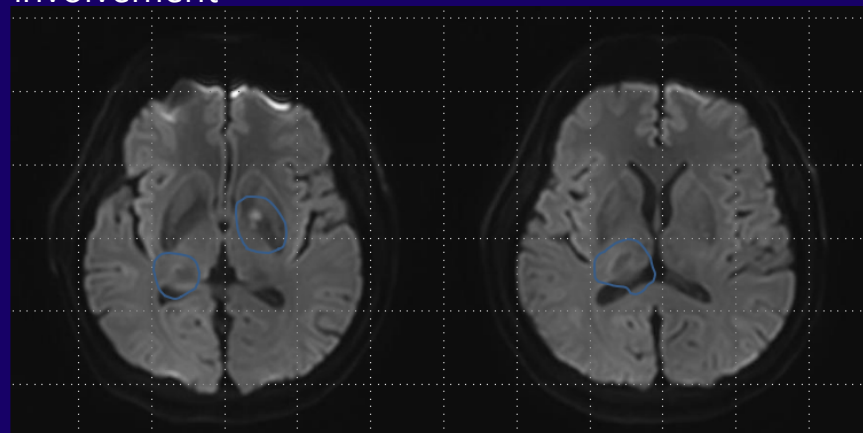
Coexistence of acute and sub-acute stroke

Objects

Using stroke registry of CBNUH neuro-department,

We aimed to develop a deep learning algorithm of brain

MRI classification technique for etiological analysis on

embolic stroke

Methods

- **Brain MRI protocol**

➤ **Diffusion weighted image / afferent diffusion coeffient = DWI /ADC**

➤ **Diffusion gradient was weighted by b level (b=1000s/mm^2)**

➤ **1.5 T or 3 T MRI**
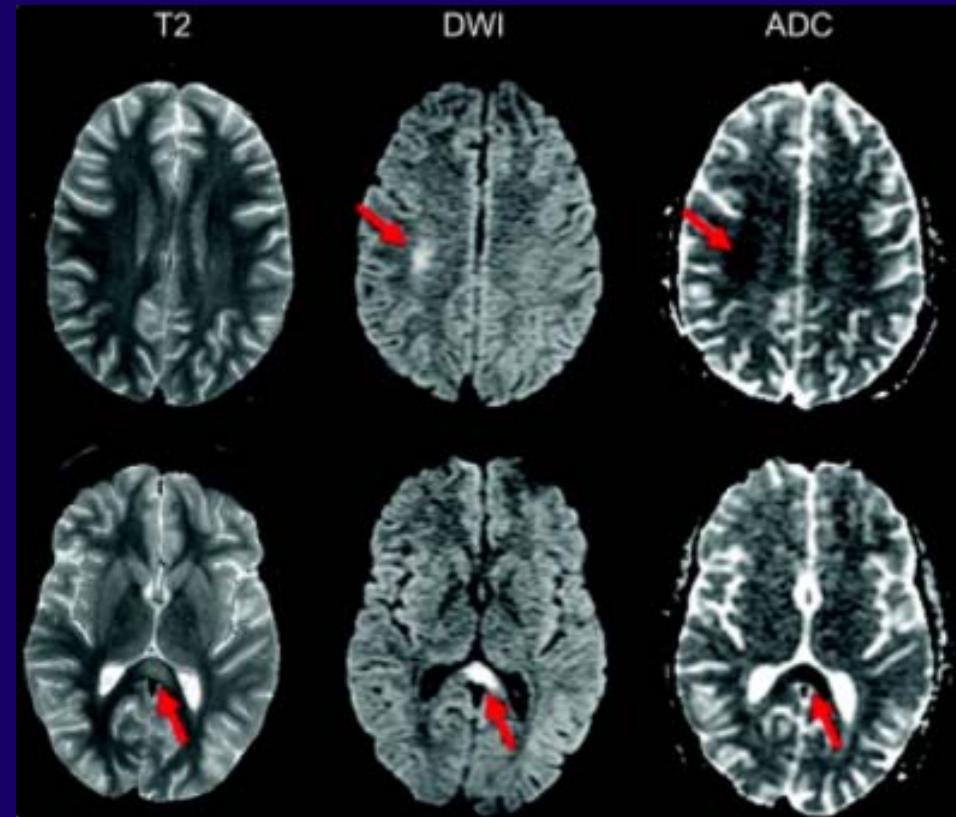
Etiology Subclassification of Ischemic Stroke

Trial of Org10172 in Acute Stroke Treatment (TOAST)

classification

- Large-artery artherosclerosis (LAA)

- Cardioembolism (CE)

- Small-vessel occlusion (SVO)

- Stroke of other determined etiology

- Stroke of undetermined etiology

Methods

- **Inclusion criteria**
  - ➤ Patients with ischemic stroke (2013 to 2018)
  - ➤ Admitted at CBNUH

- **Exclusion criteria**
  - ➤ Poor quality of brain MRI
  - ➤ Stroke of undetermined etiology, other determined etiology (cancer, connective tissue disease...)

Study Population
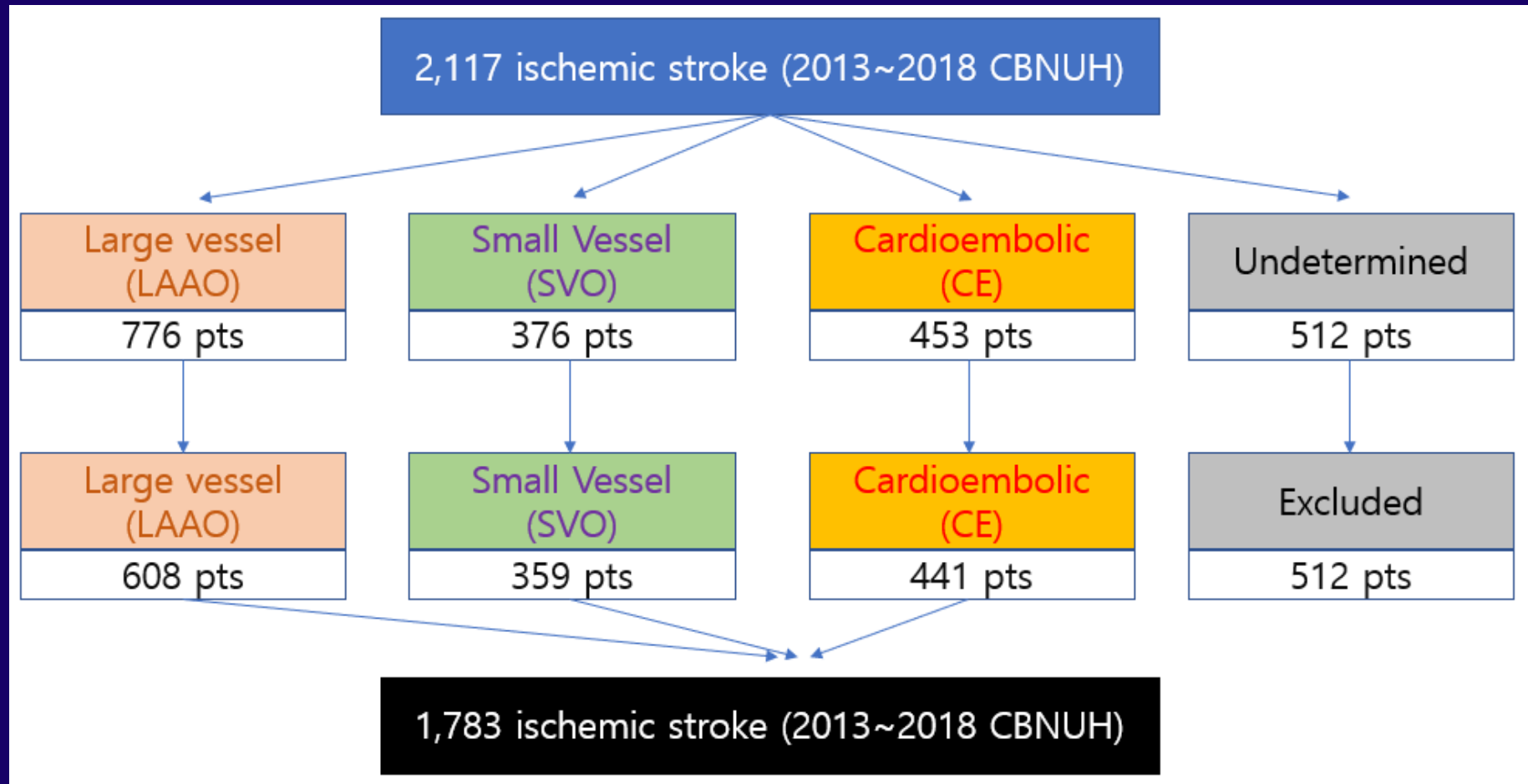
Brain MRI Database & Annotation

- **Brain MRI scans of 1,783 stroke patients**

➢ Lesions are annotated by experienced two neurologists

➢ (Dr. B.-K. Kim, Dr. K.-S. Yeom)
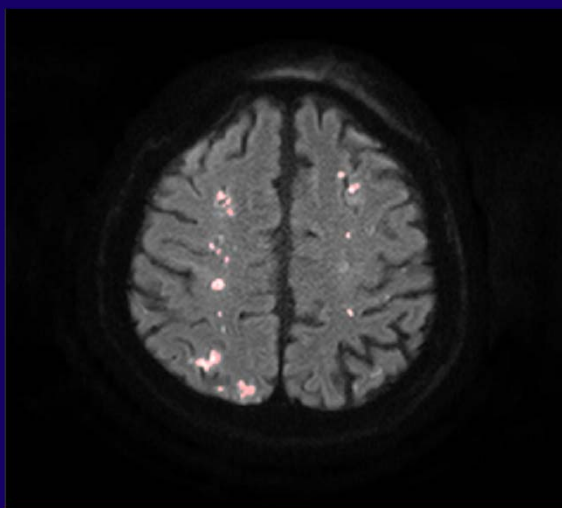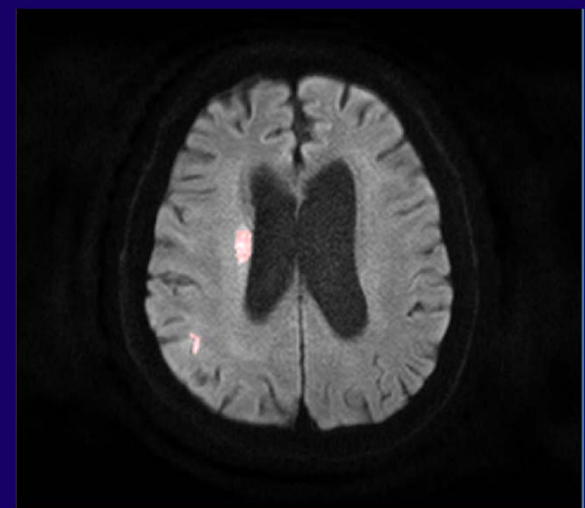
SVO　　　　　　**CE**　　　　　　**LAAO**

Architecture of Algorithm
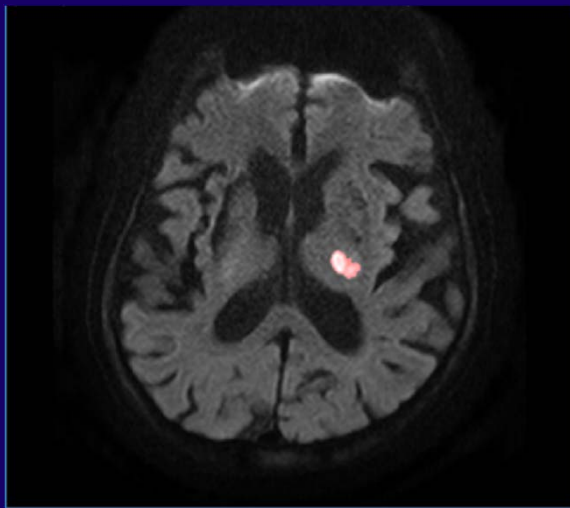
- **Single slide-level classification**

➤ We trained a classification network predicting subtype of acute ischemic stroke.

Single-slide DWI (Input) → Image classifier network (ResNet-50) [Convolution layers, Fully connected layers] → Confidence score (Output): 0.1 CE, 0.2 LAA, 0.6 SVO (✔), 0.1 Control
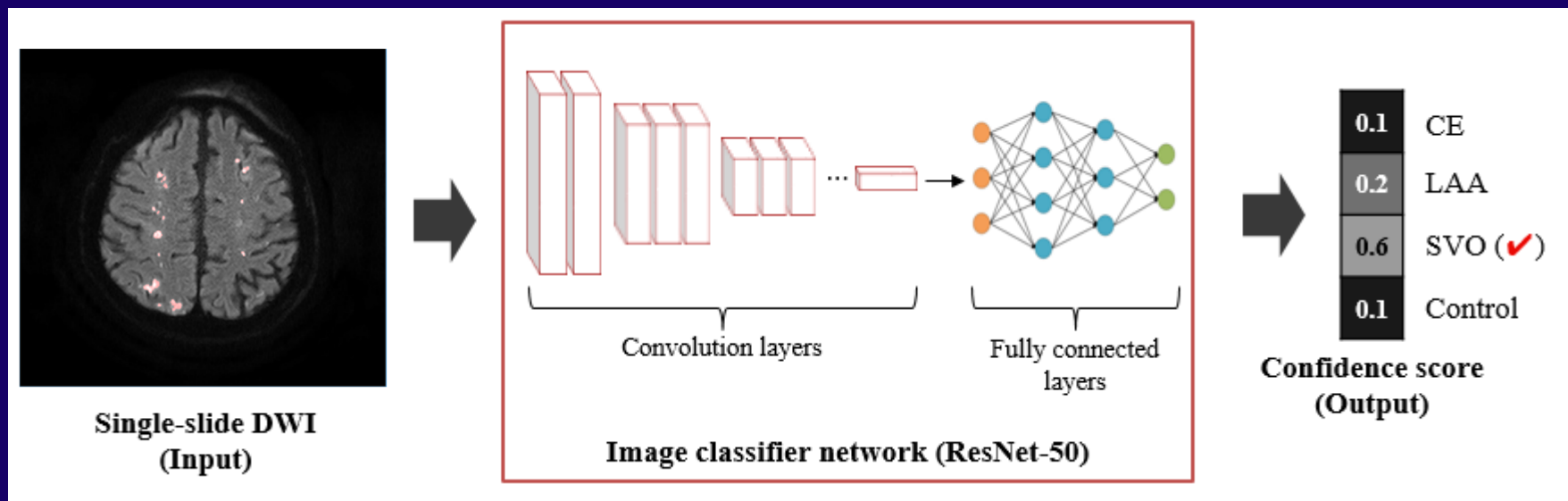
Results_Baseline Characteristics

Age-yr (interqutile range)	65.8 (54.5-76.0)
Male sex – no. (%)	1051 (57.9)
History of ischemic stroke– no. (%)	221 (12.4)
Diabetes mellitus-no. (%)	260 (14,6)
Hypertension -no. (%)	1087 (61.2)
Hyperlipidemia –no. (%)	624 (35.7)

Experimental Results_Confusion Matrix_Single Slide Level

- **Confusion matrix**
- ➢ Ground truth (diagnosis by neurologists) vs. AI prediction
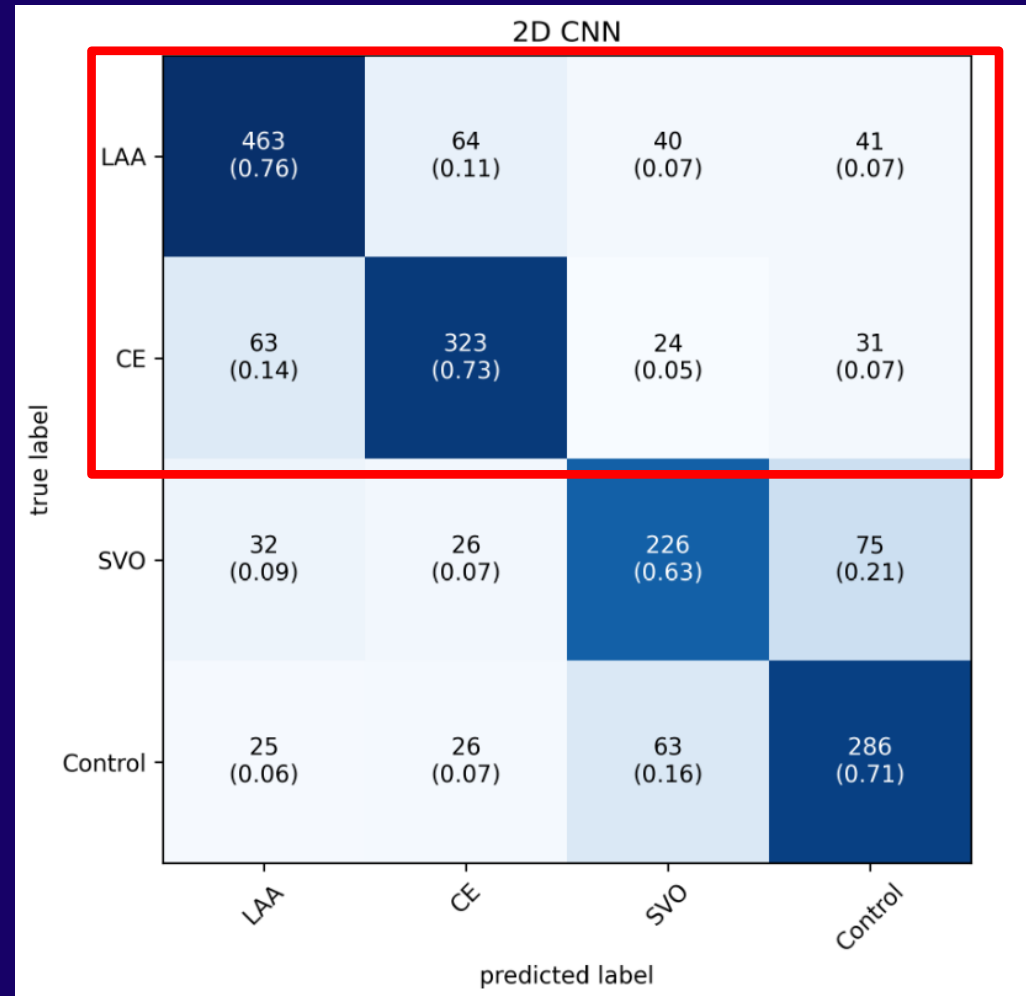
Under submission (Scientific report)

Limitation

- **Single slide-level classification cannot provide enough information for diagnosis**
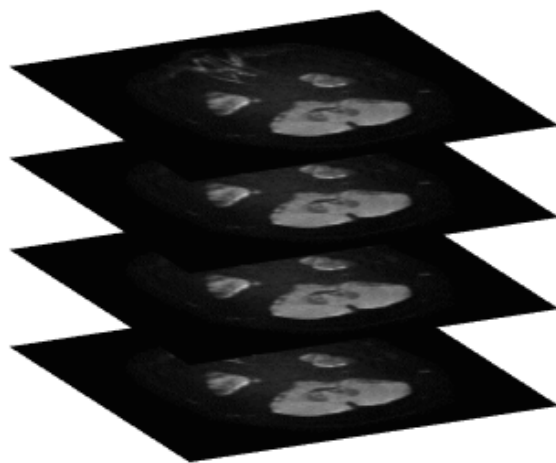
Slide 1 → Control

Slide 2 → LAA

Slide 3 → SVO

Slide 4 → Control

Advanced Architecture of Deep Learning Algorithm

Single slide-level classification

Multi slide-level classification
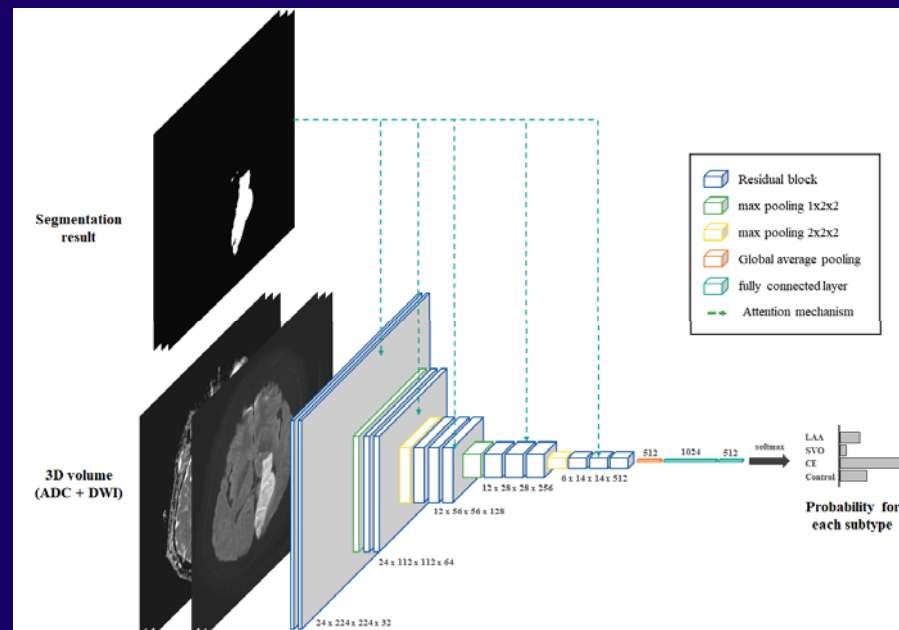
Result – Lesion Segmentation (Multi-Slide Level)
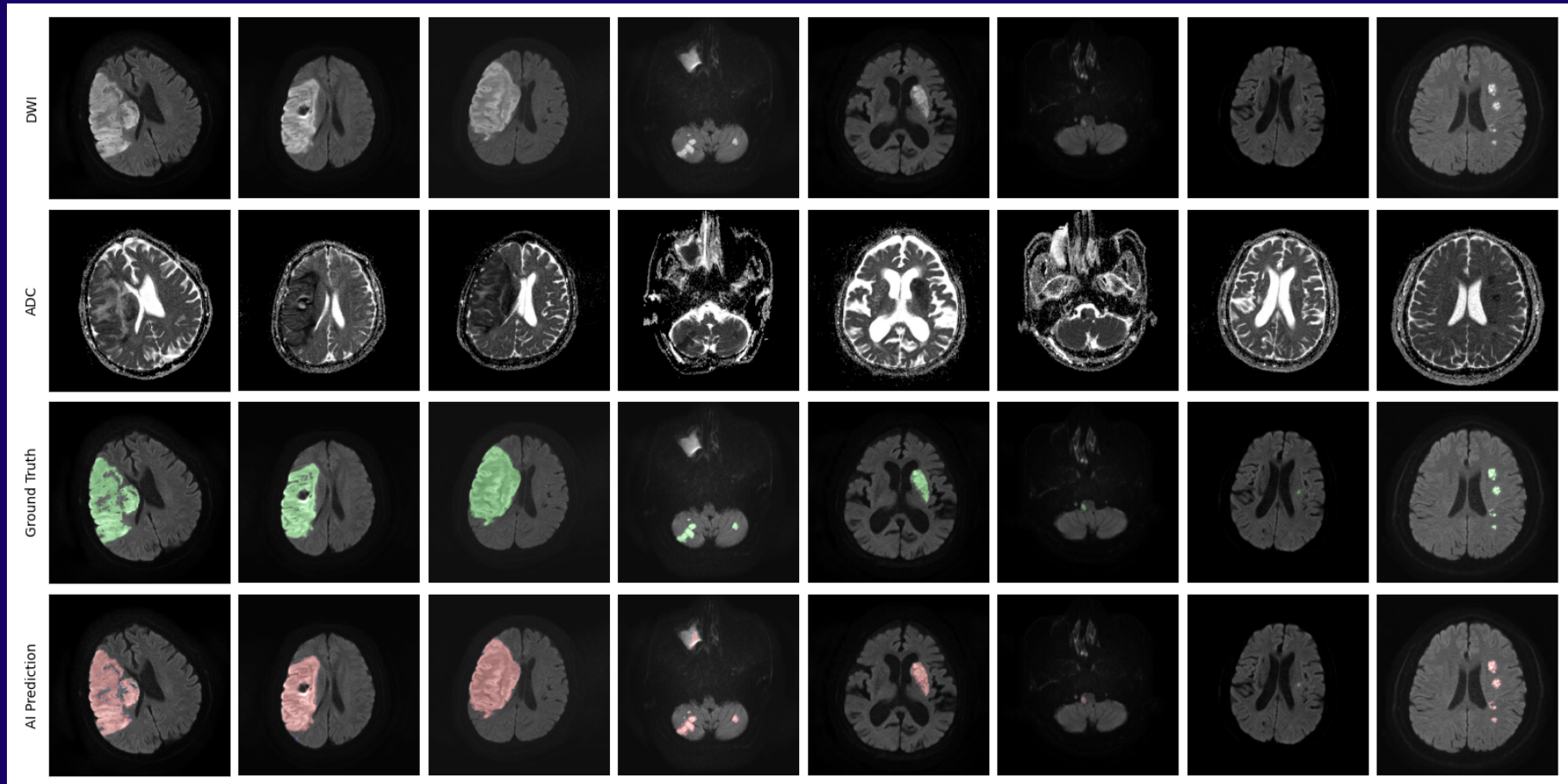
Dice Score = 91% for detecting stroke lesion
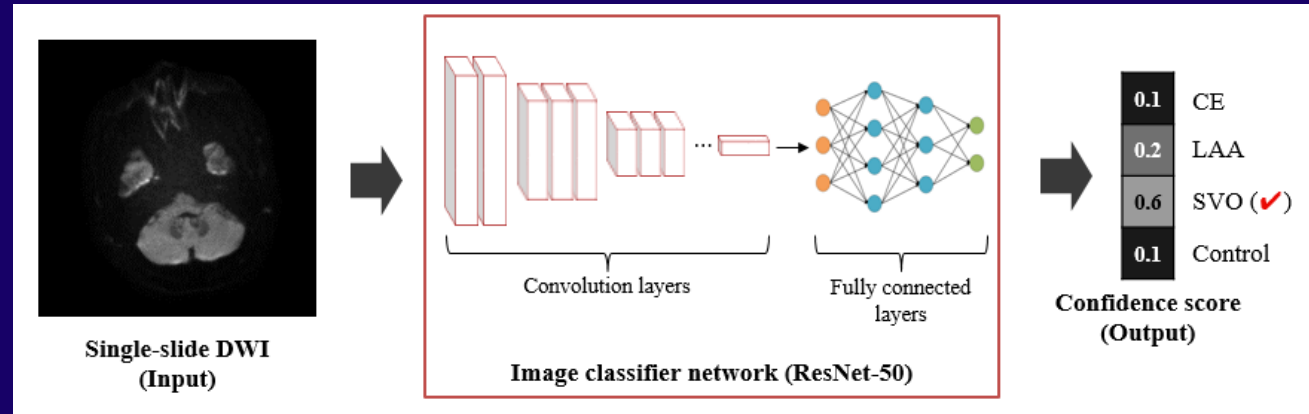
Experimental Results_Ground Truth_Multislide Level

- **Confusion matrix**
- ➤ Ground truth vs. AI prediction
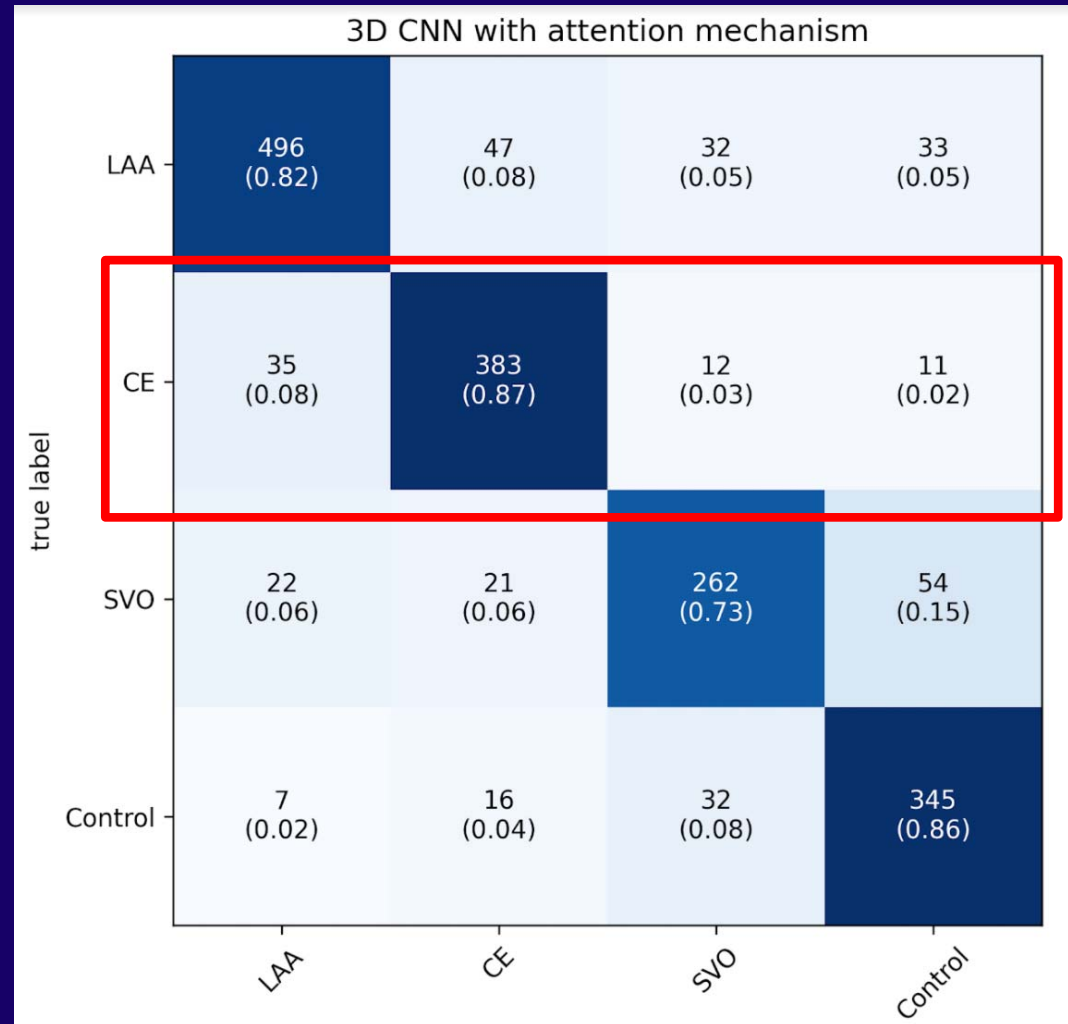
Under submission (Scientific report)

Future Direction

- **Preparing external validation of algorithm performance**
  - **Bundang National University Hospital**
  - **Keimyung university dongsan medical center**

- **Preparing application of this algorithm in ESUS patients undergoing ILR**

Left Atrial Volume Index Is Associated With Cardioembolic Stroke and Atrial Fibrillation Detection After Embolic Stroke of Undetermined Source

Kevin Jordan, MD; Shadi Yaghi, MD; Athena Poppas, MD; Andrew D. Chang, MS;
Brian Mac Grory, MD; Shawna Cutting, MD; Tina Burton, MD; Mahesh Jayaraman, MD;
Georgios Tsivgoulis, MD; M. Khaled Sabeh, MD; Alexander E. Merkler, MD;
Hooman Kamel, MD; Mitchell S.V. Elkind, MD; Karen Furie, MD; Christopher Song, MD

1224 consecutive patients

Table 3. Multivariate Model Showing Association Between LAVI and Stroke Sub-Type

	CES*		ESUS*	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Unadjusted	1.06 (1.05–1.08)	<0.001	1.00 (0.99–1.01)	0.844
Model 1	1.06 (1.04–1.07)	<0.001	1.00 (0.99–1.02)	0.582
Model 2	1.06 (1.04–1.07)	<0.001	1.00 (0.99–1.01)	0.981
Model 3	1.07 (1.05–1.09)	<0.001	1.00 (0.99–1.02)	0.720

Future Direction – Multi-modal approach

Simple Neural Network — Deep Learning Neural Network
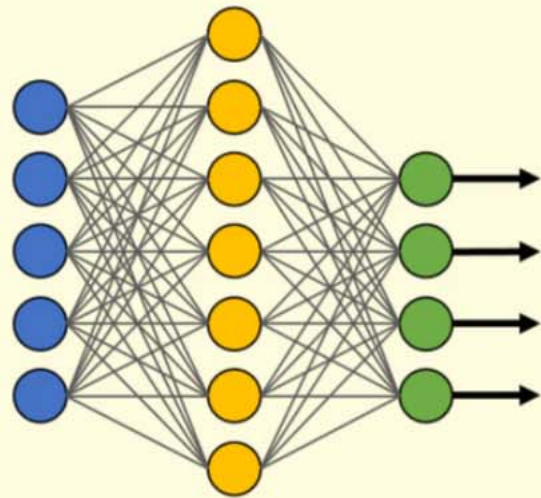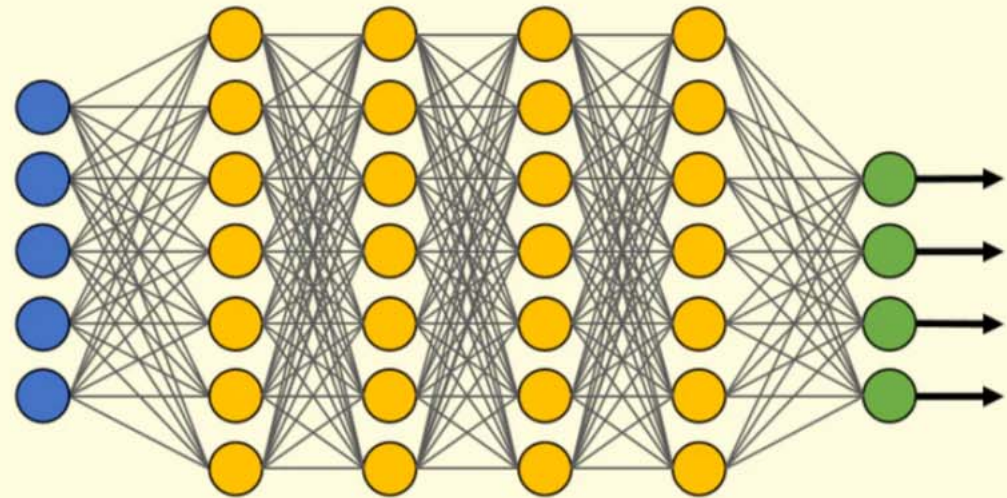
● Input Layer   ● Hidden Layer   ● Output Layer

	Input	Output
ESUS patients	Brain MRI LA volume EKG Life log data…	CE
		LAA
		SVO
		Other determined

Left Atrial Segmentation Algorithm

Ground-truth (annotation data)

Model prediction

단일 CT 영상 단위 결과 영상

Ground-truth (annotation data)

Model prediction

3D로 재구성한 좌심방 영역 결과 영상
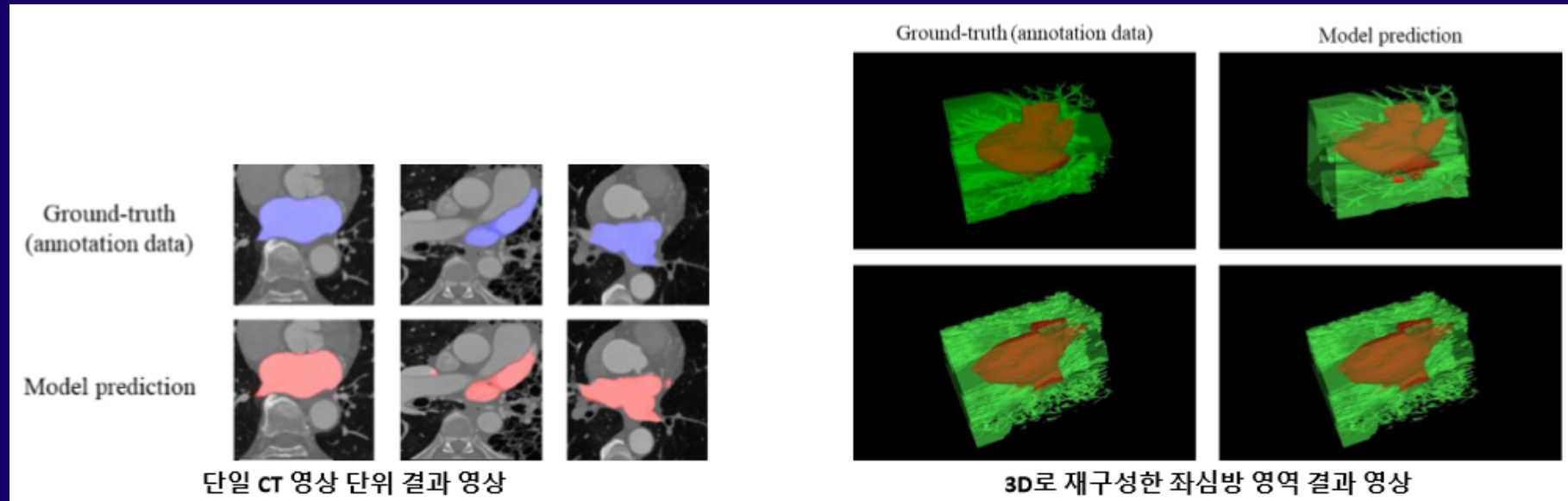
Accuracy of deep learning based LA segmentation reached 99% in the similarity of the semiauto-volume performed by imaging specialist

Conclusions

Even though using only brain MR imaging,

the performance of 3D-CNN based sub-classification

algorithm for etiology of acute ischemic stroke (esp.

cardioembolic source) reached 87% sensitivity and

specificity.

In future, we will test the performance of this algorithm

conjunct to multi-modal dataset in ESUS patients .

Medical Part

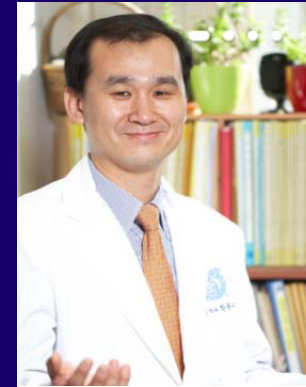**Dae-In Lee**
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Ph.D. candidate in Korea
Univ.

Conclusion

The performance of 3D-CNN based sub-classification algorithm for etiology of acute ischemic stroke (esp. cardioembolic source) reached 84% sensitivity and specificity.

In future, we will test the performance of this algorithm conjunct to multi-modal dataset in ESUS patients .

Thank you for your attention.