



東京大学  
THE UNIVERSITY OF TOKYO



SIOS

# A novel development of deep neural network model for diagnosis of uterine sarcomas

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- ☛ Uterine sarcomas are **rare**, occurring in approximately 5 of 10,000 women.

Bosch. et al. *Best. Pract. Res. Clin. Obstet. Gynaecol*, 2012.

- ☛ The five-year overall survival rate **does not typically reach 50%**, especially among patients in the advanced stages.

Burghaus. et al. *Arch. Gynecol. Obstet*. 2016.

- ☛ Uterine myomas **with degeneration** frequently **mimic uterine sarcomas on MRI**, and misdiagnosis of uterine sarcomas as benign myomas is not uncommon.

Sun. et al. *Diagn. Interv. Imaging*. 2019.

	Uterine myoma	Uterine sarcoma
Size	Variable	Variable (>10 cm, associated with poorer prognosis)
Margins	Well-defined	Irregular and ill-defined, often nodular and with invasion of adjacent structures
Signal on T1WI	Low to intermediate <b>High for fat content or hemorrhage</b>	Heterogenous and low <b>High for hemorrhage from necrosis</b>
Signal on T2WI	Generally, homogenous low signal <b>Intermediate/high in degeneration</b>	Intermediate to high signal
DWI and ADC signal	Low DWI, low ADC SI: ordinary Low DWI, high ADC SI: degenerated	Generally high DWI and low ADC SI
ADC values ( $10^{-3}\text{mm}^2/\text{s}$ )	<b>0.88-1.40</b>	<b>0.79-1.17</b>
Contrast-enhanced MRI	<b>Variable</b>	Early heterogenous enhancement with central areas of contrast non-enhancement

SI: signal intensity, T1WI: T1-weighted images; T2WI: T2-weighted images.

Sun, *Diagnostic and Interventional Imaging*, 2019

Image features are **overlapped between uterine sarcomas and myomas**.  
In some cases, it is difficult to diagnose uterine tumors, especially **degenerated tumors**.

## Preoperative diagnosis

If misdiagnosis happens, it might happen...

Uterine tumor

**Malignancy**

- Total hysterectomy

**Loss of fertility**

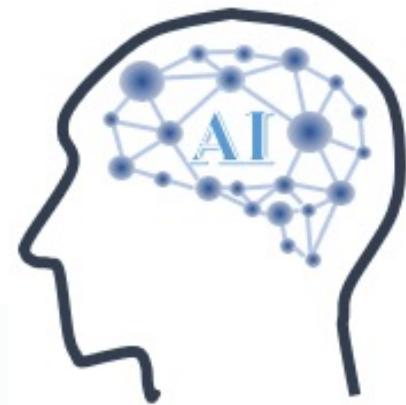
**Benign**

- Myomectomy
- Hormone therapy etc.
- Observation

**Poor prognosis**  
Due to tumor dissemination,  
late diagnosis and etc.

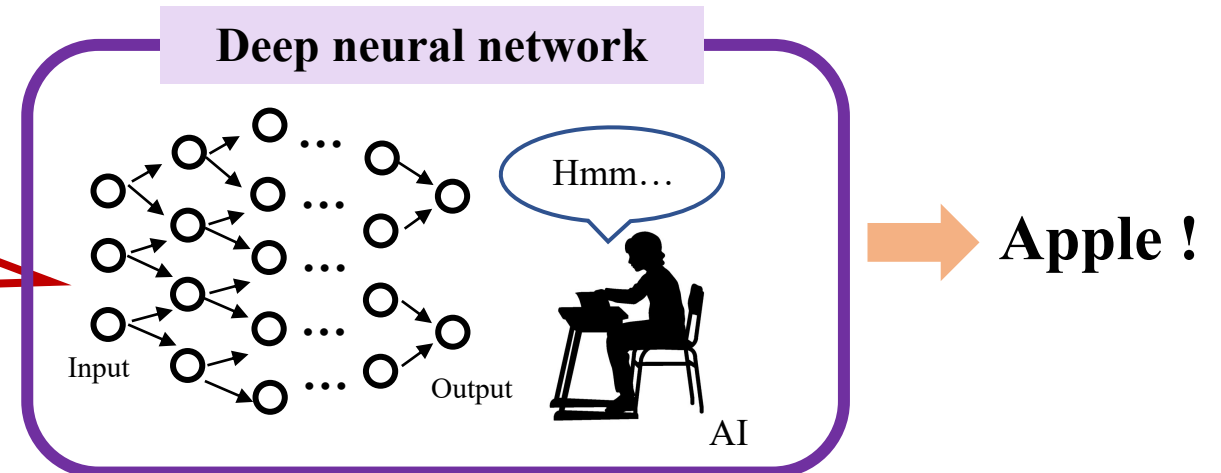
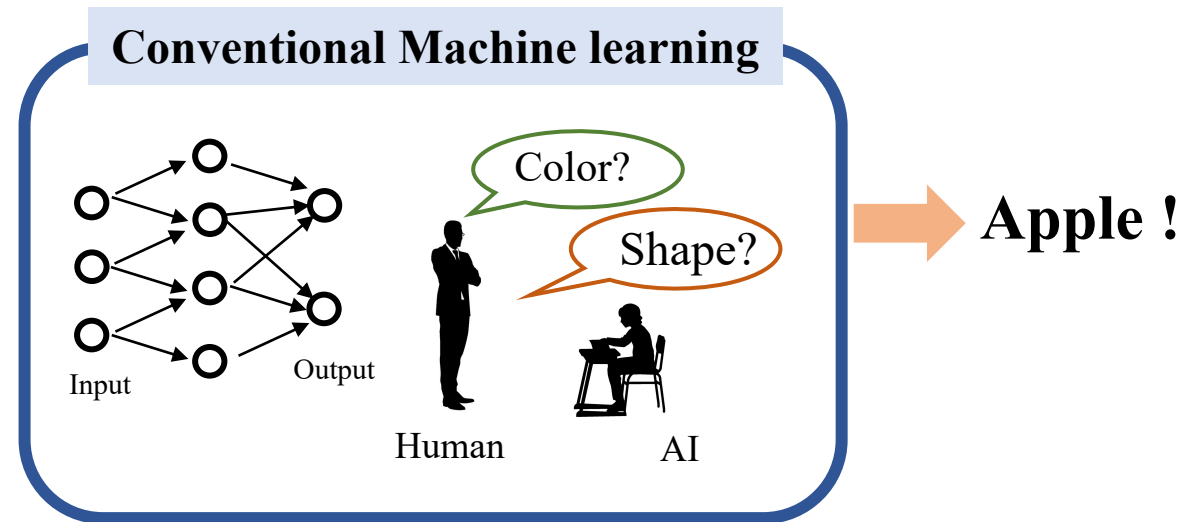
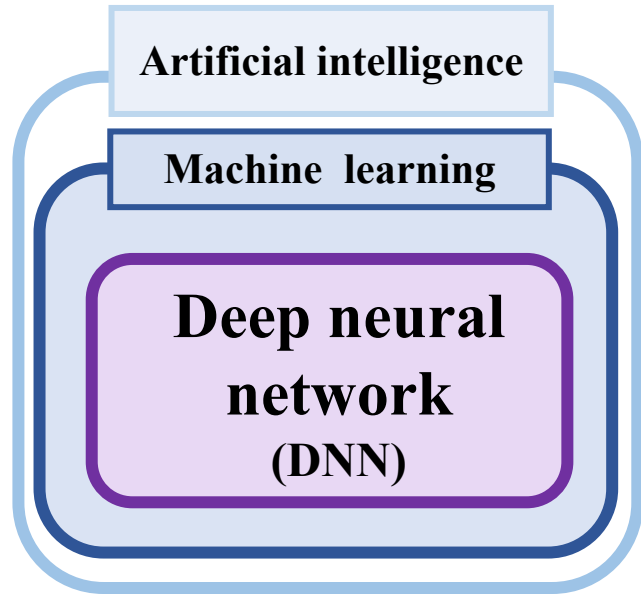
Accurate preoperative diagnosis is critical for patients.

Can artificial intelligence(AI) be helpful?



# What is AI and deep neural network?

**Artificial Intelligence (AI) : Reproduction of human's neural activity in a computer.**

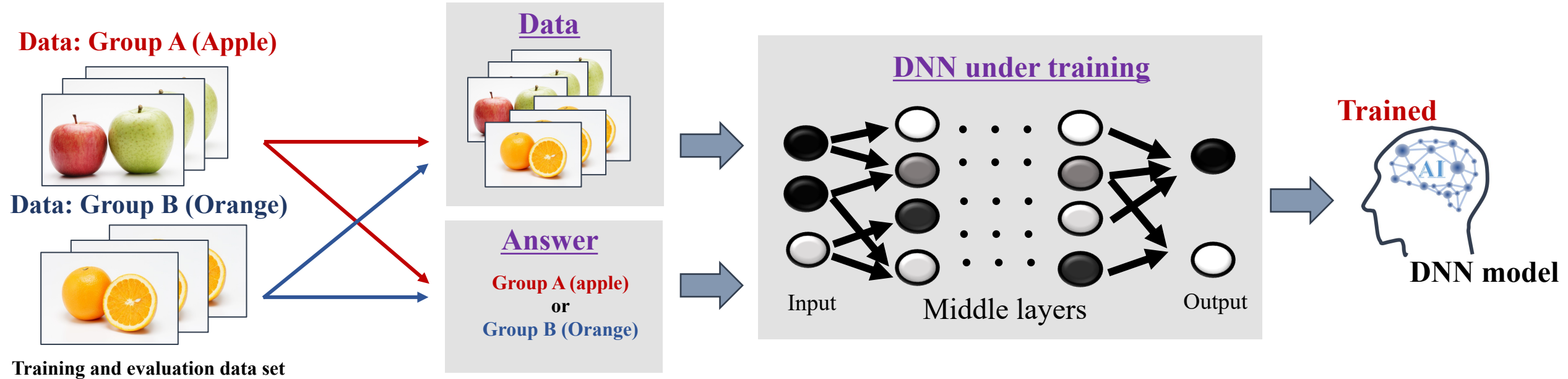


The layers are deeper than conventional machine learning, so called **“Deep” neural network.**

DNN is more suitable for **image recognition.**

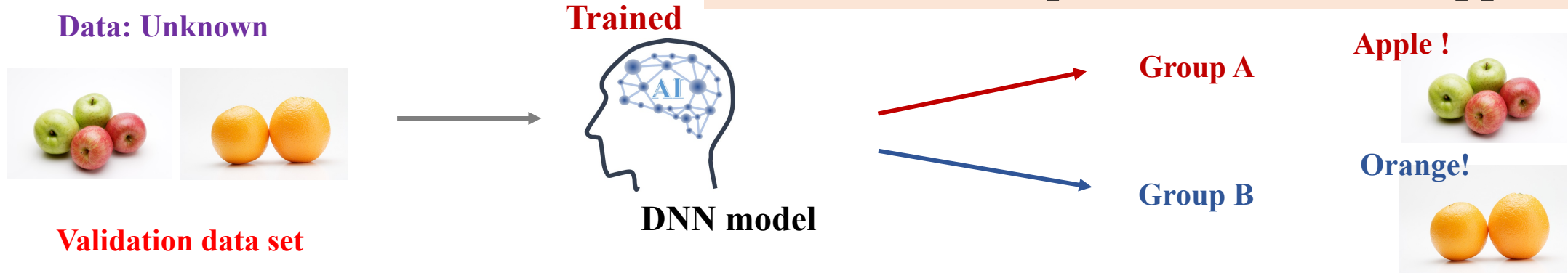
# Overall flow of clinical use of DNN model : image recognition

## Training



## Prediction

**Validation is important for clinical application!!**



# Previous reports for imaging diagnosis of uterine sarcomas with AI

	Authors	Years	Article	Images	Sarcoma	Myoma	Accuracy	DNN / Machine learning
1	Malek et al.	2019	European journal of radiology	MRI	9	33	accuracy 91% AUC 0.972	<b>Machine learning</b>
2	Xie et al.	2019	European journal of radiology	MRI	29	49	accuracy 73.9% AUC 0.83	<b>Machine learning</b>
3	Nakagawa et al.	2019	Clinical Radiology	MRI PET	11	56	AUC 0.92	<b>Machine learning</b>
4	Lakhman et al.	2018	European radiology	MRI	19	22	accuracy 75%	<b>Machine learning</b>
5	Gerges L et al.	2018	American Journal of Roentgenology	MRI	17	51	sensitivity 88.2% specificity 78.4%	<b>Machine learning</b>
6	Wang et al.	2020	European Radiology	MRI	53	84	AUC 0.91	<b>Machine learning</b>
7	Malek et al.	2020	Scientific Reports	MRI	21	84	Accuracy 96.2% Sensitivity 100% Specificity 95%	<b>Machine learning</b>

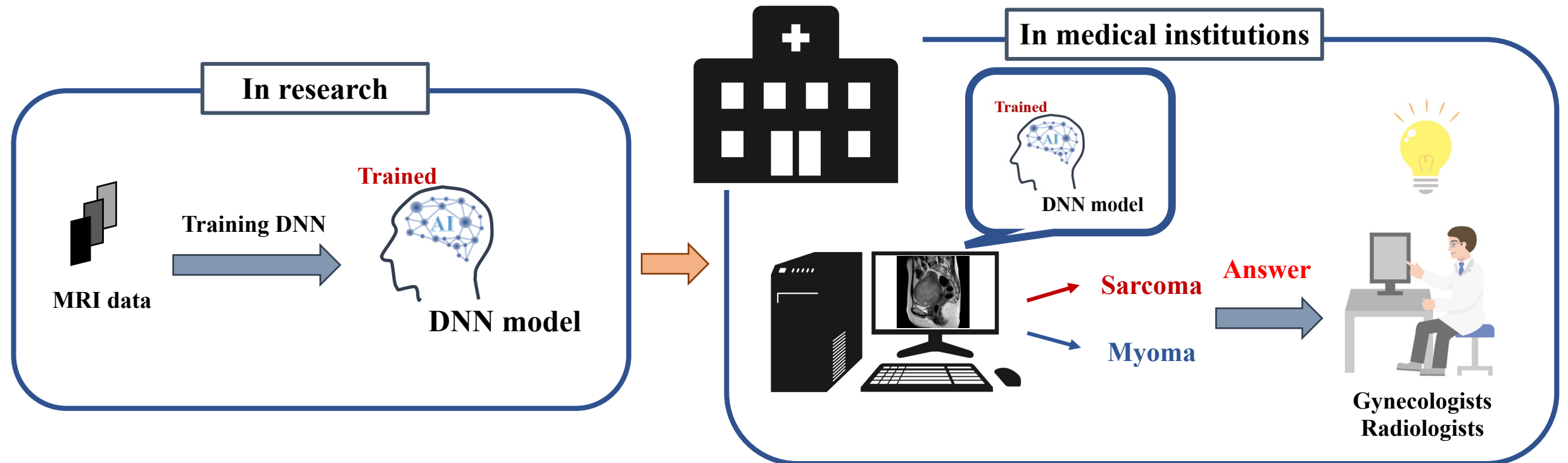
**No report** which investigates diagnosis of uterine sarcoma **using DNN**.

## Objects of this study:

Investigation of **DNN model** for **imaging diagnosis of uterine sarcomas**


## Our future goal:

**Clinical application** of our diagnosing DNN model in medical institutions



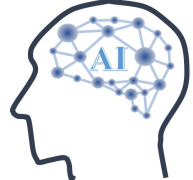


## 1<sup>st</sup> examination.


  
MRI data of  
uterine tumors

Training DNN




  
DNN model

V.S.

  
Radiological  
specialists

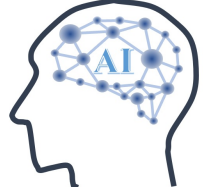
V.S.

  
Radiological  
practitioners



Assessment of DNN  
model's accuracy

Under article submission

## 2<sup>nd</sup> examination. (One month later)

  
DNN model

V.S.

  
AI-supported  


V.S.

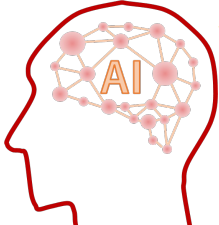


Assessment of DNN model's  
supporting ability for radiologists


Under article submission

## 3<sup>rd</sup> examination.

Developed new DNN model  
and  
Prepared validation set

  
New DNN model

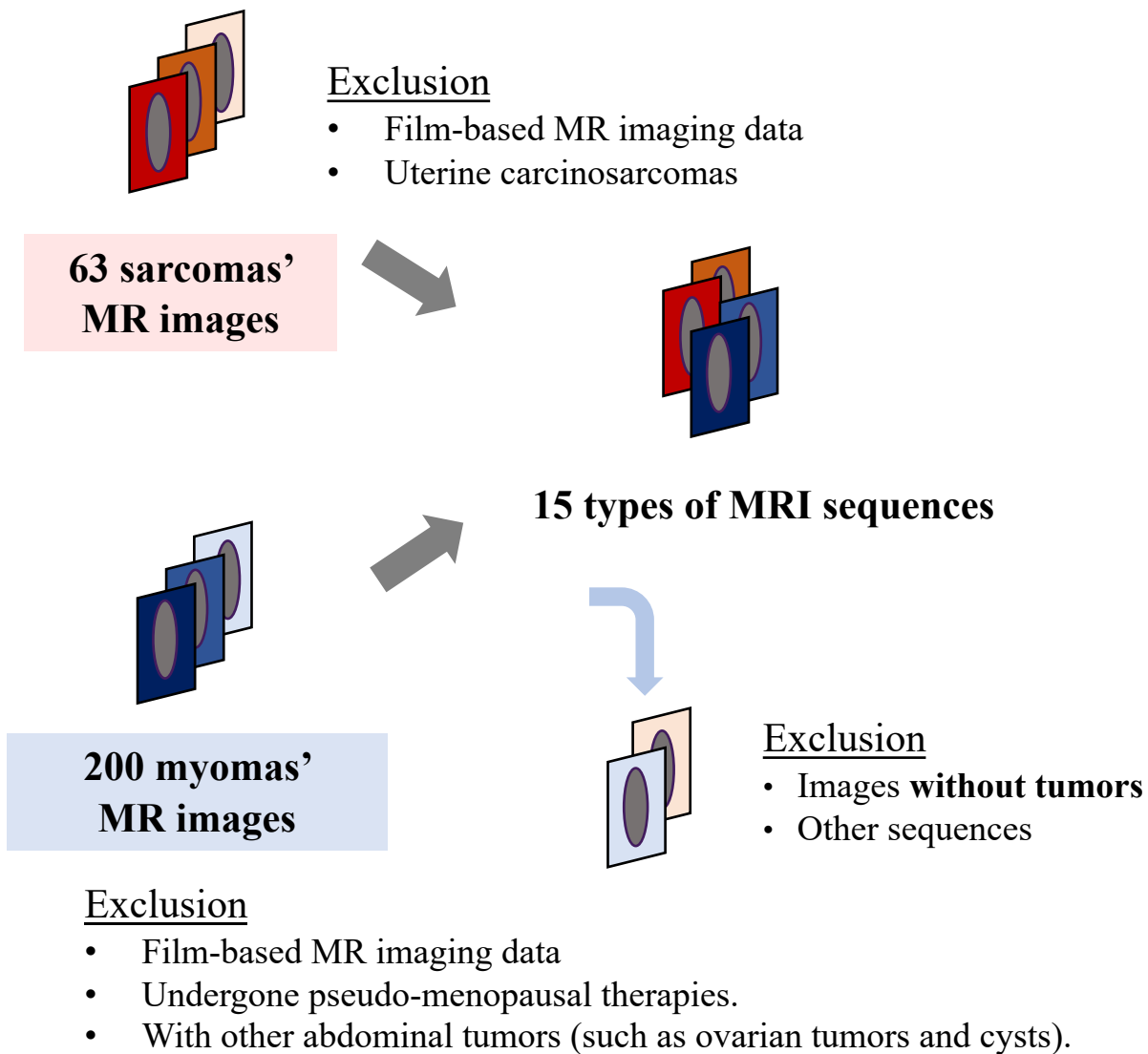
Automated data preparation

+ 



**Validation**

Assessment of more practical DNN  
model for clinical diagnosing



15 types of MRI sequences	Abbreviation
Axial T1-weighted image	<b>T1axi</b>
Sagittal T1-weighted image	<b>T1sag</b>
Fat suppressed axial T1-weighted image	<b>fsT1axi</b>
Fat suppressed sagittal T1-weighted image	<b>fsT1sag</b>
Axial T2-weighted image	<b>T2axi</b>
Sagittal T2-weighted image	<b>T2sag</b>
Coronal T2-weighted image	<b>T2cor</b>
Fat suppressed axial T2-weighted image	<b>fsT2axi</b>
Diffusion-weighted image	<b>DWI</b>
Apparent diffusion coefficient map image	<b>ADC</b>
Axial dynamic contrast-enhanced image	<b>dynamicaxi</b>
Sagittal dynamic contrast-enhanced image	<b>dynamicsag</b>
Axial fat suppressed contrast-enhanced T1-weighted image	<b>fsT1CEaxi</b>
Sagittal fat suppressed contrast-enhanced T1-weighted image	<b>fsT1CEsag</b>
Coronal fat suppressed contrast-enhanced T1-weighted image	<b>fsT1CEcor</b>

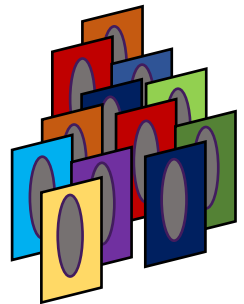
# Methods ~ overall flow of this study ~

**MR images with tumors**  
(15 types of sequences, 59,377 slices)

**63 sarcomas**  
and **200 myomas**'  
MR images



**Augmentation**  
(875,000 slices)



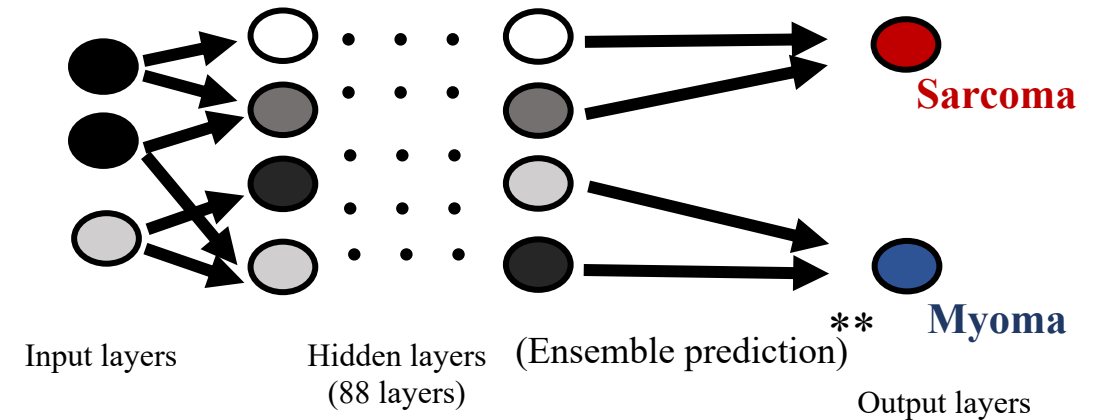
(6 datasets)

- Group-1
- Group-2
- Group-3
- Group-4
- Group-5
- Group-6

**Deep neural network model:**

**DNN model** (MobileNetV2)\*

(35,000 slices × 50 epochs = 1,750,000 slices)



**6 datasets** → **cross validation**  
(training : evaluation = 5:1)

\*MobileNetV2

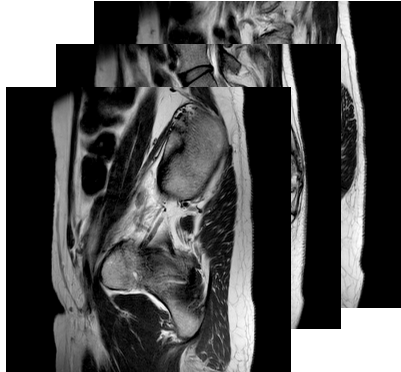
MobileNetV2 is one type of DNN network which consists of 88 layers and has around 3.5million learning parameters.

\*\*Ensemble prediction

Ensemble prediction is one method of machine learning and, in a simple term, a type of majority decision.

# Results ~ comparison of diagnosing accuracy ~

## The 1<sup>st</sup> examination.



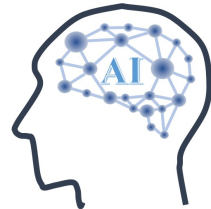
63 sarcomas  
and 200 myomas'  
MR images



Radiological  
practitioners (n = 3)



Radiological  
specialists (n = 3)



DNN model

### Accuracy

**69.6%**

**82.4%**



**90.8%**

### Sensitivity

**47.6%**

**71.0%**



**89.8%**

### Specificity

**91.5%**



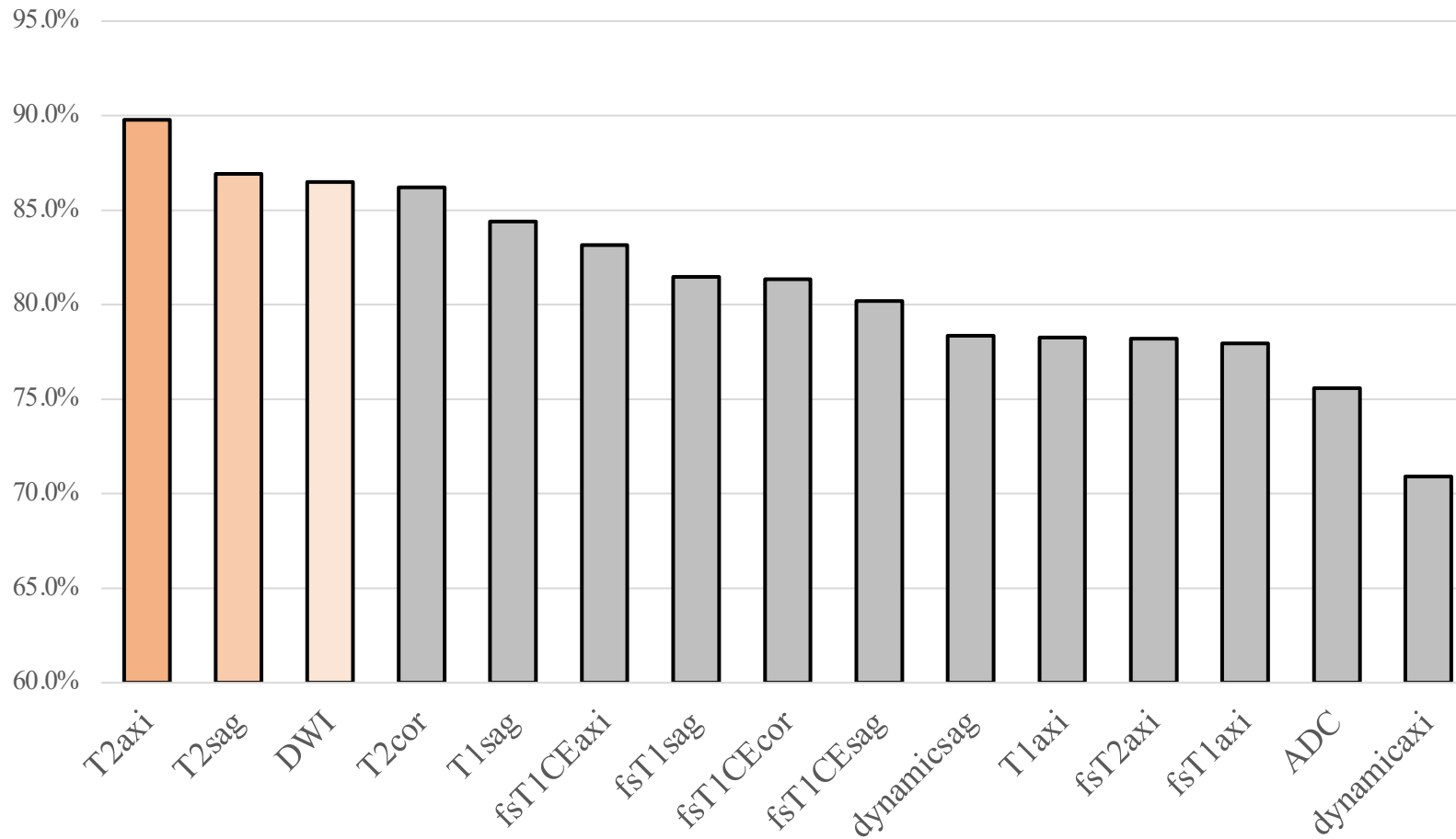
**93.8%**

**91.7%**

# Results ~ individual MRI sequences ~

## Results of individual MRI sequences.

### Accuracy



### TOP-3 of MRI sequences.

**Axial T2WI** : 89.8%  
**Sagittal T2WI** : 86.9%  
**DWI** : 86.5%

# Results ~ TOP10 of combination sets of MRI sequences ~

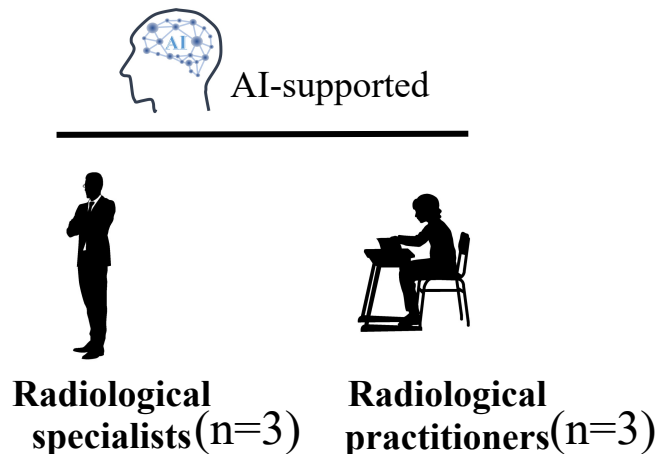
## TOP10 of combination sets of MRI sequences.




Combination set	Accuracy	Sensitivity	Specificity	ADC	DWI	dynamicaxi	dynamic sag	fsT1axi	fsT1CEaxi	fsT1CEcor	fsT1CEsag	fsT1sag	fsT2axi	T1axi	T1sag	T2axi	T2cor	T2sag
Set 1	91.3%	88.7%	94.0%		●											●		●
Set 2	91.3%	89.8%	92.9%			●	●	●	●	●	●	●	●	●	●	●	●	●
Set 3	91.1%	91.9%	90.3%	●	●	●	●	●		●	●	●	●		●	●	●	●
Set 4	91.0%	87.8%	94.2%	●									●					●
Set 5	90.8%	90.7%	90.9%		●	●	●	●	●	●		●	●		●	●	●	●
Set 6	90.5%	90.5%	90.5%		●	●	●	●	●	●		●	●		●	●	●	●
Set 7	90.5%	88.5%	92.5%	●	●	●	●	●	●	●	●		●		●	●	●	●
Set 8	90.5%	89.6%	91.3%	●		●	●	●	●	●	●	●	●		●	●	●	●
Set 9	90.4%	89.0%	91.8%		●	●	●		●	●	●	●	●	●	●	●	●	●
Set 10	90.3%	91.9%	88.8%		●	●	●	●	●	●	●	●	●	●		●	●	●
Average	<b>90.8%</b>	<b>89.8%</b>	<b>91.7%</b>															

The results **combining MRI sequences can be better** than that of individual sequences. **Axial T2WI, sagittal T2WI and DWI** seem to be important sequences for DNN models.

# Results ~ AI-supported examination ~

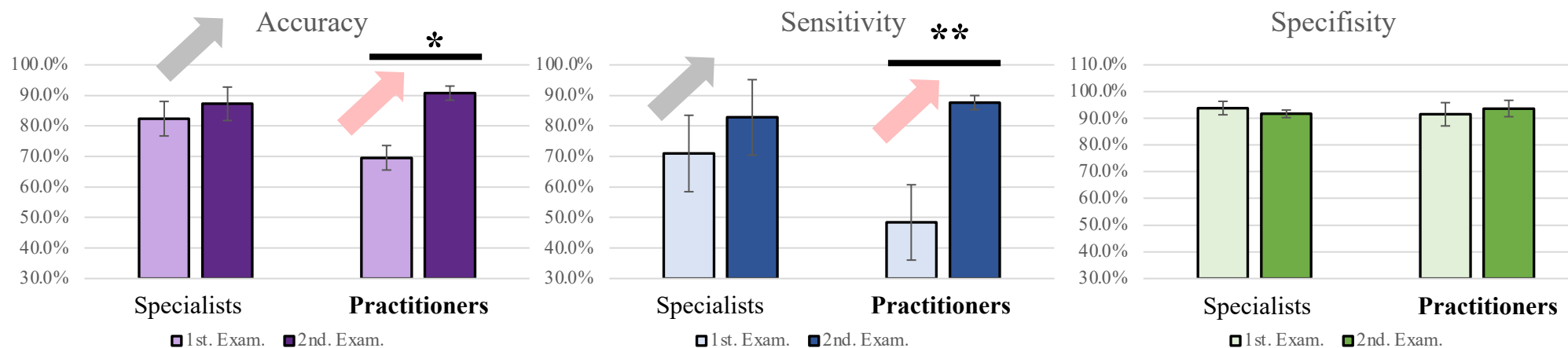
## The 2<sup>nd</sup> examination. (One month later)



	Accuracy	Sensitivity	Specificity
DNN model 	<b>90.8%</b>	<b>89.8%</b>	<b>91.7%</b>
Specialists 	<b>87.3%</b>	<b>83.1%</b>	<b>91.7%</b>
Practitioners 	<b>90.8%</b>	<b>87.8%</b>	<b>93.7%</b>

The results of DNN model in the 1<sup>st</sup> examination were provided.

## Comparison the average between 1<sup>st</sup> and 2<sup>nd</sup> examination.



DNN models can be helpful for diagnosing uterine sarcoma, especially **reducing occult tumors**, and **filling the gap** of readers skills.

## Our DNN model shows

**High diagnosing accuracy**

**Supporting ability to fill the gaps**

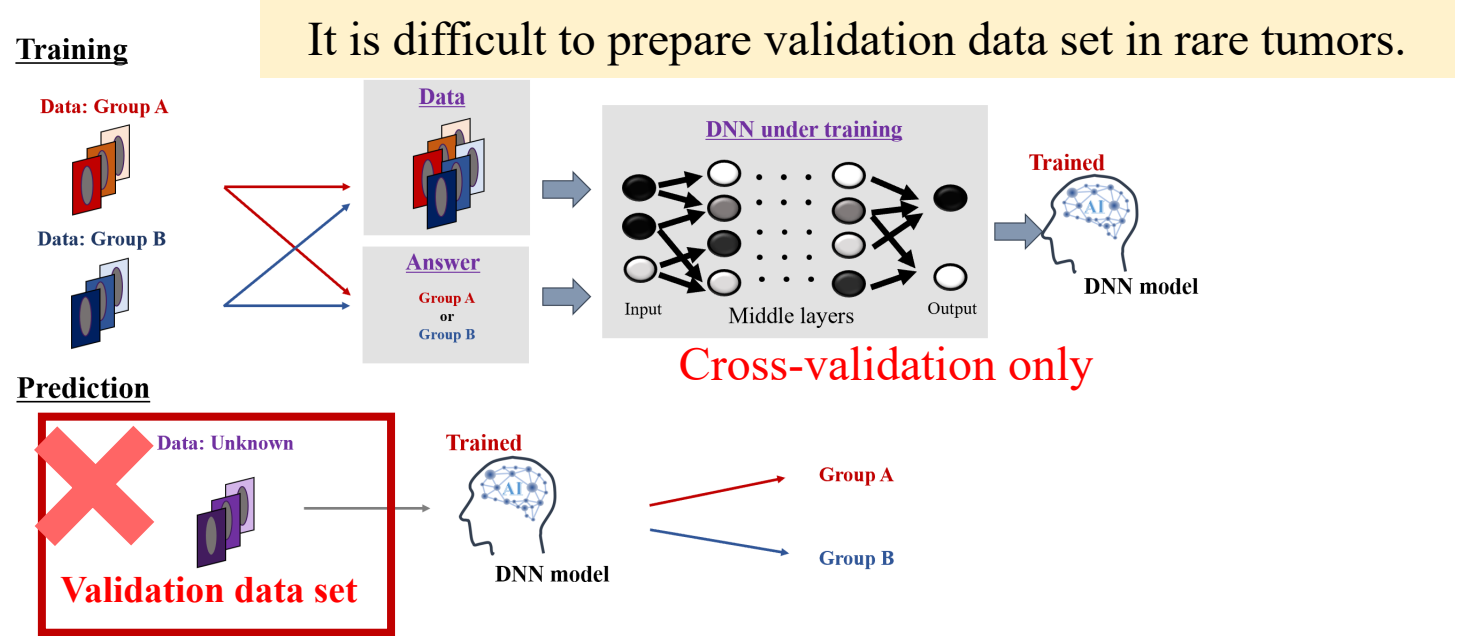
**Supporting ability to reduce occult tumors**

**Under article submission**



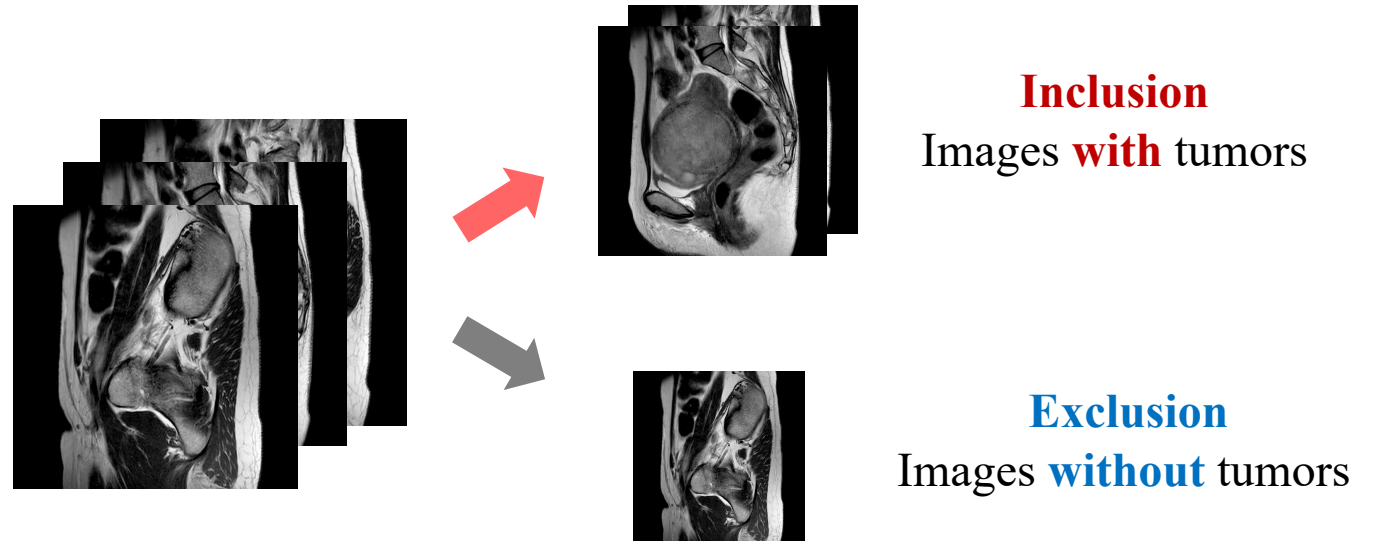
## Limitation 1

No validation data set

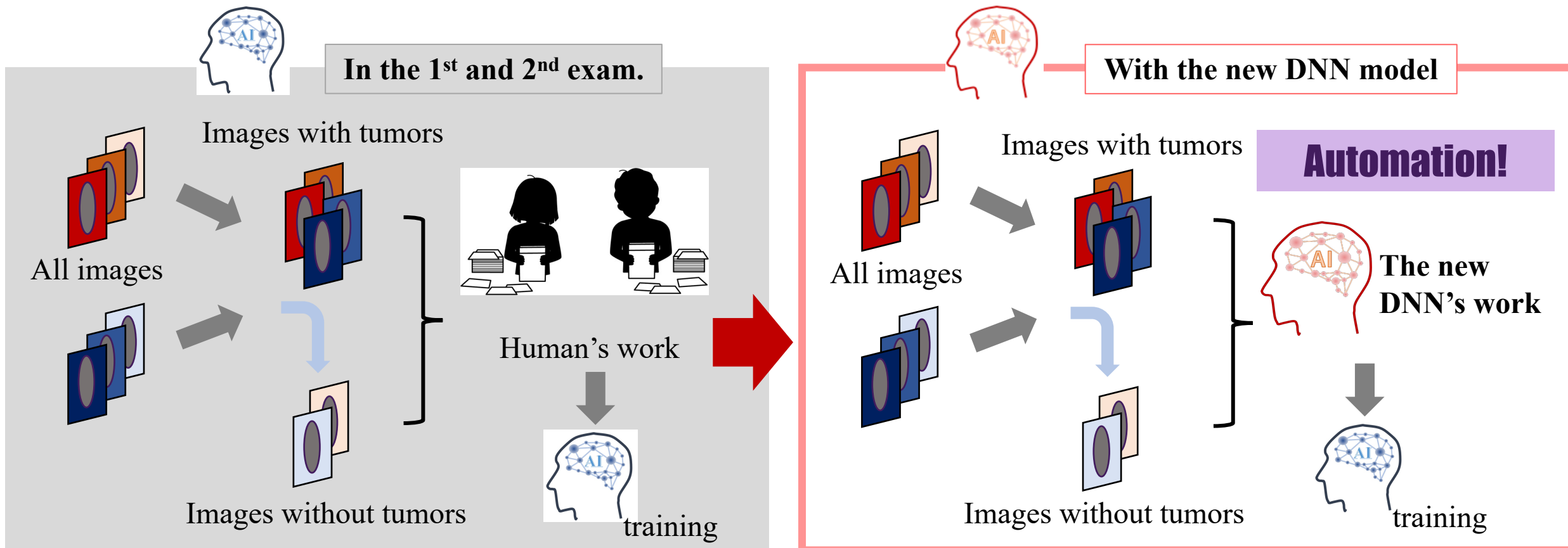


## Limitation 2

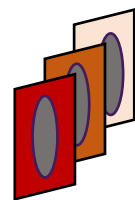
Requirements for preparation of data set



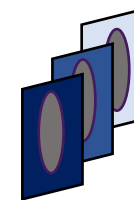
# Development of new DNN models



**New Unknown Data for Validation!!**



8 sarcomas'  
MR images



24 myomas'  
MR images

# Overall flow of 3<sup>rd</sup> examination

## 3<sup>rd</sup> examination.

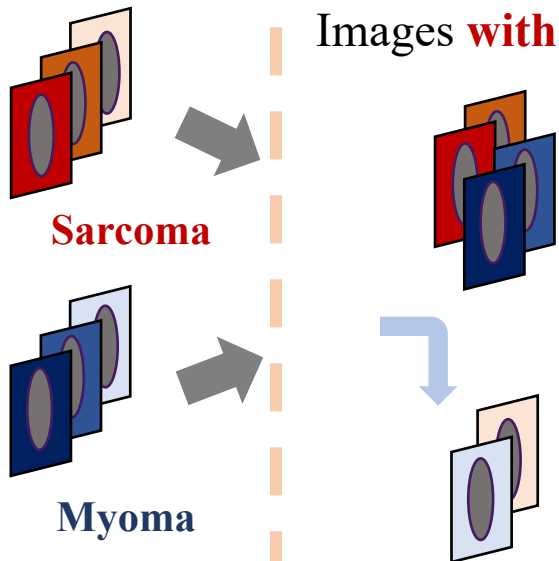
Training set:  
263 cases



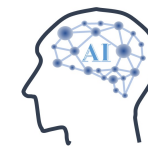
For sorting data

The new DNN model

Images **with** tumors

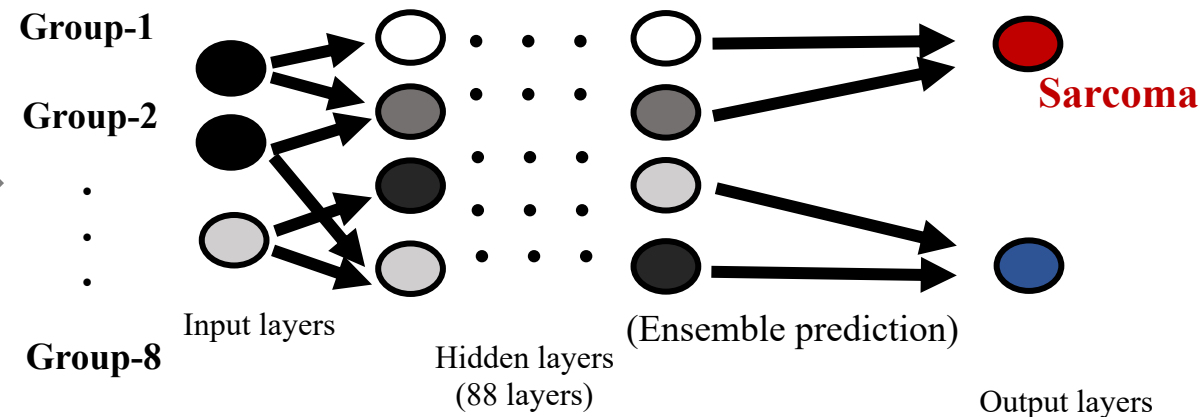


Images **without** tumors



For evaluating data

The first DNN model



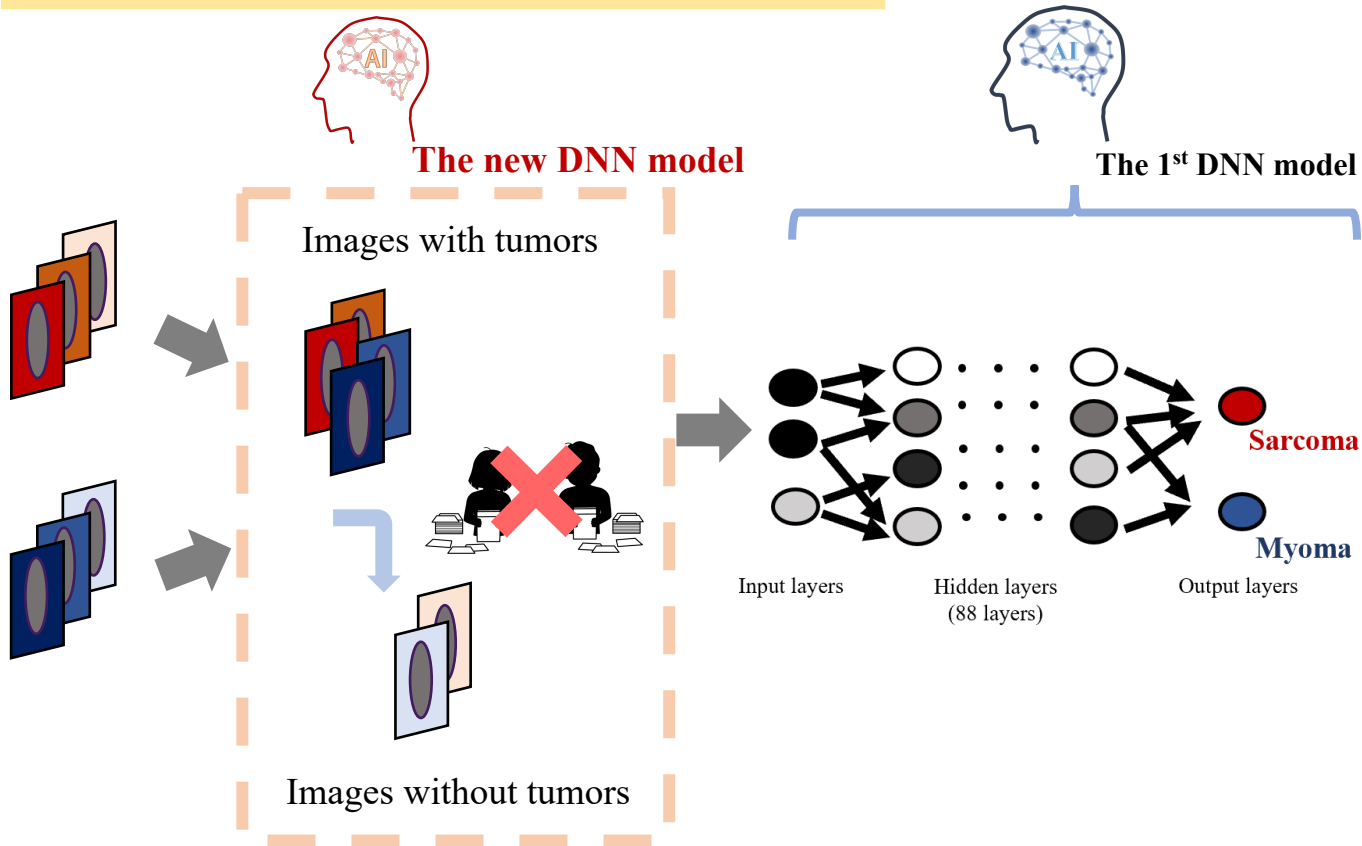
8 datasets → cross validation (MobileNetV2)  
(training : evaluation = 7:1)

**New!!**

Validation  
Validation set : 32 cases

# The evaluation for training data set

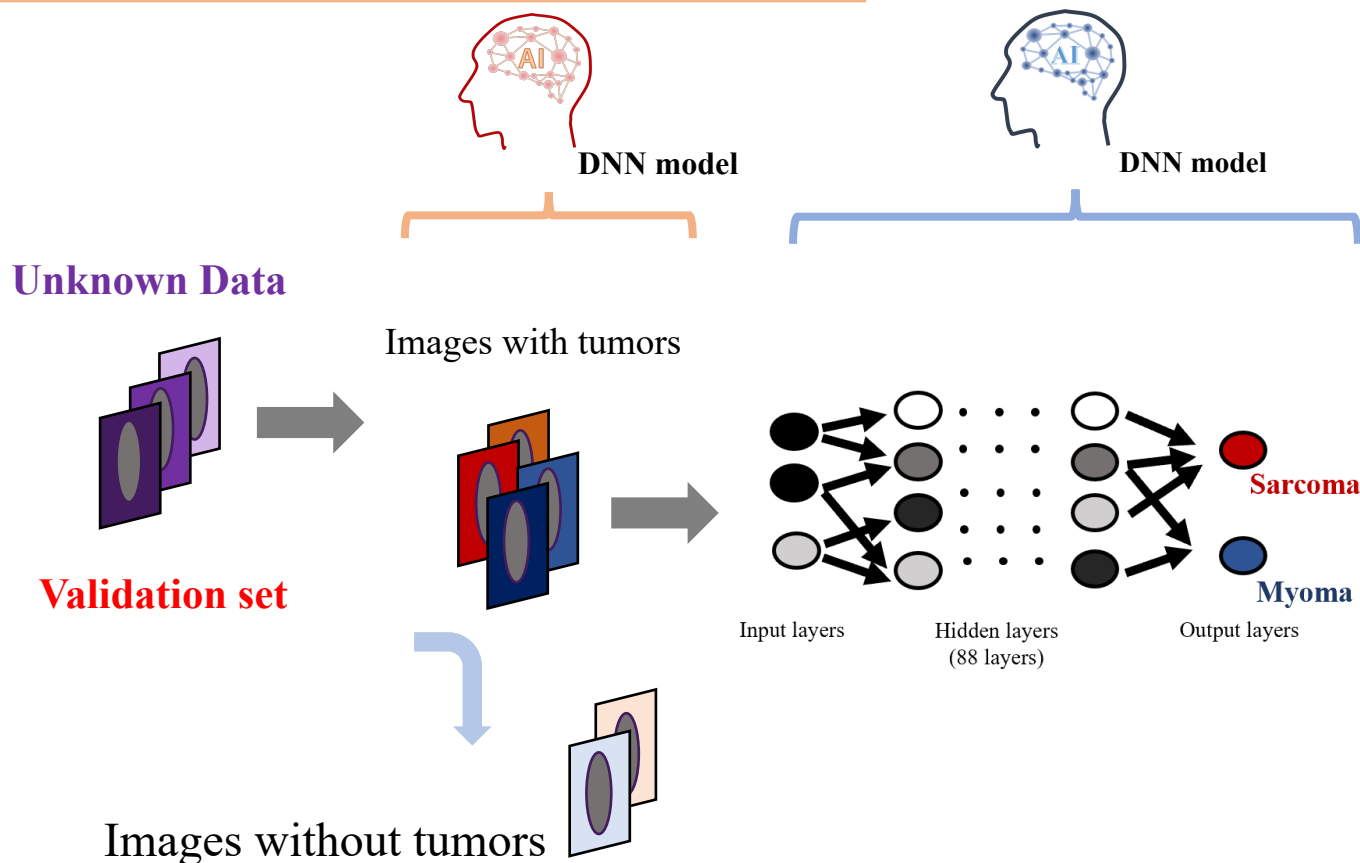
Training data set: 263 cases



	The New Model combined	The 1st exam.
Accuracy	90.6%	90.8%
Sensitivity	90.7%	89.8%
Specificity	90.4%	91.7%

DNN models can **recognize images containing tumors** and **keep high accuracy**, which means new DNN model can **automate** preparation of MR images.

Validation data set: 32 cases



Accuracy

96.9%

Sensitivity

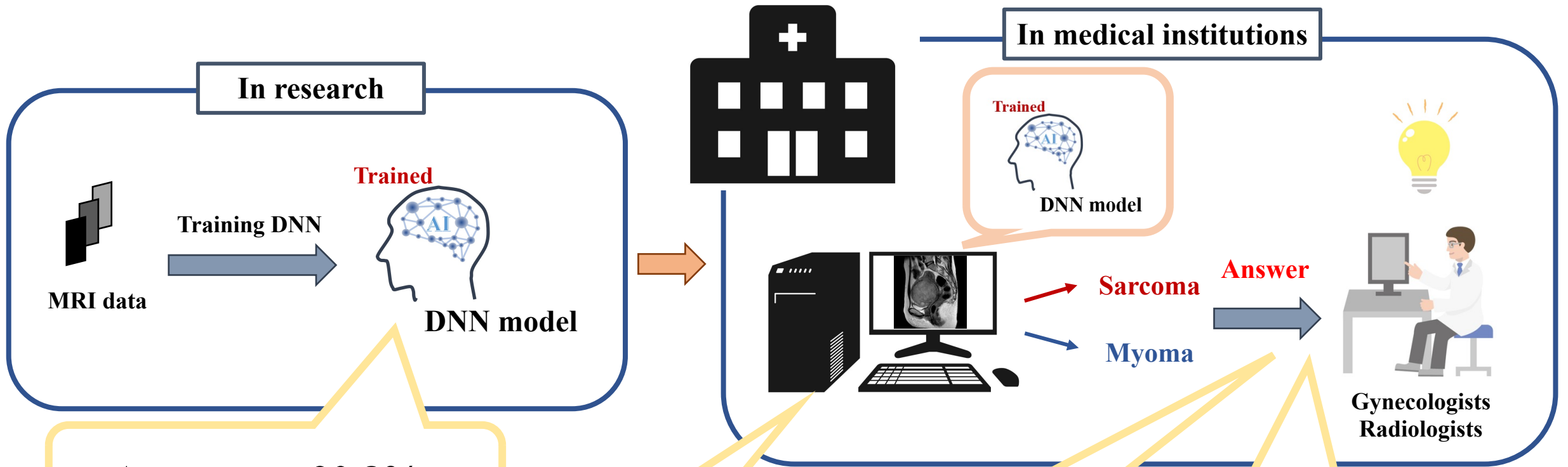
93.8%

Specificity

100.0%


Our DNN models showed **high diagnosing ability for the validation data set**, which is **important for clinical application**.

# Conclusion




**Accuracy : 90.8%**

**Automation by new model**

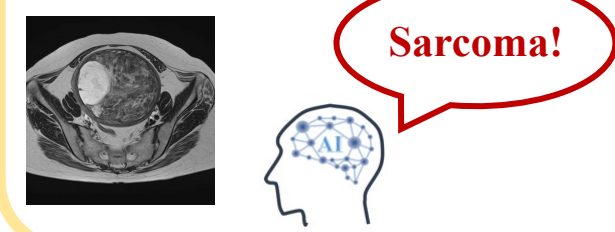


DNN model

**Filling the gap of skills**



**Reducing occult tumors**



Sarcoma!