Investigation of artificial intelligence for imaging diagnosis of uterine sarcomas: devices for the improvement of diagnostic accuracy for rare tumors.

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Introduction ~Uterine sarcomas~

☛ 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 leiomyomas is not uncommon.

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

Introduction ~Image features of uterine sarcomas and myomas~

	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 **High for fat content or hemorrhage**	Heterogenous and low **High for hemorrhage from necrosis**
Signal on T2WI	Generally, homogenous low signal **Intermediate/high in degeneration**	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 ($10^{-3}mm^2/s$)	**0.88-1.40**	**0.79-1.17**
Contrast-enhanced MRI	**Variable**	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

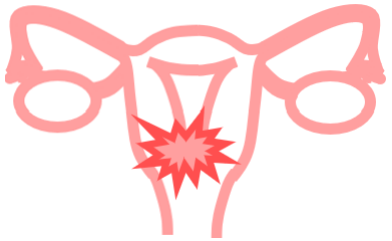
Image features are **overlapped between uterine sarcomas and myomas**.
In some cases, it is difficult to diagnose uterine tumors, especially **degenerated tumors**.

Introduction ~Diagnosing problems of uterine 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?

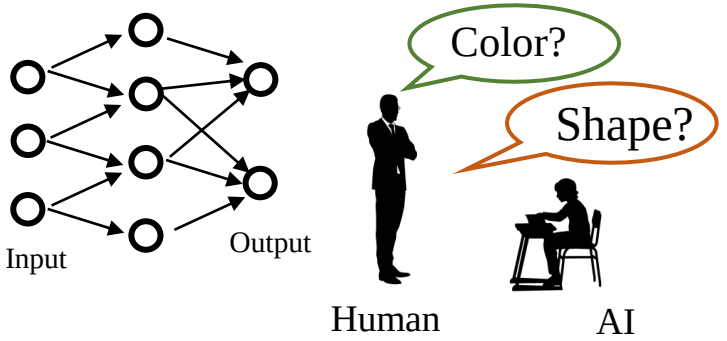
Artificial Intelligence (AI) : Reproduction of human's neural activity in a computer.

Artificial intelligence

Machine learning

Deep neural network (DNN)

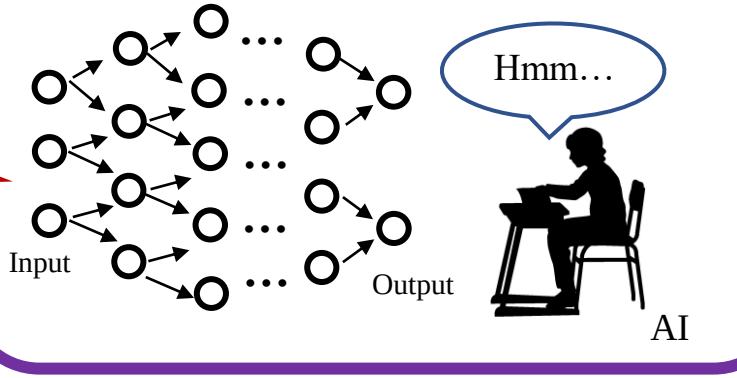
Conventional machine learning



Apple !

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

Deep neural network



Apple !

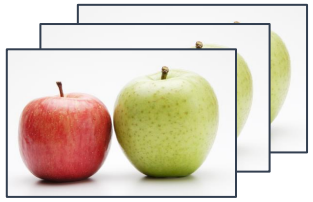
DNN is more suitable for **image recognition.**

※brief description

Overall flow of clinical use of DNN model : image recognition

Training

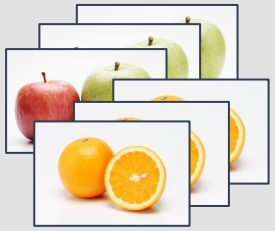
Data: Group A (Apple)



Data: Group B (Orange)

Training and evaluation data set

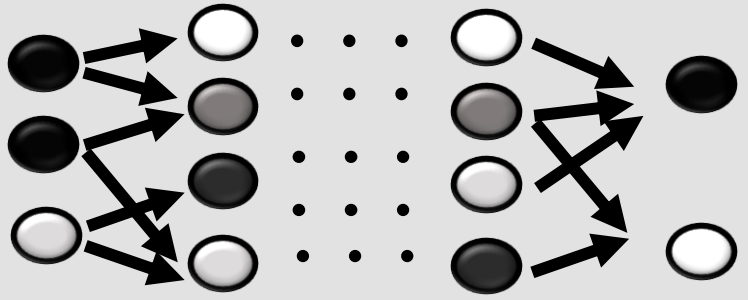
Data



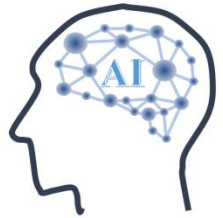
Answer

Group A (apple)
or
Group B (Orange)

DNN under training

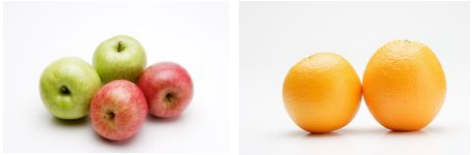


Trained

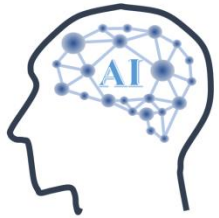


DNN model

Prediction



Trained



DNN model

Group A

Group B

Apple !

Orange!

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	**Machine learning**
2	Xie et al.	2019	European journal of radiology	MRI	29	49	accuracy 73.9% AUC 0.83	**Machine learning**
3	Nakagawa et al.	2019	Clinical Radiology	MRI PET	11	56	AUC 0.92	**Machine learning**
4	Lakhman et al.	2018	European radiology	MRI	19	22	accuracy 75%	**Machine learning**
5	Gerges L et al.	2018	American Journal of Roentgenology	MRI	17	51	sensitivity 88.2% specificity 78.4%	**Machine learning**
6	Wang et al.	2020	European Radiology	MRI	53	84	AUC 0.91	**Machine learning**
7	Malek et al.	2020	Scientific Reports	MRI	21	84	Accuracy 96.2% Sensitivity 100% Specificity 95%	**Machine learning**

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

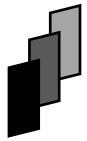
*** Machine learning = conventional machine learning**

Objects and methods

Objects: Investigation of DNN model for imaging diagnosis of uterine sarcomas

Methods:

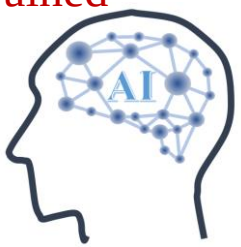
1st examination.



MRI data of uterine tumors

Training DNN

trained



DNN model

V.S.

Radiological specialists

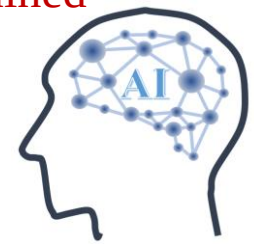
V.S.

Radiological practitioners

Assessment of DNN model's accuracy

2nd examination.

trained



DNN model

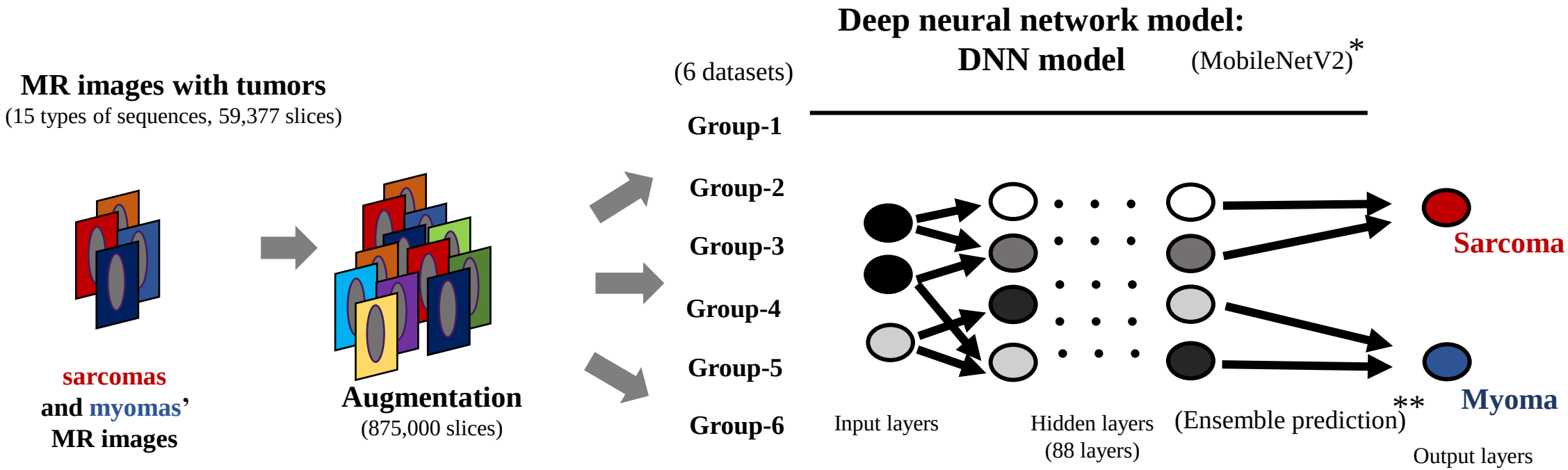
V.S.

AI-supported

V.S.

Assessment of DNN model's supporting ability for radiologists

Methods ~ overall flow of this study ~



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

*MobileNetV2

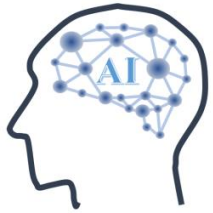
MobileNetV2 is one type of DNN network which consists of 88 layers and has around 3.5million learning parameters.

**Ensemble prediction

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

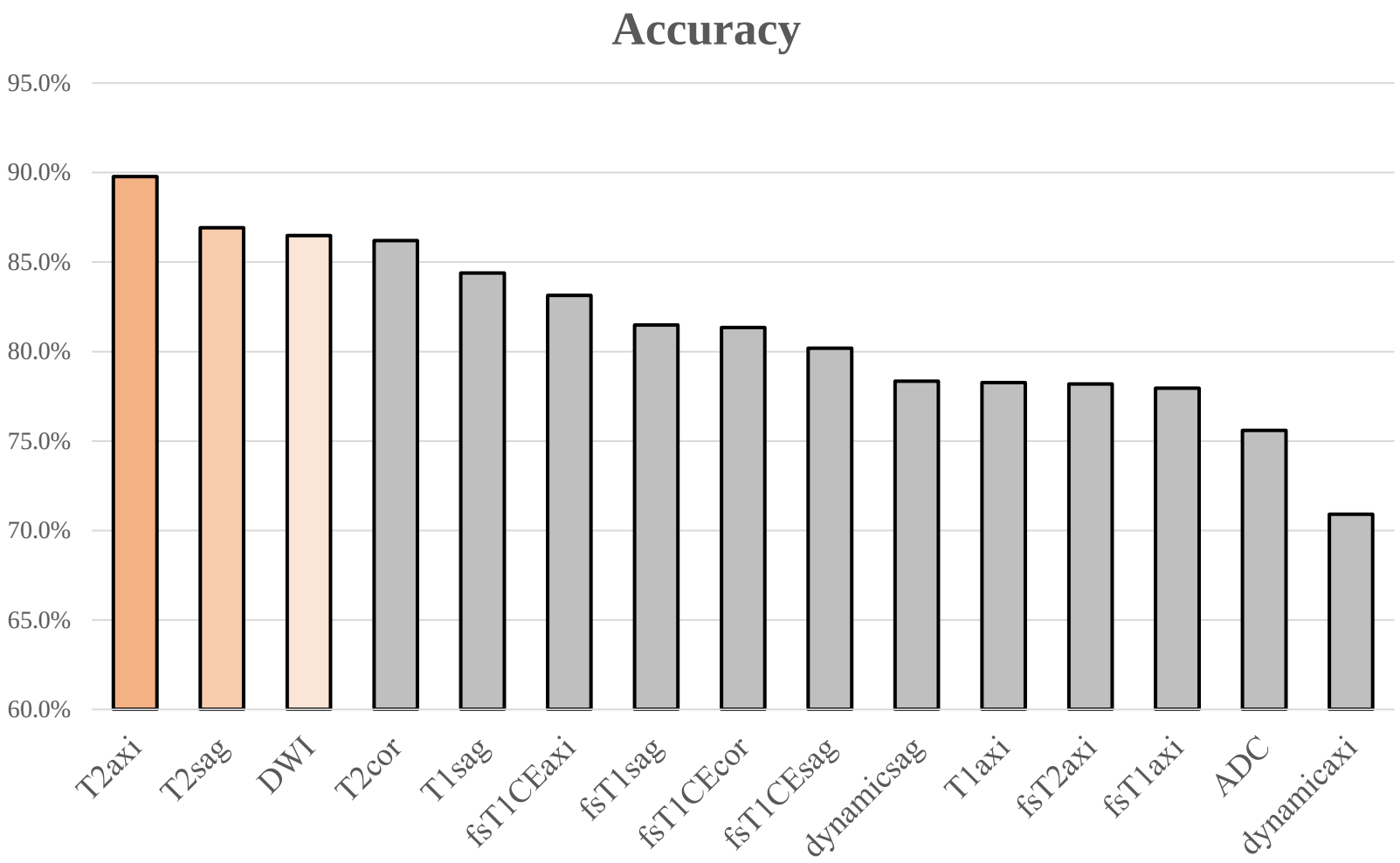
Results ~ diagnosing accuracy of each group ~

The 1st exam.

	Accuracy	Sensitivity	Specificity
Radiological practitioners (n = 3)	69.6%	47.6%	91.5%
Radiological specialists (n = 3)	82.4%	71.0%	93.8%
 DNN model	90.8%	89.8%	91.7%

Results ~ individual MRI sequences ~

Results of individual MRI sequences.



TOP-3 of MRI sequences.

T2WI axial : 89.8%
T2WI sagittal : 86.9%
DWI : 86.5%

Results ~ TOP10 of combination sets of MRI sequences ~

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TOP10 of combination sets of MRI sequences.

Combination set	Accuracy	Sensitivity	Specificity	ADC	DWI	dynamicaxi	dynamicsag	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	**90.8%**	**89.8%**	**91.7%**															

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

Results ~ AI-supported examination~

The 2nd examination. (One month later)

AI-supported

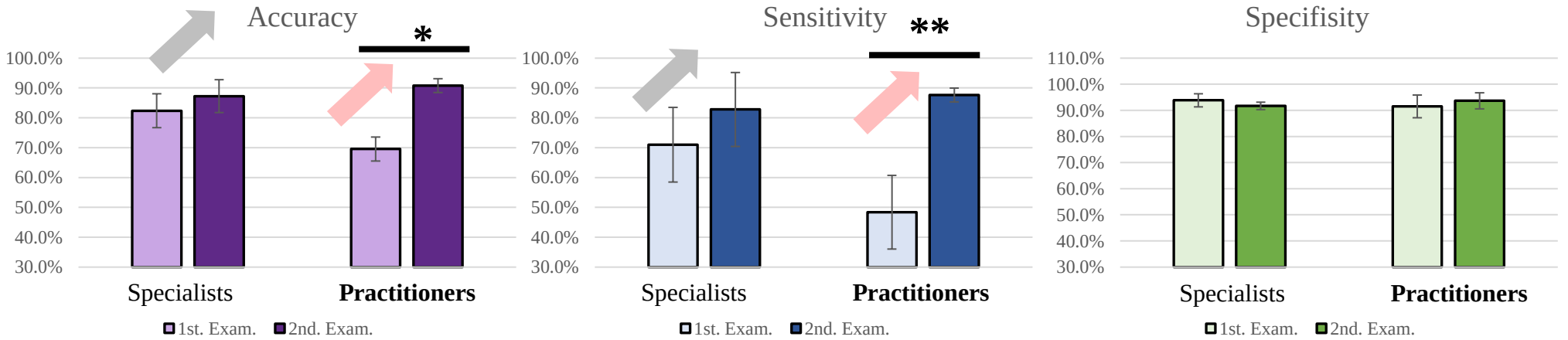
Radiological specialists(n=3)

Radiological practitioners(n=3)

	Accuracy	Sensitivity	Specificity
DNN model	**90.8%**	**89.8%**	**91.7%**
Specialists	**87.3%**	**83.1%**	**91.7%**
Practitioners	**90.8%**	**87.8%**	**93.7%**

The results of DNN model in the 1st examination were provided.

Comparison the average between 1st and 2nd examination.



* P value=0.01
** P value=0.03

DNN models can be helpful for **filling the gap** of readers skills and **reducing occult tumors**.

Discussion

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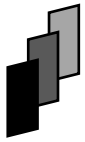
Our DNN model shows

- **High diagnosing accuracy**
- **Supporting ability to fill the gaps of readers**
- **Supporting ability to reduce occult tumors**

Conclusion

This study

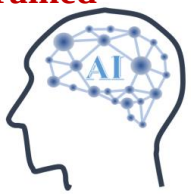
In research



MRI data

Training DNN

Trained



DNN model

Accuracy : 90.8%

Future plan

In medical institutions

Trained

DNN model

Sarcoma

Myoma

Answer

Gynecologists
Radiologists

Filling the gap of skills

Reducing occult tumors

Sarcoma!