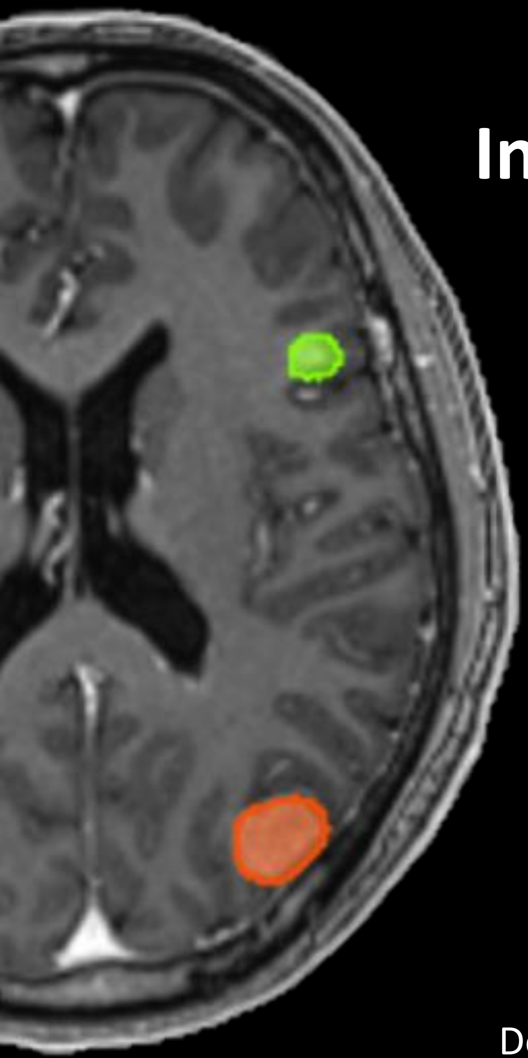


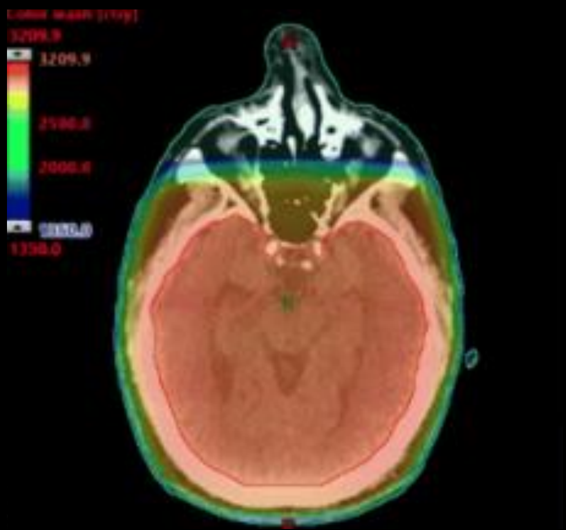
Integrating Collaborative Intelligence into Brain Stereotactic Radiosurgery -- a randomized multi-reader evaluation

Shao-Lun Lu 呂紹綸, MD, PhD

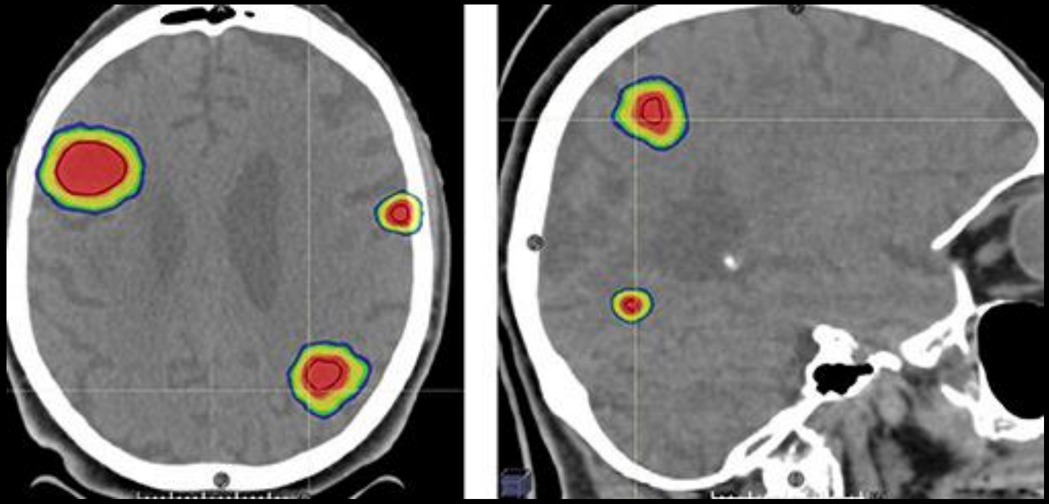
Department of Radiation Oncology, National Taiwan University Cancer Center

Brain metastases complicates 20-40% cancer patients

Increasing incidence with advances in systemic therapy



Whole brain radiotherapy



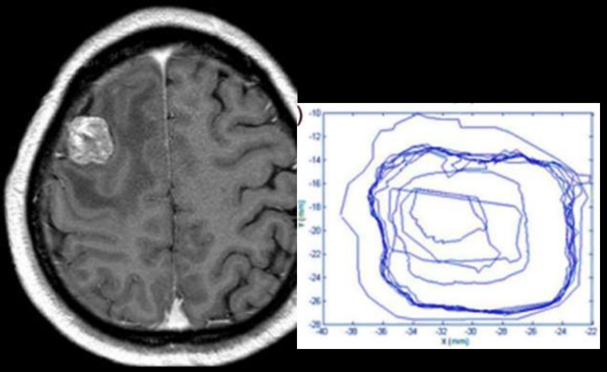
Stereotactic radiosurgery (SRS)

Contouring the brain tumor

Contouring brain metastases

Labor intensive

Inter-observer variability is large

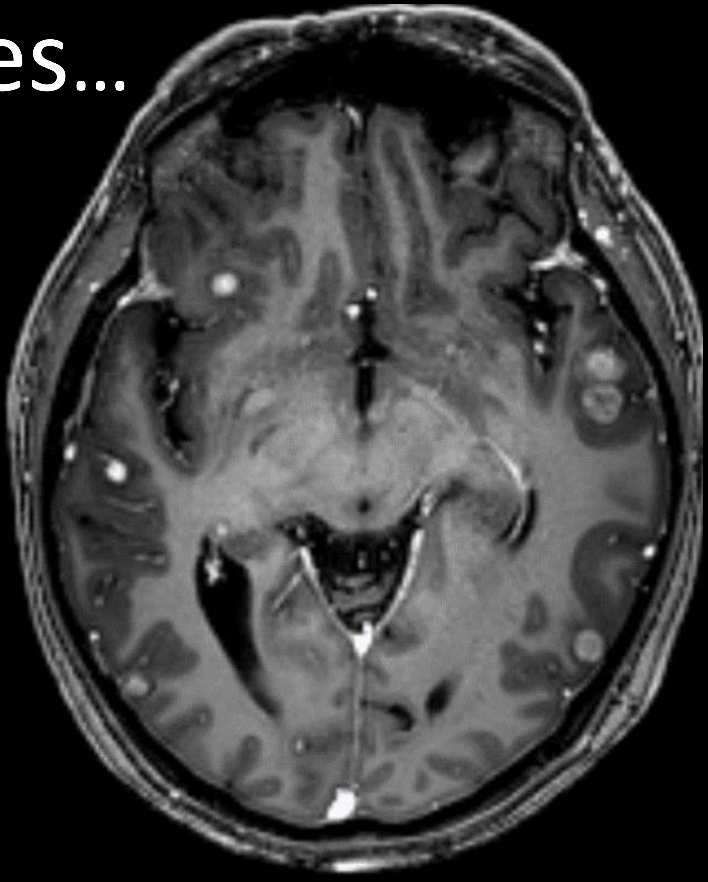


Sandström et al. Acta Oncol. 2018

Especially for multiple metastases…

Labor intensive

Inter-observer variability is large



Motivation

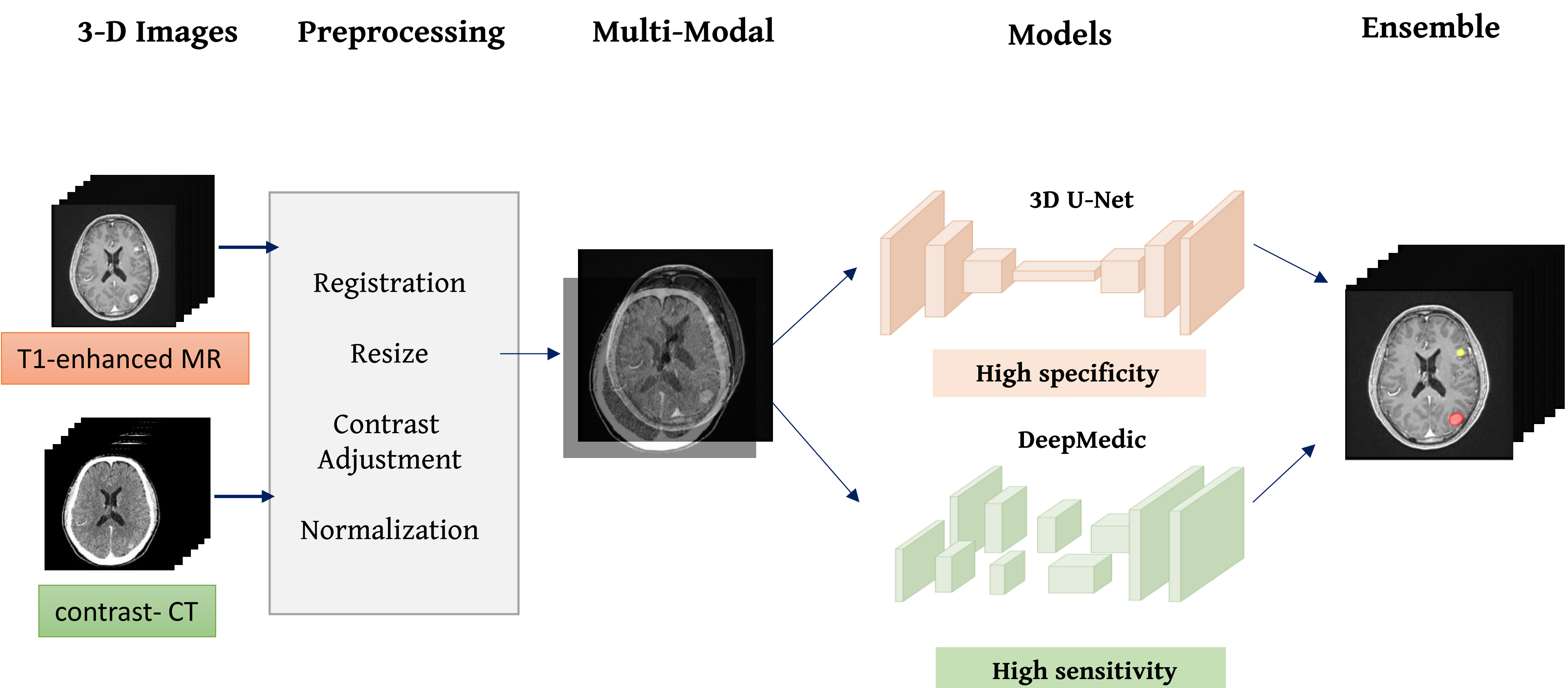
Automated BM **detection** and **segmentation** for **SRS**

1. Tiny, punctate lesion **High sensitivity**
2. Limited imaging modalities (Enhanced T1 MR and CT) **Low False positive**
3. Clustered tumors **Precision delineation**
4. Rapid clinical flow **Integration into daily practice**

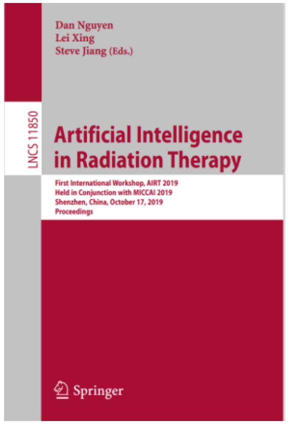
2008-2018 2 NS and 3 RadOnc
CyberKnife® system with Multiplan®
MR 2 scanners/ CT 2 scanners

Number of patients	**638**
Number of metastases	1877
Training/Validation/Testing	8:1:1 ratio with random split
patients with	
1 tumor	42
2 tumors	22
3 tumors	11
≥ 4 tumors (%)	25
Tumor Size (ml) (Median; Min-Max)	0.61 (Diameter ~ 1 cm); 0.002-59.306

State-of-the-art AI solution



- **US patent** granted
- Oral Presentation at **MICCAI 2019**
- Oral Presentation at **ASTRO 2019**



Multimodal Volume-Aware Detection and Segmentation for Brain Metastases Radiosurgery

Szu-Yeu Hu[1], Wei-Hung Weng[2], Shao-Lun Lu[3], Yueh-Hung Cheng[4], Furen Xiao[5], Feng-Ming Hsu[3], and Jen-Tang Lu[4](✉)

[1] Massachusetts General Hospital, Boston, MA, USA
[2] Massachusetts Institute of Technology, Cambridge, MA, USA
[3] Department of Oncology, National Taiwan University Hospital, Taipei, Taiwan
[4] Vysioneer Inc., Cambridge, MA, USA
jt@vysioneer.com
[5] Department of Surgery, National Taiwan University Hospital, Taipei, Taiwan

arXiv:1908.05418v1 [eess.IV]

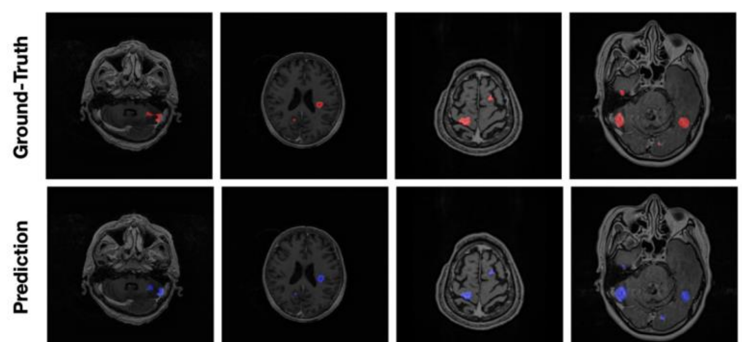
Volume-Aware Dice Loss

optimizing the overall segmentation using the information of lesion size. $\ell_{\text{vol-dice}}$

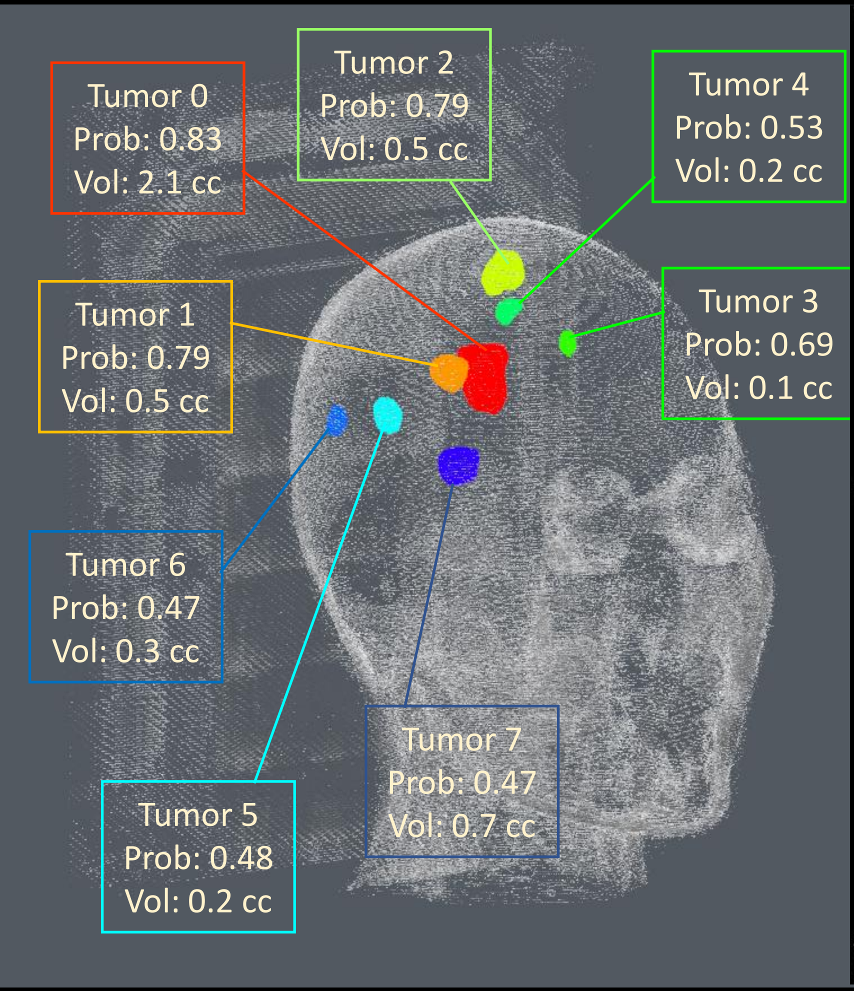
$$\ell_{\text{vol-dice}}(\boldsymbol{g}, \boldsymbol{p} \mid W) = -\frac{C\boldsymbol{g}^\top W \boldsymbol{p} + \epsilon}{\boldsymbol{p}^\top \boldsymbol{p} + \boldsymbol{g}^\top W \boldsymbol{g} + \epsilon},$$

Table 3. Model performance of different configurations of loss functions, image modalities, and neural network models. The values are represented as median (std).

Model	$\ell_{\text{vol-dice}}$	DSC	Precision	Recall
3D U-Net		0.669 (0.006)	0.689 (0.001)	0.700 (0.015)
DeepMedic		0.625 (0.013)	0.631 (0.004)	0.734 (0.035)
3D U-Net + DeepMedic		0.719 (0.004)	**0.788** (0.002)	0.713 (0.023)
3D U-Net + DeepMedic	✓	**0.740** (0.022)	0.779 (0.010)	**0.803** (0.001)



Multiple tumors



Performances

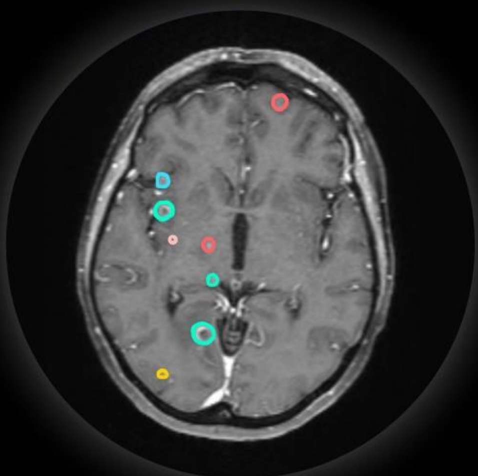
Model	Modality	Dice	FP / Sensitivity
DeepMedic	MR	0.625	3.344/0.900
Unet 3D	MR	0.699	0.609/0.709
Ensemble DeepMedic + Unet 3D	MR	0.723	0.484/0.752
Ensemble	**MR + CT**	**0.761**	**0.594/0.787 (2.625/0.900)***

*At a high-sensitivity operating point

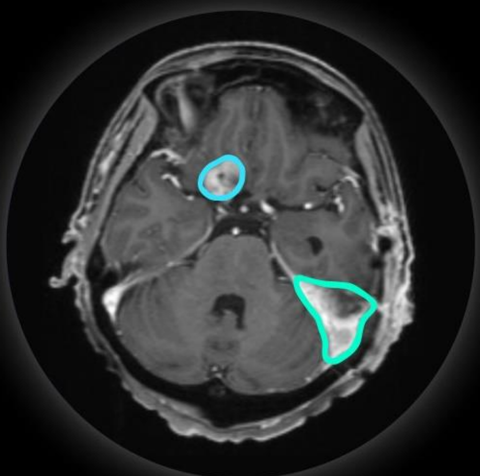
Voxel-by-voxel AUC=0.99

VBrain: AI-empowered Brain Tumor Auto-contouring

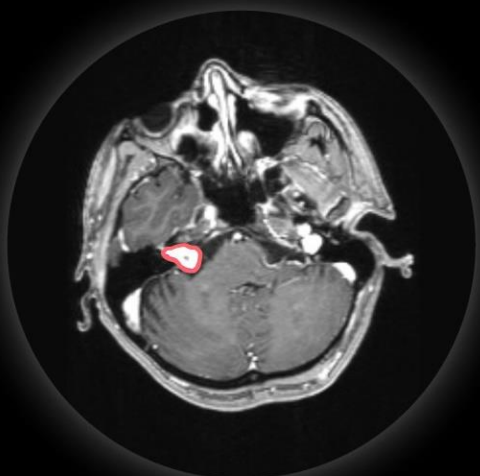
Works for **the 3 most common brain tumors (75+% cases in brain radiosurgery)**



Metastasis



Meningioma



Acoustic Neuroma


臺大醫院
VYSIONEER 醫隼智慧
腦瘤治療研究榮登醫學期刊Neuro-Oncology
美國FDA首次核准腫瘤AI圈選系統

FDA
CLEARED

Clinicians do not need to change any routines to adopt to the new technology

Integration into clinical workflow

Inference time less than 2 minutes

Start a New Workflow

Patient ID

Lee_1234567

Example: Lee_1234567

Submit

Patient ID	Status	Created At
Yeh_8658421	succeeded	2019-05-17T14:41:08+08:00
Wang_21760505	succeeded	2019-05-17T14:42:03+08:00
Lee_1234567	running	2019-05-17T14:44:27+08:00

A prospective reader study within the clinical scenario

Impact of AI-assisted brain tumor segmentation for SRS

- **Inter-reader variability**
- **Accuracy**
- **Efficiency**

Neuro-Oncology

SNO
Society for NeuroOncology

Randomized multi-reader evaluation of automated detection and segmentation of brain tumors in stereotactic radiosurgery with deep neural networks

Neuro-Oncology, noab071, https://doi.org/10.1093/neuonc/noab071

Shao-Lun Lu, Fu-Ren Xiao, Jason Chia-Hsien Cheng, Wen-Chi Yang, Yueh-Hung Cheng, Yu-Cheng Chang, Jhih-Yuan Lin, Chih-Hung Liang, Jen-Tang Lu, Ya-Fang Chen ✉, Feng-Ming Hsu ✉

Author Notes

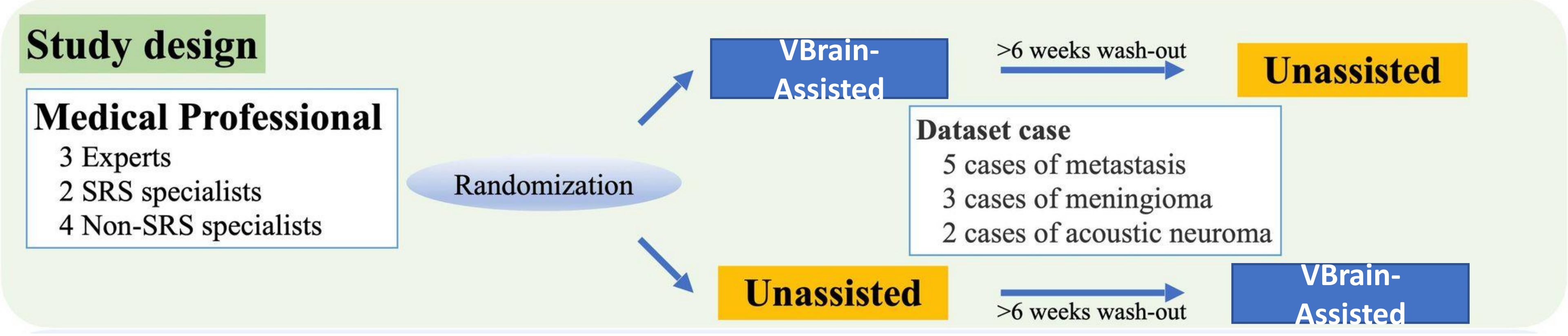
Neuro-Oncology, Volume 23, Issue 9, September 2021, Pages 1560–1568, https://doi.org/10.1093/neuonc/noab071

Reader Study

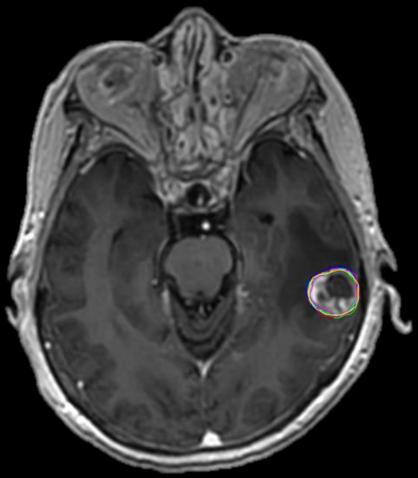
OXFORD ACADEMIC
Neuro-Oncology
SNO Society for NeuroOncology

Randomized multi-reader evaluation of automated detection and segmentation of brain tumors in stereotactic radiosurgery with deep neural networks

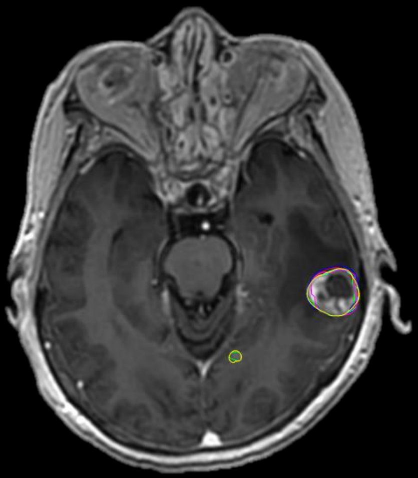
Neuro-Oncology, noab071, https://doi.org/10.1093/neuonc/noab071
Published: 22 March 2021 **Article history** ▾



Increase sensitivity



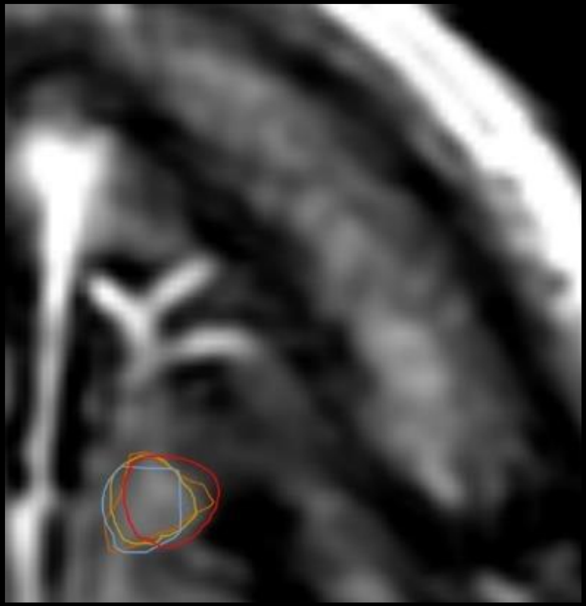
Without AI



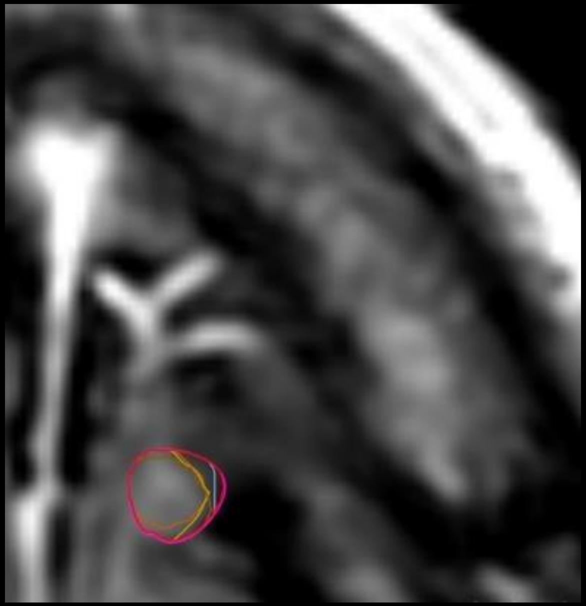
With AI

Lu, Shao-Lun, et al. "Randomized Multi-Reader Evaluation of Automated Detection and Segmentation of Brain Tumors in Stereotactic Radiosurgery with Deep Neural Networks." *Neuro-Oncology* (2021).

Reduce inter-reader variability



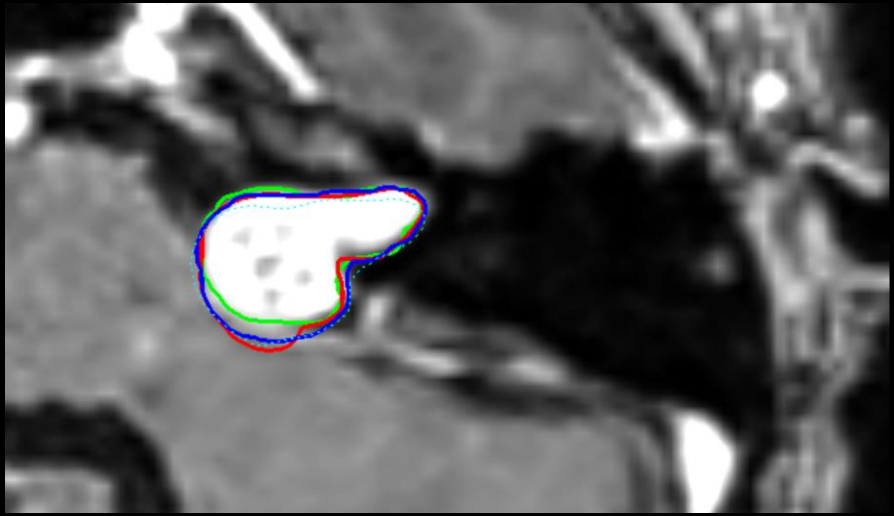
Without AI



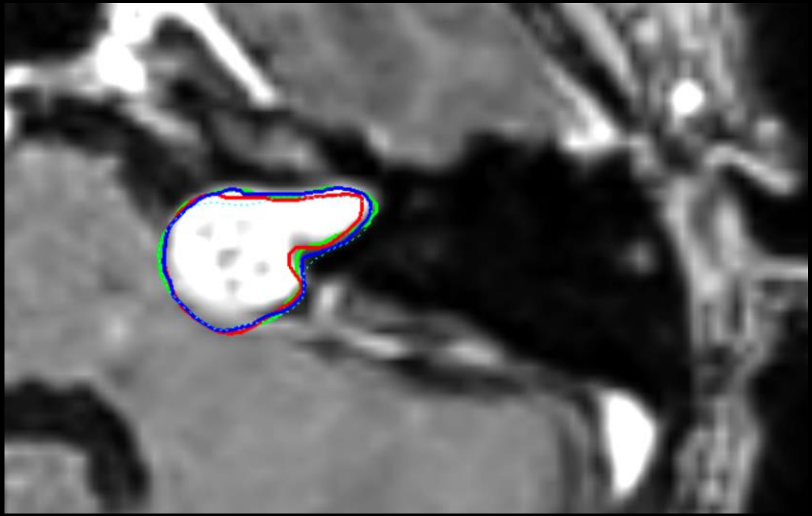
With AI

Lu, Shao-Lun, et al. "Randomized Multi-Reader Evaluation of Automated Detection and Segmentation of Brain Tumors in Stereotactic Radiosurgery with Deep Neural Networks." *Neuro-Oncology* (2021).

Reduce inter-reader variability



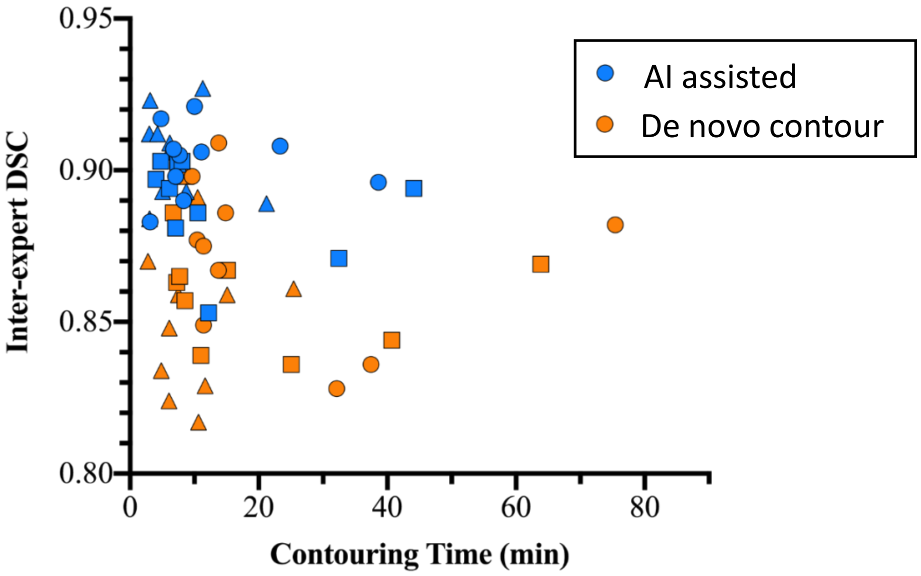
Without AI



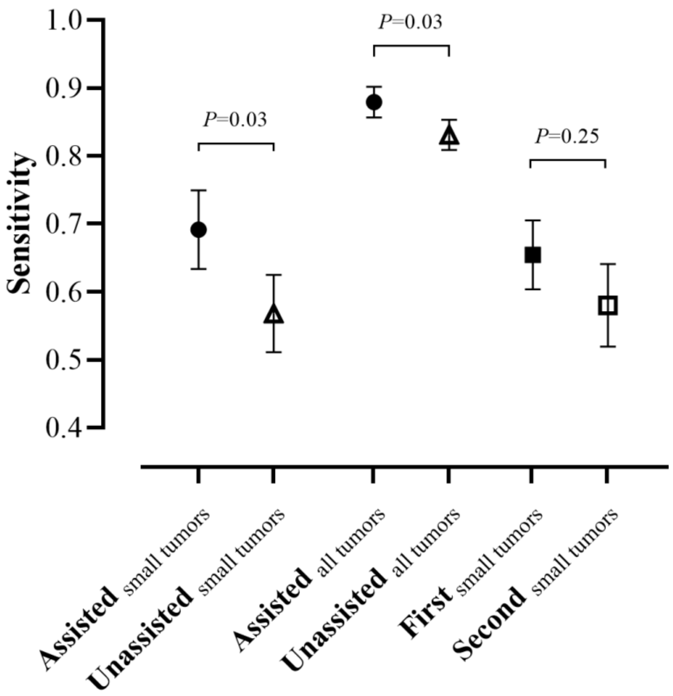
With AI

Collaborative intelligence SRS

Reduce inter-reader variability by 50%
Reduce Contouring Time by 31%

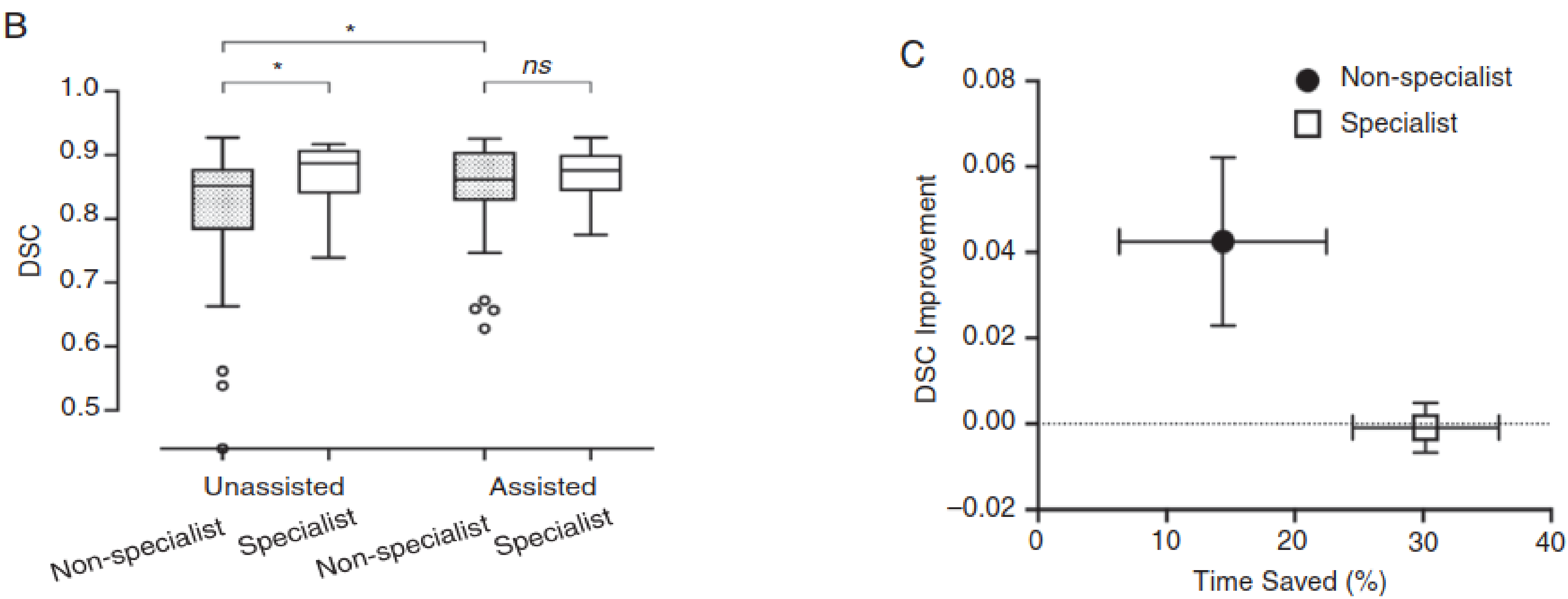


Improve Sensitivity by 12%



Lu, Shao-Lun, et al. "Randomized Multi-Reader Evaluation of Automated Detection and Segmentation of Brain Tumors in Stereotactic Radiosurgery with Deep Neural Networks." *Neuro-Oncology* (2021).

Collaborative intelligence SRS

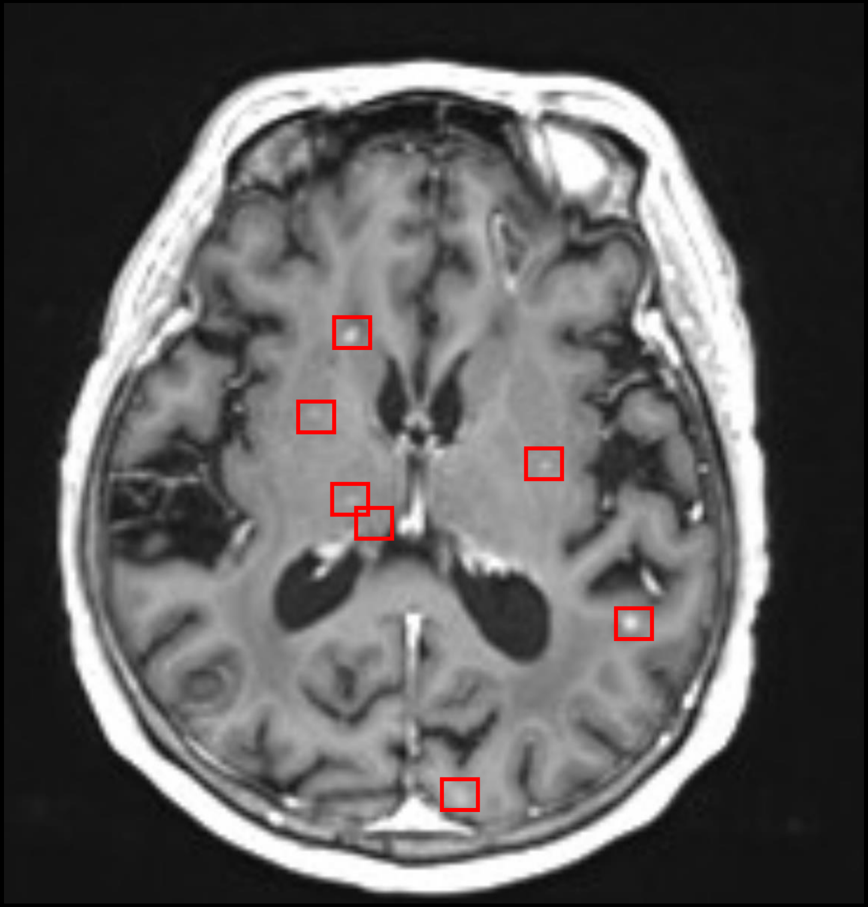


Lu, Shao-Lun, et al. "Randomized Multi-Reader Evaluation of Automated Detection and Segmentation of Brain Tumors in Stereotactic Radiosurgery with Deep Neural Networks." *Neuro-Oncology* (2021).

Multi-mets after previous SRS

70 y/o woman
SCLC, s/p WBRT (2020/1),
Brain met recurrence in 2021/7 ECOG 2
s/p CK SRS 20 Gy (n=13)

Brain progression

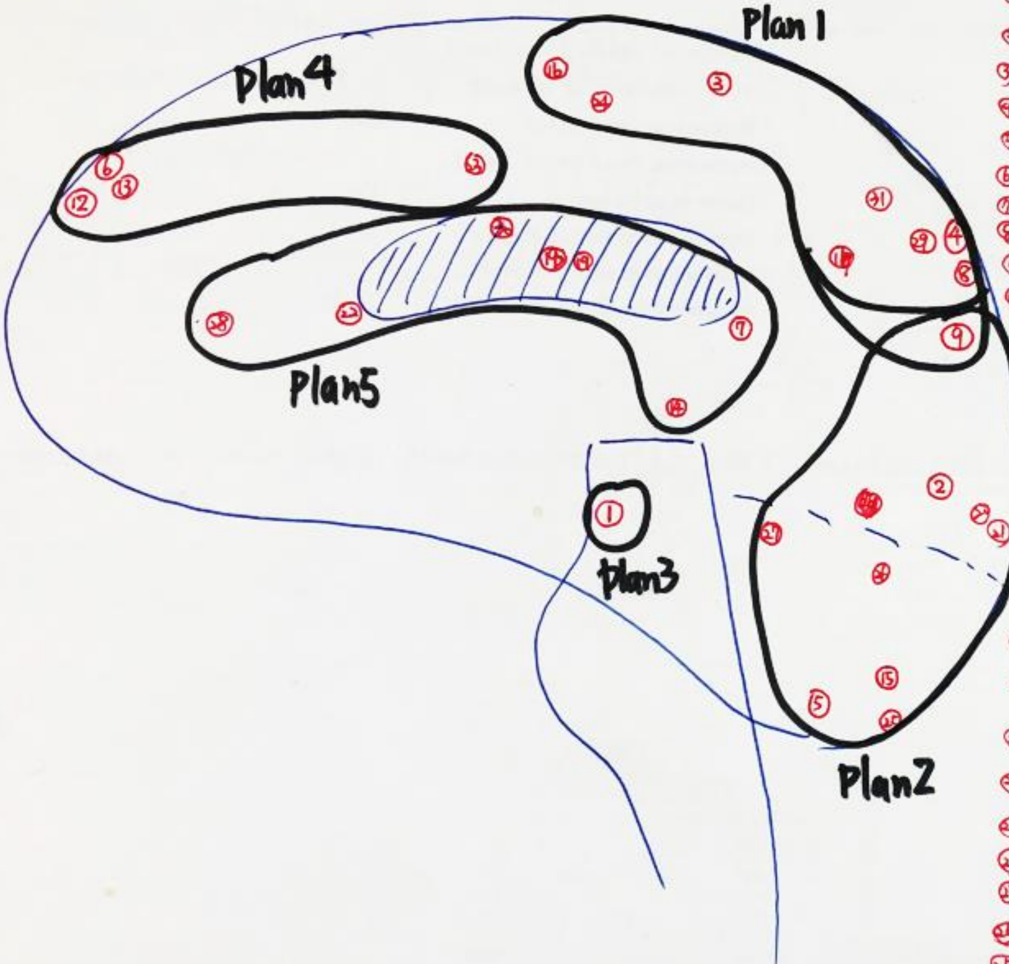


Multi-mets after previous SRS

Fusion previous planning MR
With this current AI-generated ROI

- ✓ Overlapping tumor→ treated!
- ✓ No any target missed

[redacted]



lesions

Lt

① GTV1 : Brainstem (No.103)
② GTV2 : Lt occipital (No.115)
③ GTV3 : Rt parietal (No.164)
④ GTV4 : Rt parietal (No.144).
⑤ GTV5 : Lt cerebellar (No.80)
⑥ GTV6 : Lt frontal (No.146)
⑦ GTV7 : Lt temporal (No.125)
⑧ GTV8 : Lt occipital (No.137)
⑨ GTV9 : Rt occipital (No.120).
GTV10、11 已治療過.
⑩ GTV12 : Rt frontal (No.138)
⑪ GTV13 : Lt frontal (No.133)
⑫ GTV14 : Lt thalamus (No.116)
⑬ GTV15 : Lt cerebellar (No.82).
⑭ GTV16 : Lt posterior frontal (No.162).
⑮ GTV17 : Rt parietal (No.136).
⑯ GTV18 : Rt lateral ventricle (No.133).
⑰ GTV19 : Rt ~~frontal~~ parietal (No.132).
⑱ GTV20 : Rt cerebellar (No.104).
⑲ GTV21 : Rt cerebellar (No.101).
⑳ GTV22 : Rt lateral ventricle (putamen) (No.123).
㉑ GTV23 : Lt frontal (No.151)
㉒ GTV24 : Rt posterior frontal (No.158).
㉓ GTV25 : Lt cerebellar (No.75).
㉔ GTV26 : Lt cerebellar (No.93).
㉕ GTV27 : Lt cerebellar (No.90).
㉖ GTV28 : Rt frontal (No.134)
㉗ GTV29 : Rt parietal (No.143).
㉘ GTV30 : Rt ~~frontal~~ lateral ventricle (No.137)
㉙ GTV31 : Rt parietal (No.149).

Plan

Plan1 : GTV3-4-8-■-16-17-24-29-31 (8Ls) (Plan)

⇒ Plan1 (8Ls)_7.5c_Fixed

Tx = 90min

Plan2 : GTV2-5-9-15-20-21-25-26-27 (9Ls)

⇒ Plan2 (9Ls)_7.5to15c_IRIS.

Plan3 : GTV1 (Plan)

⇒ Plan3_GTV1_5c_Fixed Tx = 34min

Plan4 : GTV6-12-13-23 (4Ls)

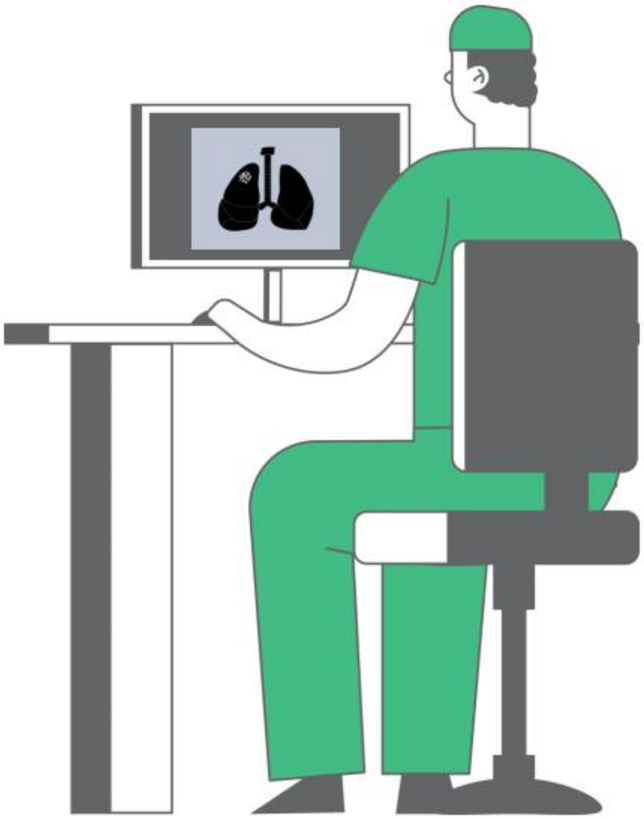
⇒ ~~Plan4_5-7.5c_Fixed (4Ls)~~

⇒ Plan4 (4Ls)_5-7.5c_Fixed

Plan5 : GTV7-14-18-19-22-28-30 (7Ls) (Plan)

⇒ Plan5 (7Ls)_7.5c_IRIS

Tx = 83min



@ Dr_RayMak

* https://www.newyorker.com/magazine/2018/11/12/why-doctors-hate-their-computers

A premise:
Artificial intelligence will enable us to be more patient-centered, more **present**…

Ray Mak, MD

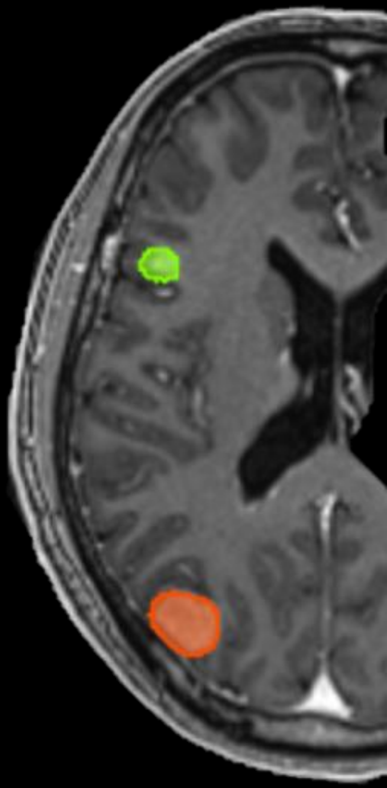
Take Home Messages

Collaborative Intelligence

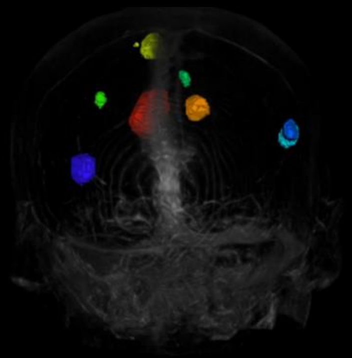
Produces reliable contouring for brain SRS
↓ mundane workload
↓ task difficulty
↑ time with patients

Integration matters

starting from clinical need
Patient-centered care!



Thank you



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