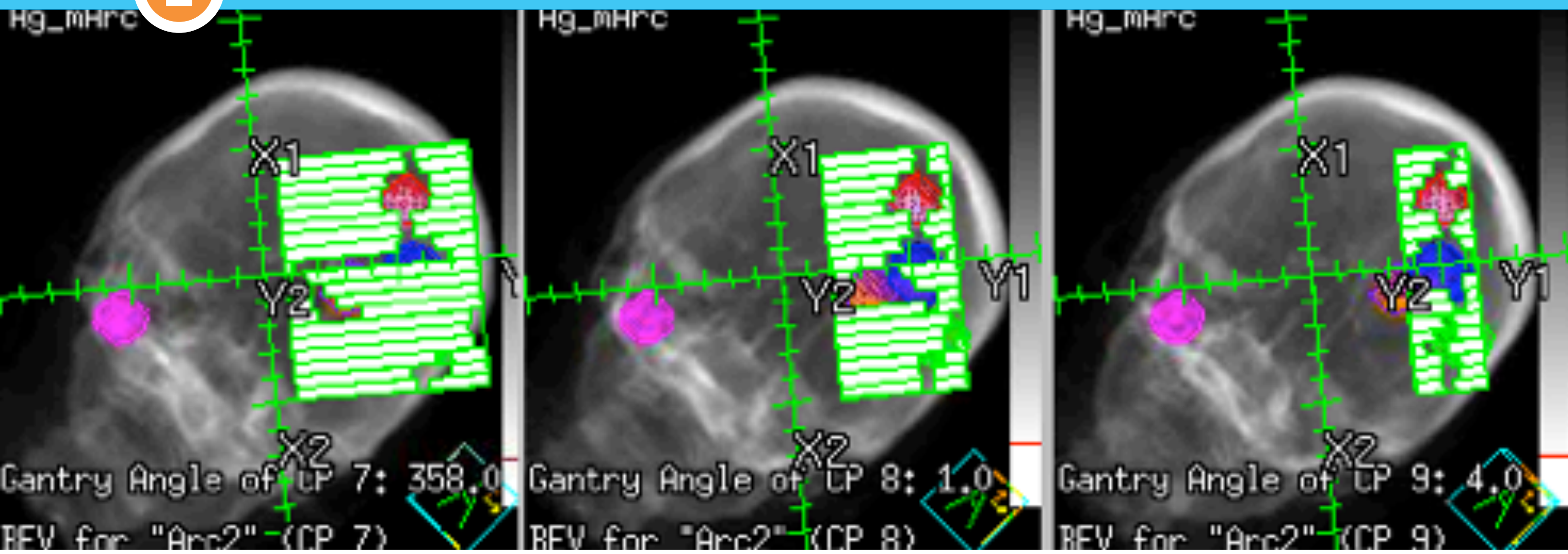
Evaluation of Monaco treatment planning system for hypofractionated stereotactic volumetric arc radiotherapy of multiple brain metastases

CASE STUDY



Institution:
Odette Cancer Centre

Location:
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Radiation Oncologist:
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Medical Physicists:
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Summary

Patient demographics:

- 66 year old female

Treatment:

- HF-SRT
- 25 Gy delivered in 5 fractions

Diagnosis:

- Primary disease: Lung
- Five brain metastases:
  - GTV1 - Left frontal
  - GTV2 - Left posterior inferior cerebellar
  - GTV3 - Left anterior cerebellar
  - GTV4 - Right occipital
  - GTV 5 - Right anterior occipital

Treatment planning and delivery system:

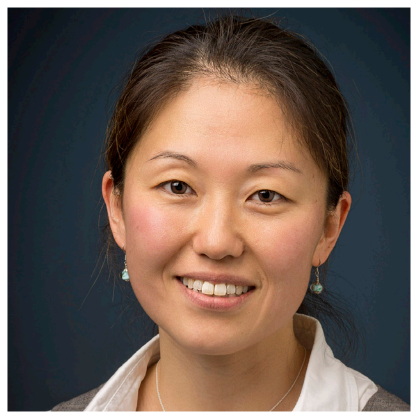
- Pinnacle treatment planning system version 9.2
- Monaco® treatment planning system version 5.1
- MOSAIQ® Radiation Oncology Information System version 2.5
- Elekta Synergy® with Agility™ MLC

Introduction

This case study forms part of a larger comparative study to observe differences between Monaco (version 5.1) and Pinnacle (version 9.2) treatment planning systems for the treatment of multiple brain metastases and spine radiosurgery using volumetric modulated arc therapy (VMAT).

There is a current debate about the treatment of brain metastases; whether to irradiate the whole brain or to treat each lesion separately[1]. Since it is likely that this population of patients will present with further brain metastases in the future, it is desirable to reduce the dose to the uninvolved brain as much as possible so that new metastases can be treated.

Treatment planning of multiple targets using a single isocenter, hypofractionated (HF) VMAT is technically challenging. The treatment planning systems investigated vary in terms of their optimization and dose calculation algorithms, which may produce substantially different dose distributions. Pinnacle uses collapsed cone convolution dose calculation and Monaco uses the Monte Carlo dose calculation. The purpose of this case study was to observe the differences in dose distributions produced by Monaco and Pinnacle for a challenging five brain metastases HF-VMAT case. Validation of these results with measurements will determine the accuracy of the dose calculation algorithms.



Young Lee, PhD

In our experience, planning multiple targets using VMAT with Pinnacle, we have observed several planning limitations. In order to achieve the desired high dose gradients, Pinnacle requires a long dose calculation resulting in lengthy planning time. The plan quality is also limited by the optimization algorithm's inability to accurately track the target using the jaws and MLC leaves as the treatment head moves around the patient. Specifically, certain leaf and jaw positions remain open when they should be closed (figure 1). In our planning experience to date using Monaco, we have found that the MLC leaves and jaws are better able to track targets throughout the VMAT arc.

The aim of the overall study is to determine if Monaco offers any gains in terms of planning and treatment times, target conformality and dose to uninvolved brain. Our hypothesis is that Monaco will perform better than Pinnacle when planning multiple brain metastases and spine SRS, because of its ability to track the target effectively using the jaws and MLC leaves. It should be noted that the study team has significant experience in planning with Pinnacle and its functionality (5-10 years), and limited experience planning with Monaco (less than 6 months).

If clinical benefit is proven, this will justify evaluating the plan quality that can be achieved using Monaco in other clinical sites.

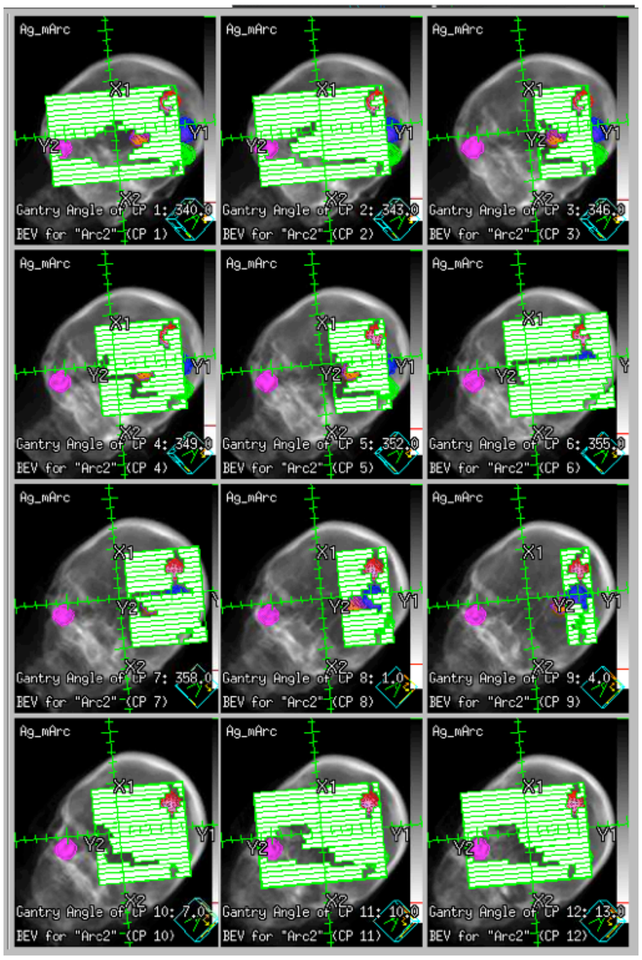


Figure 1. Stereotactic HF-VMAT of multiple brain metastases. Example where Pinnacle MLC leaves are not tracking (closing) effectively around the targets, leading to increased dose to uninvolved brain.

Patient history and diagnosis

The planning CT scans used for the investigation were from a 66 year old woman with lung cancer and five brain metastases in the left frontal, left posterior inferior cerebellar, left anterior cerebellar, right occipital and right anterior occipital positions (figure 2), which were treated at the Odette Cancer Centre using HF-SRT to deliver 25 Gy in 5 fractions. The patient was immobilized using a 5-point thermoplastic mask in the supine position. The CT slice thickness was 1 mm.

Treatment planning

Retrospective re-planning was performed with both treatment planning systems using an Elekta Agility VMAT beam model. The same energy (6MV) beam, arc geometry and single isocenter (figure 3) was used for each TPS, so that differences between the systems could be distinguished. A uniform margin of 2mm was used to create PTVs from GTVs.

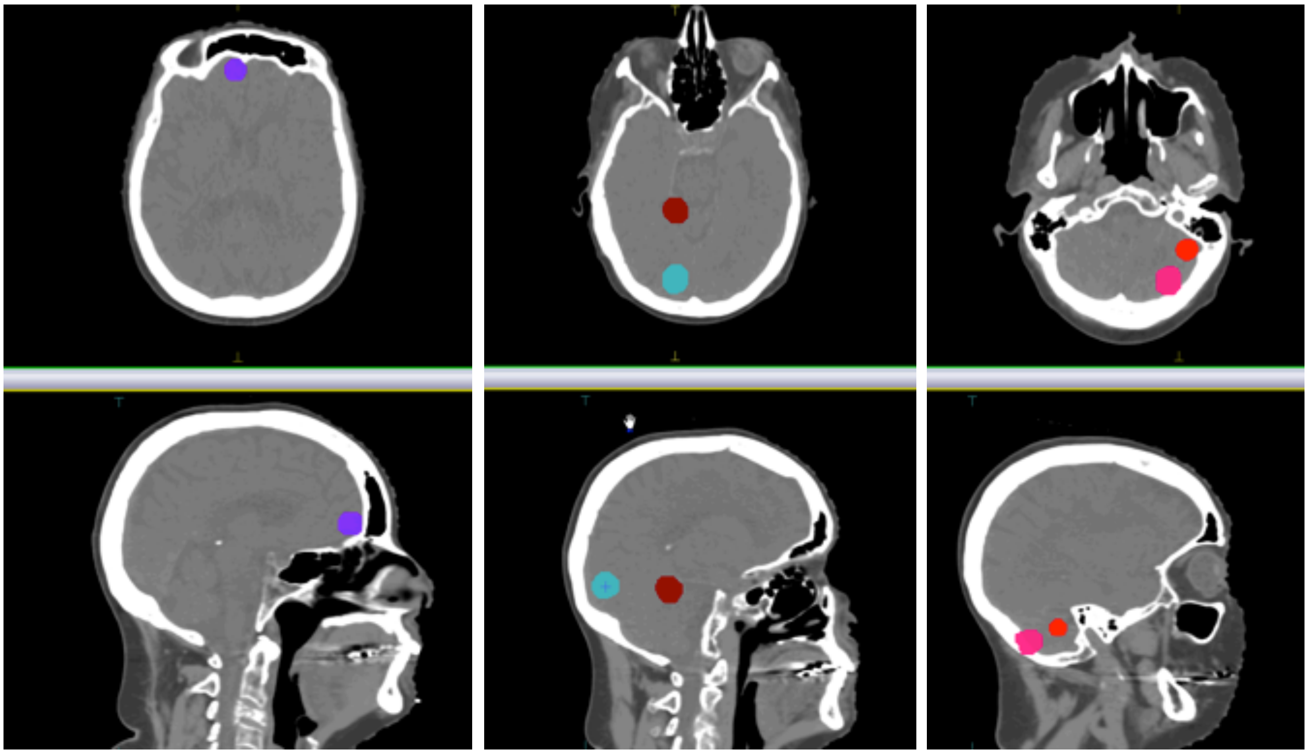


Figure 2. Planning CT scan. Transverse and sagittal slices of 5 brain metastases.

The VMAT arc arrangement used for each TPS was as follows:

- Couch 10˚; Gantry 180˚ to 310˚ clockwise
- Couch 305˚; Gantry 40˚ to 179˚ clockwise
- Couch 55˚; Gantry 180˚ to 320˚ clockwise
- Couch 350˚; Gantry 40˚ to 179˚ clockwise

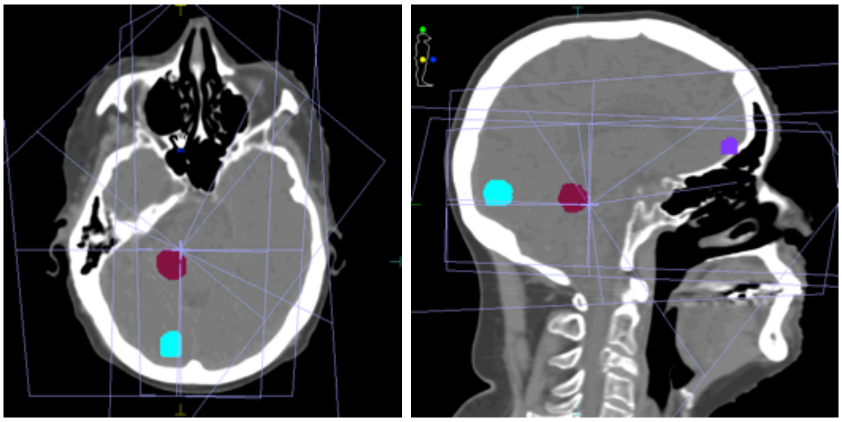


Figure 3. Single isocenter (light purple) placement shown in transverse and sagittal planes.

Dosimetric objectives used when planning this patient for treatment were as follows:

- planning target volume (PTV) 100%>98%.

- brainstem maximum dose of 18 Gy.
- optic chiasm maximum dose of 15 Gy.
- optic nerves maximum dose of 15 Gy.
- globes maximum dose of 10 Gy.
- lens maximum dose of 4 Gy.

Plans were evaluated based on integral dose to brain not including the gross tumor volumes (referred to as BrainMinusGTV), target homogeneity and conformity indices.

Results

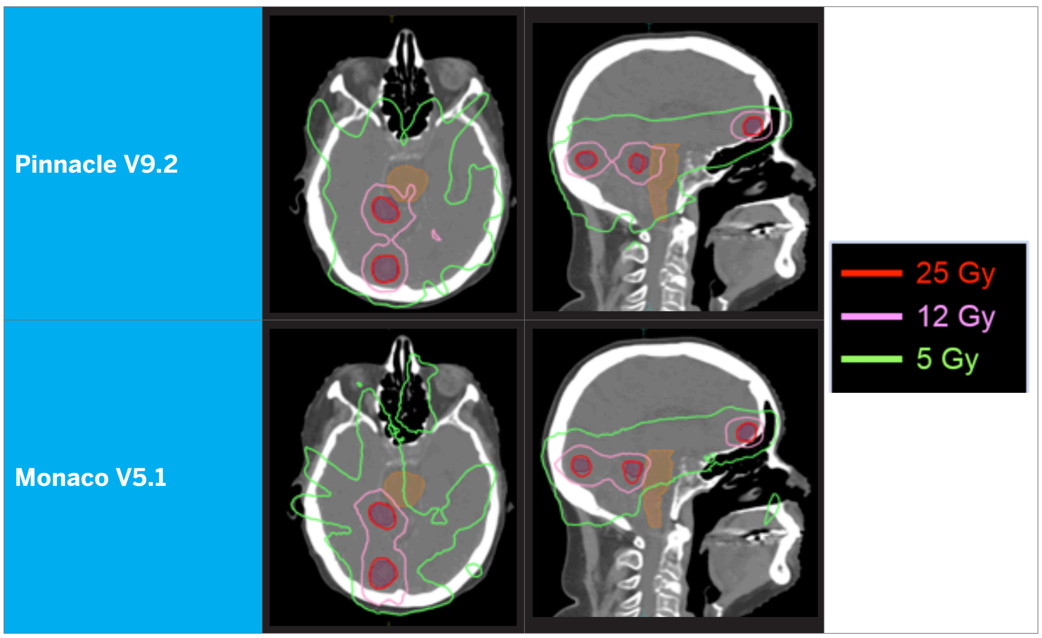


Figure 4. Dose distribution comparison between Pinnacle and Monaco.

Figure 4 compares the dose distribution between the two treatment planning systems, in transverse and sagittal planes. Figure 5 shows the dose-volume-histograms for all five targets, as well as the BrainMinusGTV and brainstem. Finally, table 1 summarizes various plan quality metrics which were examined in our evaluation of the performance of the two treatment planning systems in this case study.

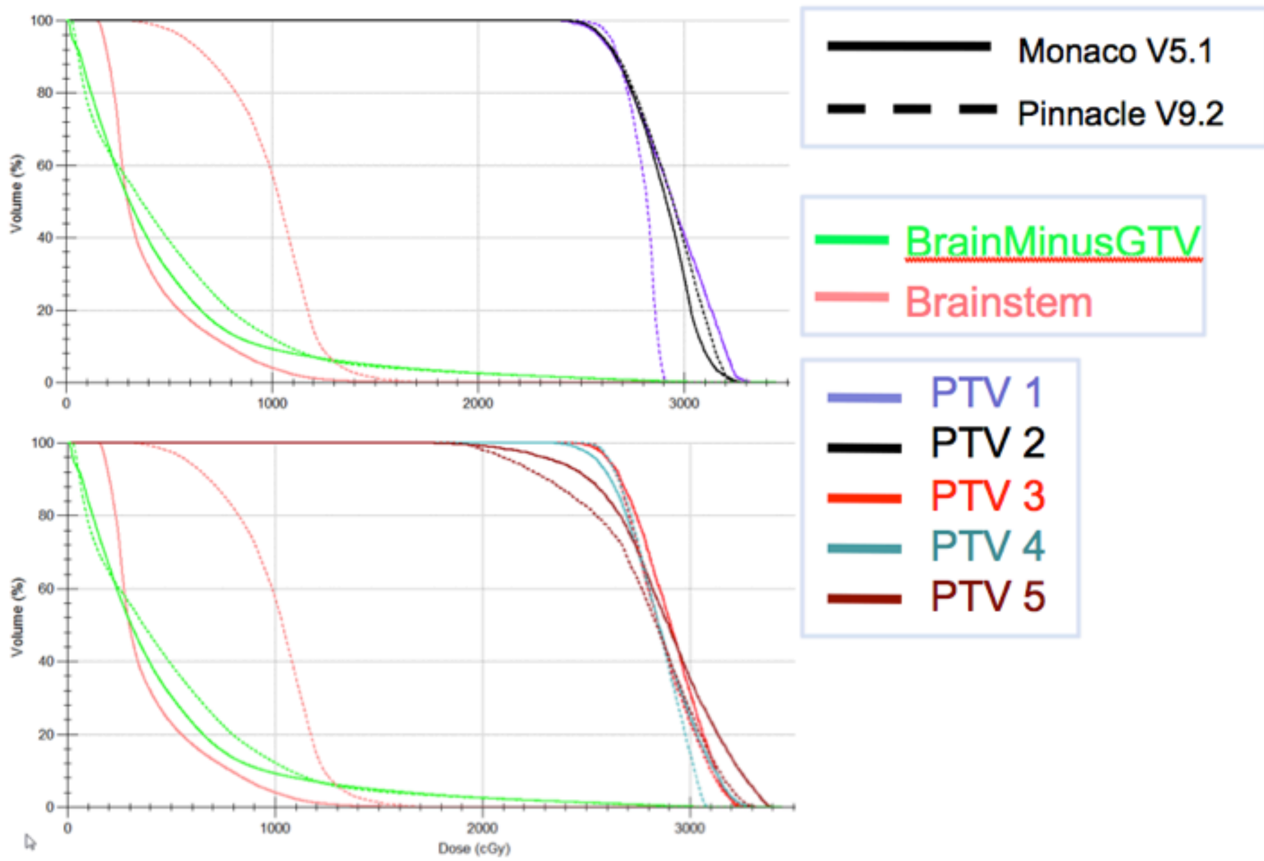


Figure 5. Comparison of treatment planning systems: Dose-volume-histograms of the five targets, brainstem and BrainMinusGTV

	PINNACLE V9.2	MONACO V5.1
Plan deemed clinically acceptable	√	√
Organ-at-risk criteria met	√	√
PTV coverage > 97.5%	Yes, with the exception of PTV1 (proximal to brainstem): V100 82.6%	Yes, with the exception of PTV1 (proximal to brainstem): V100 90.5%
Dose Homogeneity within targets	Greatest difference was a 3.5 Gy decrease in D2% for PTV1	Greatest difference was a 3.5 Gy increase in D2% for PTV1
Conformity Index	Marginally (less than 5%) higher in 4 of 5 targets	Marginally (less than 5%) lower in 4 of 5 targets
DVH: BrainMinusGTV	Below 3 Gy: DVH is marginally (less than 1 Gy) lower than in Monaco plan Above 12 Gy: DVH is marginally (less than 0.5 Gy) lower than in Monaco plan	Between 3 Gy-12 Gy: DVH is 30-32% lower than in Pinnacle plan
Mean Dose: BrainMinus GTV	499 cGy	453 cGy
Mean Dose: Brainstem	10 Gy	4.0 Gy

Table 1: Comparison of plan quality between Pinnacle and Monaco

Discussion

Both plans were deemed clinically acceptable. All clinical criteria for organs-at-risk (OAR) constraints were met (table 1). PTV coverage was greater than 97.5% in all cases except for one PTV that was proximal to the brainstem and resulted in V100% of 82.6% and 90.5 % for Pinnacle and Monaco, respectively.

Dose homogeneity within the target was similar for both systems, with the greatest difference being a 3.5 Gy increase in D2% for Monaco, in PTV1. Conformity indices were also similar but Monaco was marginally lower for 4/5 targets.

The BrainMinusGTV dose volume histograms (DVH) were most noticeably different between 5 Gy and 10 Gy (figure 5), with Pinnacle being 30%-32% higher than Monaco. At lower and higher dose levels, the DVHs crossed and Pinnacle was marginally lower. Overall, the mean dose was slightly lower for Monaco: 453 cGy versus 499 cGy for Pinnacle.

It was noted that Monaco provided greater brainstem-shielding than Pinnacle (figures 4 and 5), resulting in a mean brainstem dose of 10.0 Gy and 4.0 Gy in Pinnacle and Monaco, respectively.

In terms of ease of use, the Windows-based Monaco software is very user friendly and found to be easier to navigate than Pinnacle for new users. Due to the ability to prioritize IMRT objectives prior to optimization in Monaco, the planning process was also found to be more user-friendly. Through the use of well-structured templates, it is felt that the overall planning process using Monaco may take less time. This finding needs to be validated with a larger study.

The fusion tool in Monaco is easy to use and valuable for comparing dose distributions from different planning systems.

Conclusion

Overall, both treatment planning systems produced clinically acceptable dose distributions. Monaco may potentially result in lower normal tissue dose as exhibited by the substantial reduction in DVH between 5-10 Gy for BrainMinusGTV, but this needs to be validated in a larger patient series and findings validated with measurement.

Not considered in the present study were investigations of different beam, arc and isocenter arrangements, nor patient-specific quality assurance, which are necessary for clinical implementation.

As the treatment of multiple metastases expands, the selection of a treatment planning system that can generate multiple target plans quickly, accurately and efficiently is increasingly important in order to meet clinical and workload needs. Comparison between the two treatment planning systems continues for single, two, three and four target brain metastases and spine SBRT plans.

ABOUT ELEKTA

A human care company, Elekta pioneers significant innovations and clinical solutions harnessing both external and internal radiation therapy for treating cancer and brain disorders. Elekta provides intelligent and resource-efficient technologies that improve, prolong and save patient lives. We go beyond collaboration, seeking long-term relationships built on trust with a shared vision, and inspiring confidence among healthcare providers and their patients.

REFERENCES

[1] Sahgal A, Aoyama H, Kocher M, et al (2015). Phase 3 trials of stereotactic radiosurgery with or without whole-brain radiation therapy for 1 to 4 brain metastases: individual patient data meta-analysis. *Int J Radiat Oncol Biol Phys*. 91(4):710-7. doi: 10.1016/j.ijrobp.2014.10.024.

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