

Assessing the calculation accuracy of clinical indices using DICOM-CT based phantoms applicable in modern radiotherapy techniques

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Introduction & Purpose

Treatment-plan evaluation and acceptance in radiotherapy is based on clinical indices, whose calculation depends on volume calculation of the target and surrounding OARs. Current external beam radiotherapy QA approaches include independent verification of clinical dose calculations on commercially available TPSs. These can be facilitated by dose distributions planned on virtual, DICOM-CT based phantoms.

Main purpose is to assess the accuracy of TPS calculation algorithm aspects besides the dosimetric algorithm, using an independent verification scheme employing virtual phantoms.



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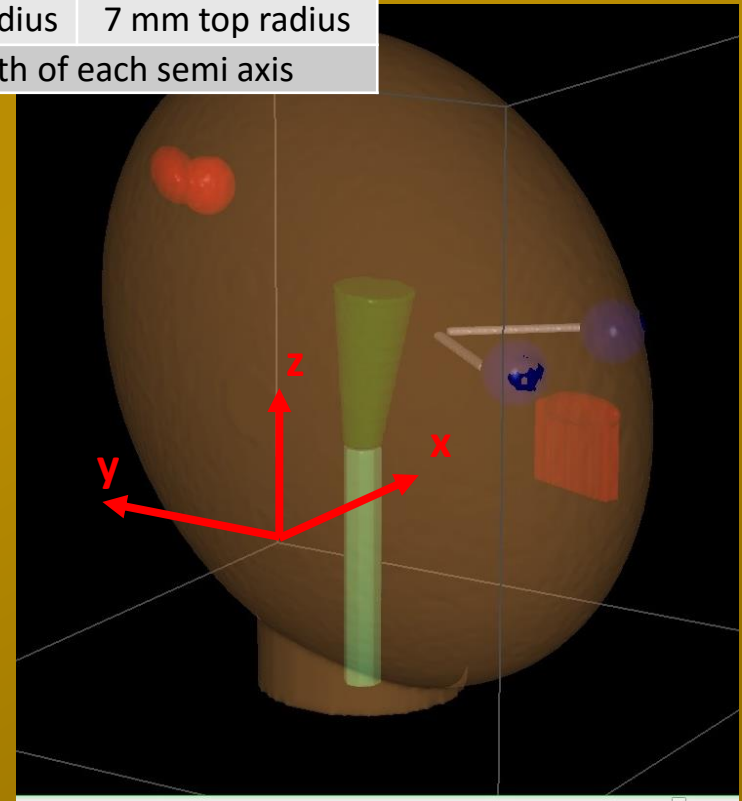
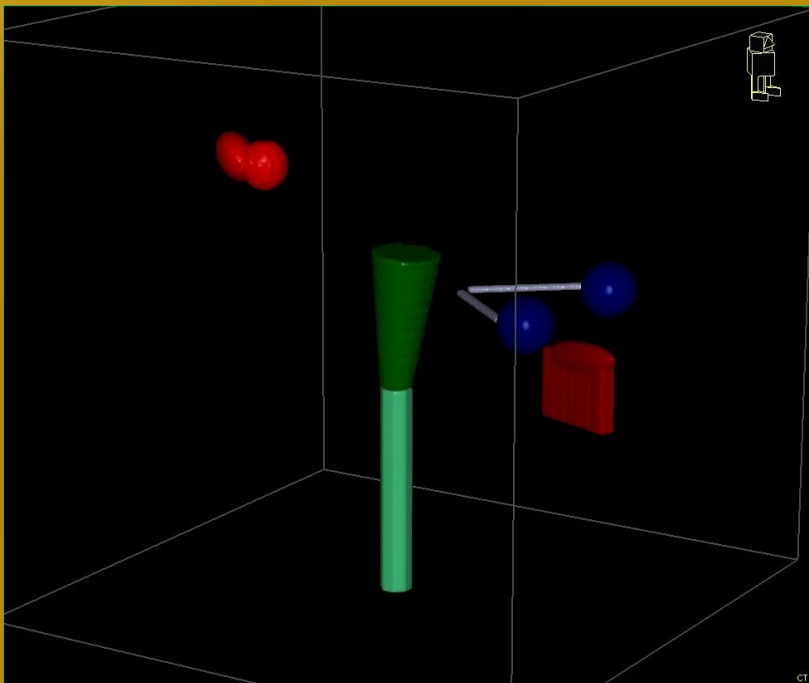
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Methods

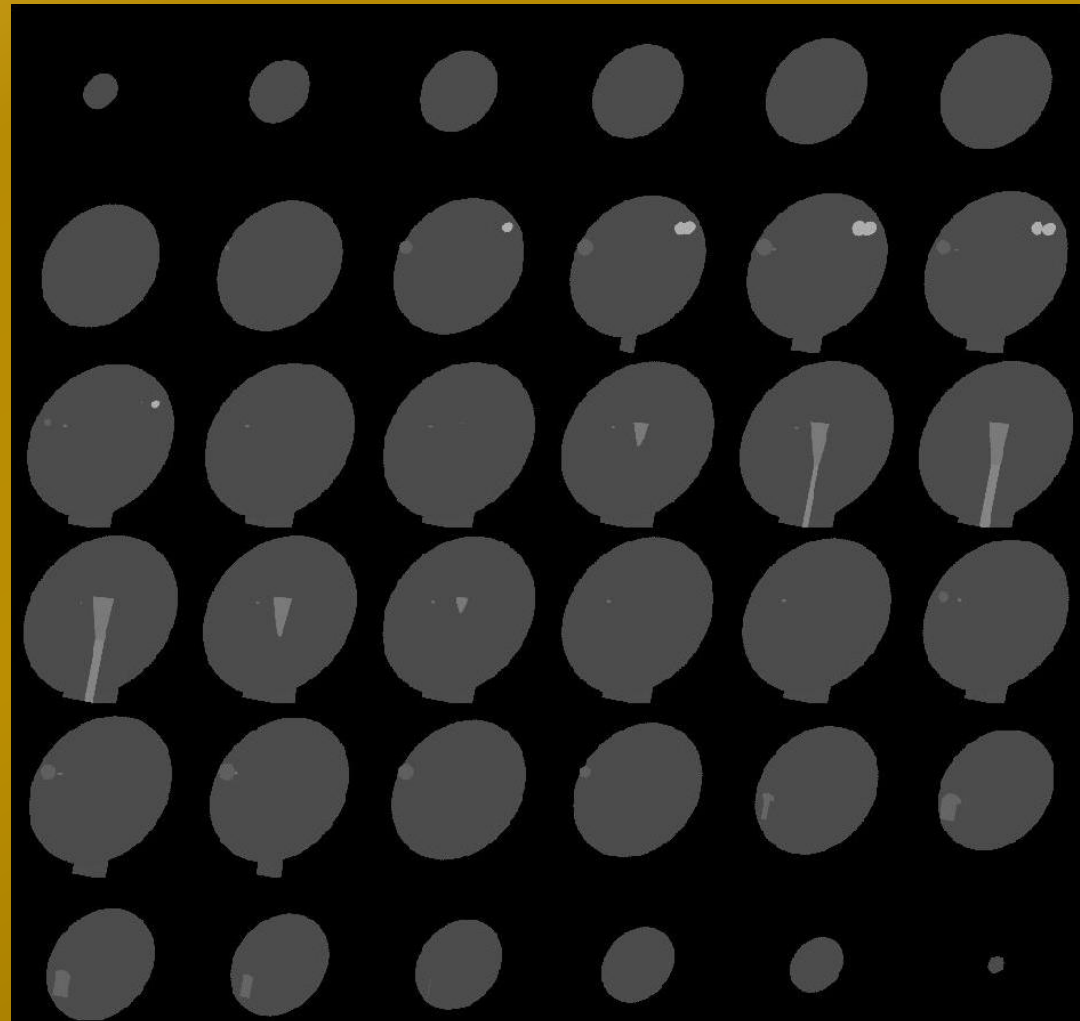
Simple geometrical shapes, simulating typical anatomical structures of human head anatomy (Organs at Risk (OARs) and tumor targets), were mathematically defined in a Cartesian coordinate system inside a human head.

Anatomical structure	Shape	Typical anatomical dimension used		
Eyes	sphere	24 mm diameter	70 mm distance	
Optic nerves	cylinder	4 mm diameter	50 mm length	
Spinal cord	cylinder	14 mm diameter		
Brain stem	conical frustum	60 mm height	15 mm base radius	7 mm top radius
Head	ellipsoid	80 mm, 100 mm, 125 mm length of each semi axis		



The resulting virtual phantom was converted in several CT image series of various resolutions and were subsequently written in corresponding series of DICOM-CT files.

Pixel Size	Slice Thickness
(0.5 x 0.5) mm ²	0.5 mm
(1 x 1) mm ²	1 mm
(1.5 x 1.5) mm ²	1.5 mm
	2 mm
	3 mm

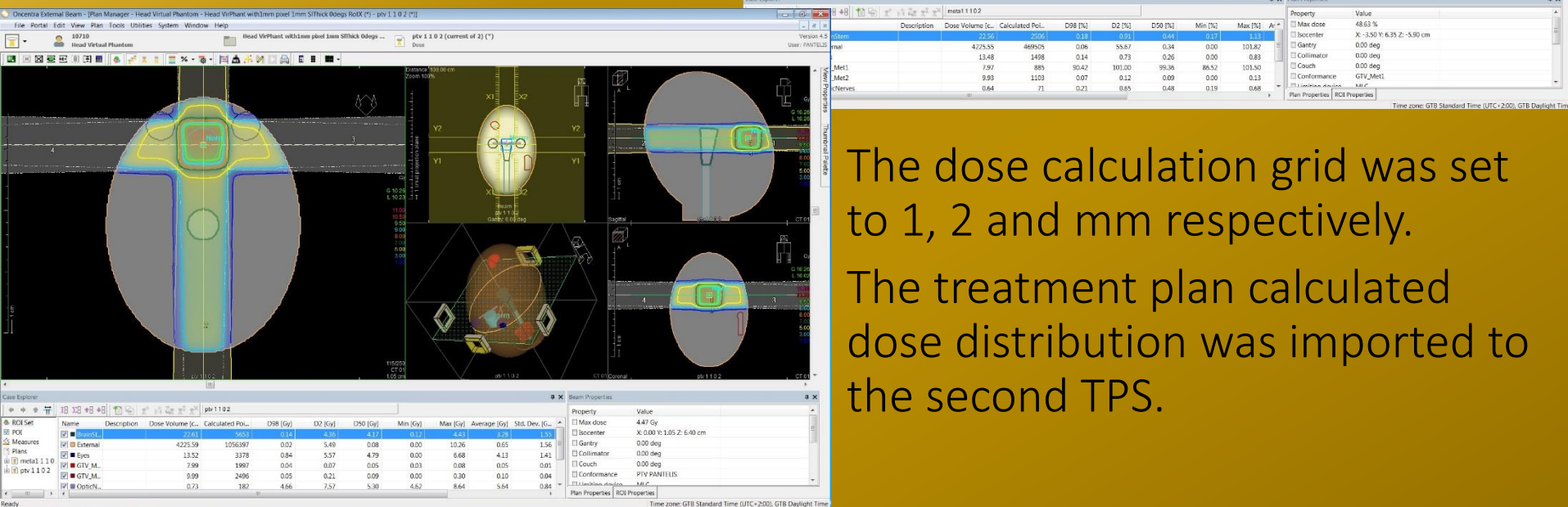
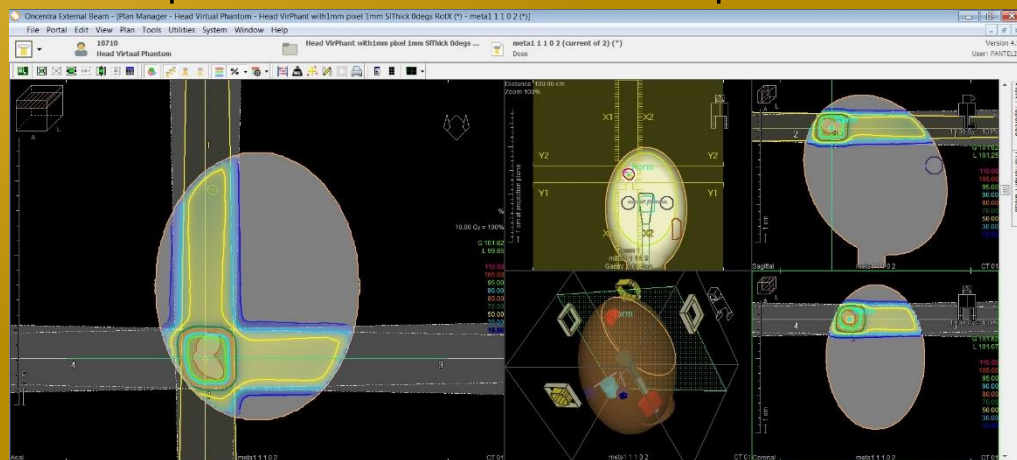


Sagittal CT slices

(Phantom: 1.5 mm PixSize, 1.5 mm SliceThickness)

The CT series were imported in 2 commercially available TPSs used in modern radiosurgery/radiotherapy techniques: Oncentra Masterplan and Monaco.

Two irradiation schemes were planned, one targeting the “metastasis1” structure and a second one with an arbitrarily defined PTV among the OARs, so as to encounter also higher doses delivered to them.



The dose calculation grid was set to 1, 2 and mm respectively. The treatment plan calculated dose distribution was imported to the second TPS.

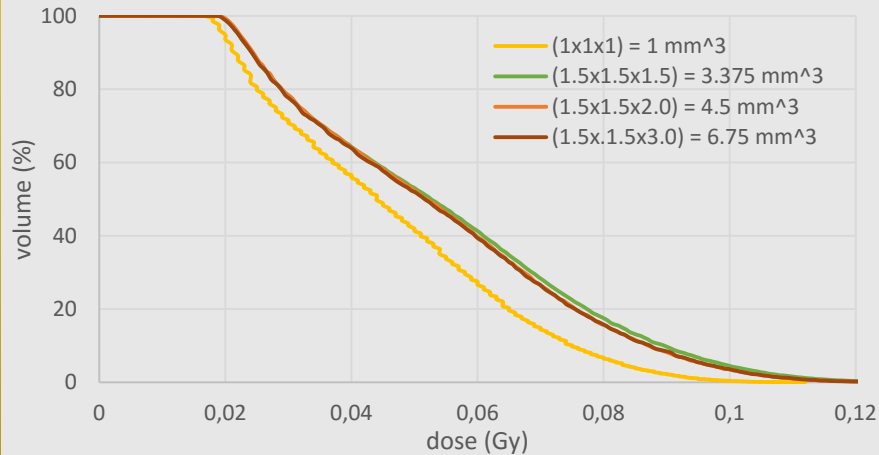
The exported dose distributions along with the structures' volumes were used to calculate Dose Volume Histograms in each case, which were then compared.

Results I

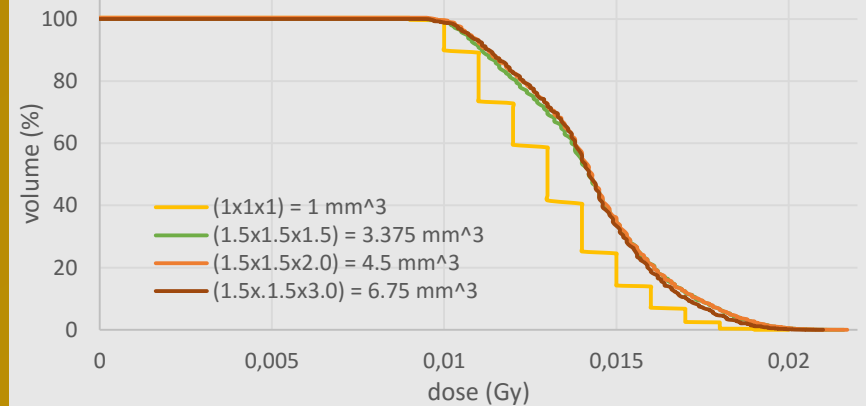
Metastasis1 target case.

Comparison of several OARs' DVHs for different DICOM-CT phantom resolutions.

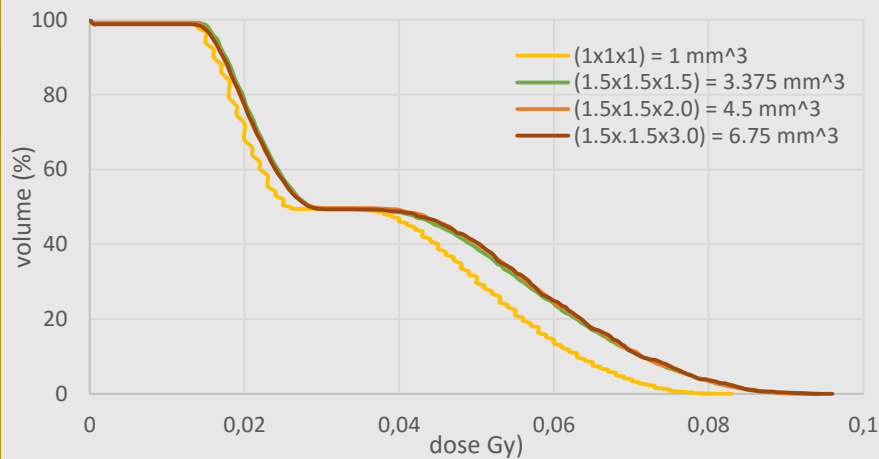
Brain Stem - OAR



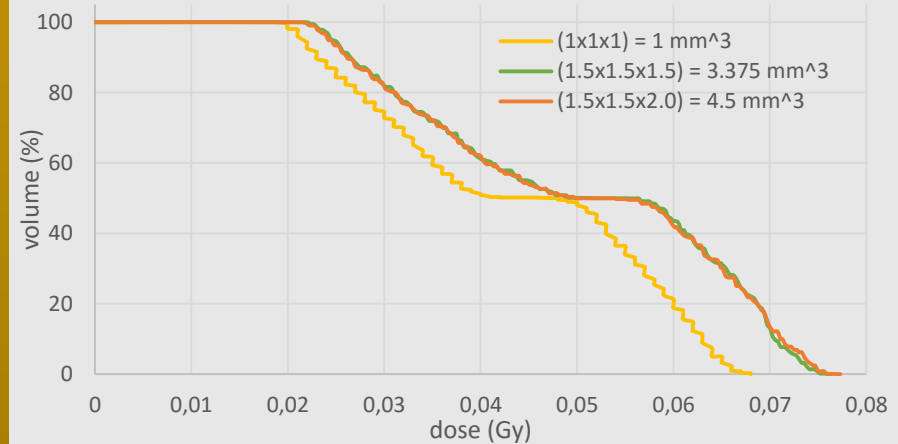
Spinal Cord - OAR



Eyes - OAR



Optic Nerves - OAR

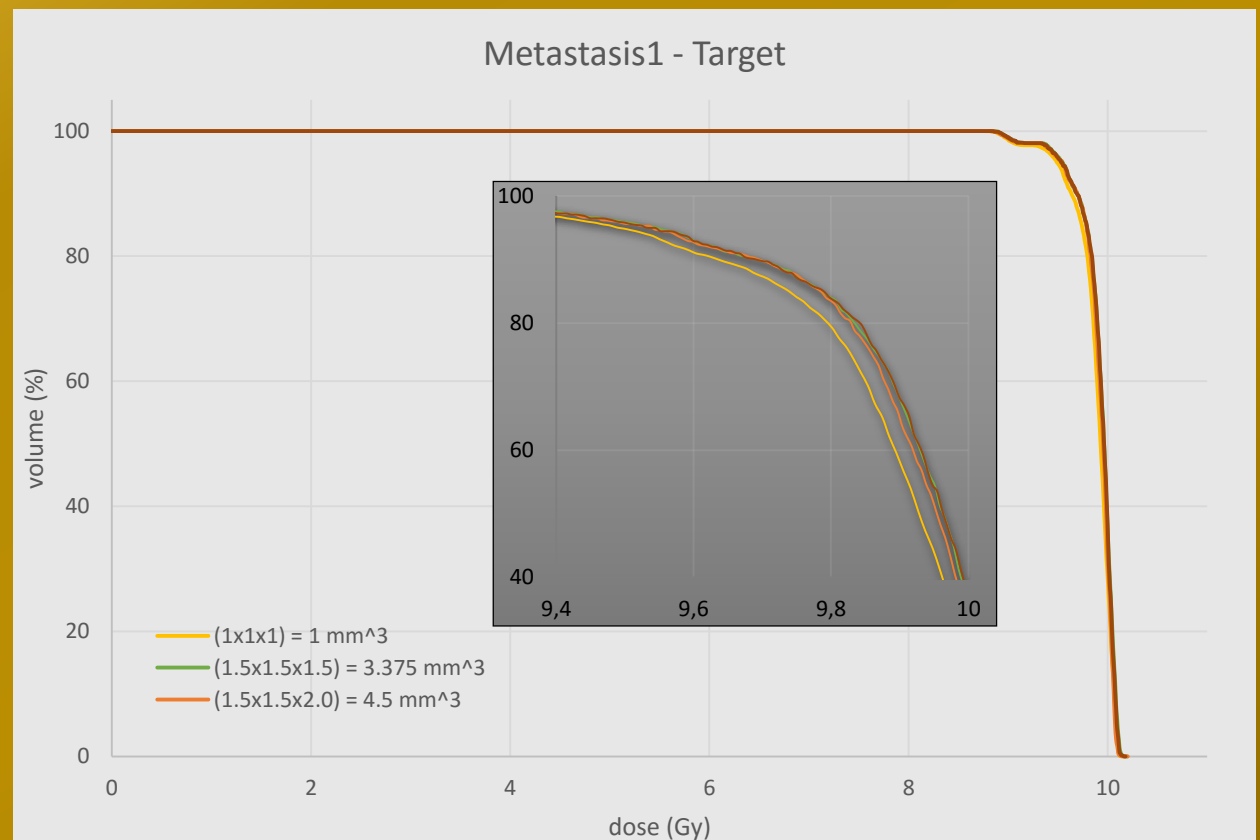


Results II

Metastasis1 target case.

Gross tumor volume DVH comparison for different DICOM-CT phantom resolutions.

A zoomed in region is presented in the inset.



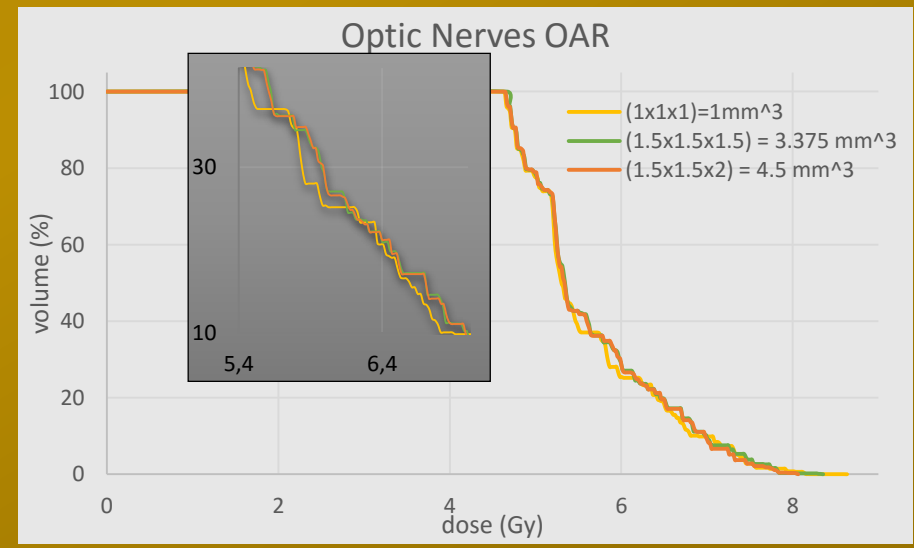
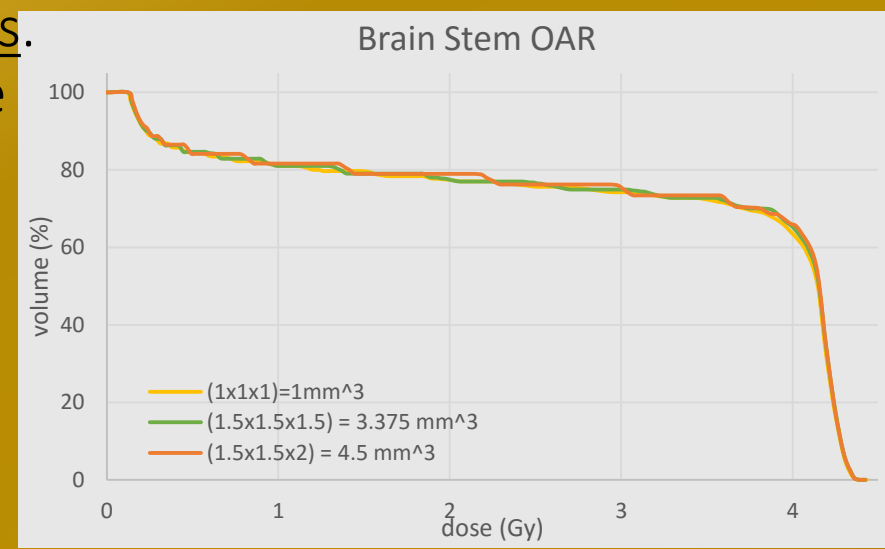
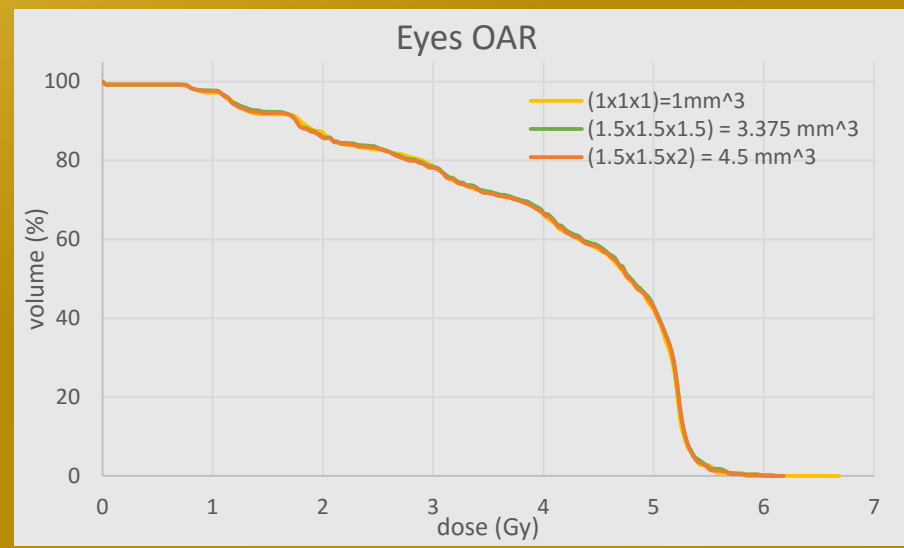
Results III

Arbitrarily defined, centrally placed PTV case.

Comparison of several OARs' DVHs for different DICOM-CT phantom resolutions.

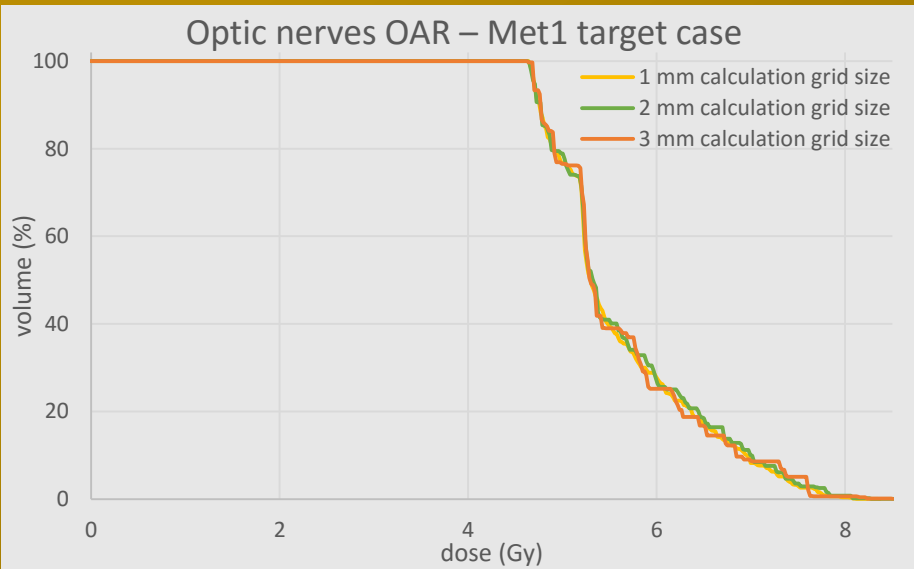
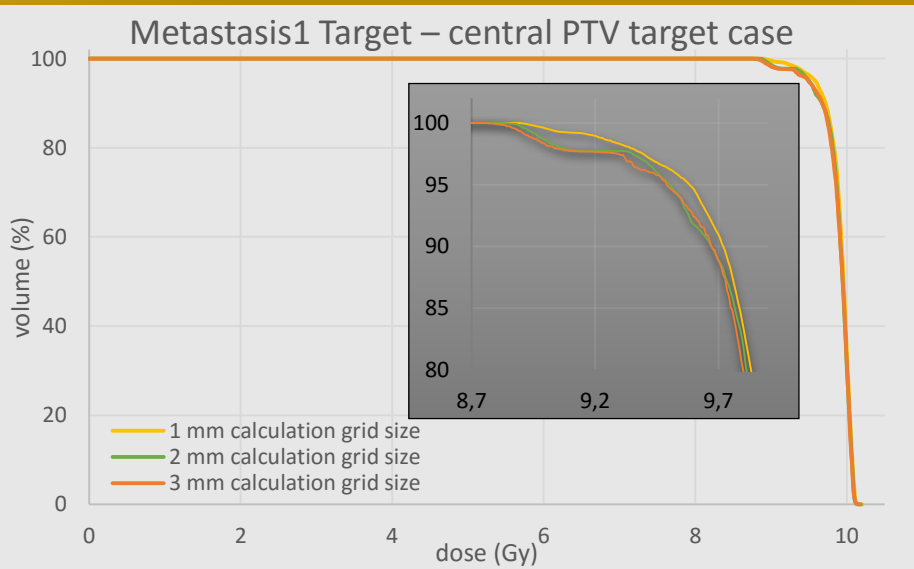
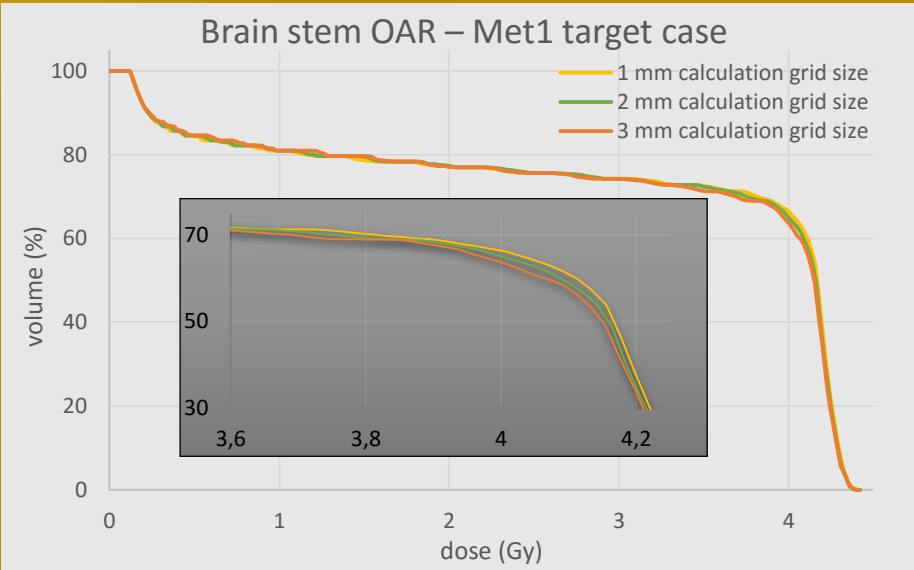
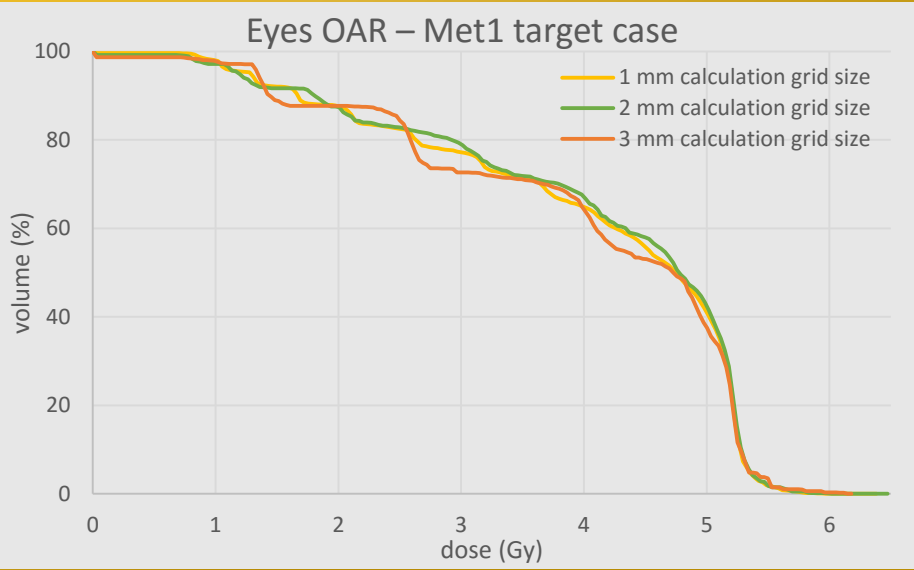
In these cases the doses delivered in the OARs were significantly larger.

The inset presents a zoomed in region.



Results IV

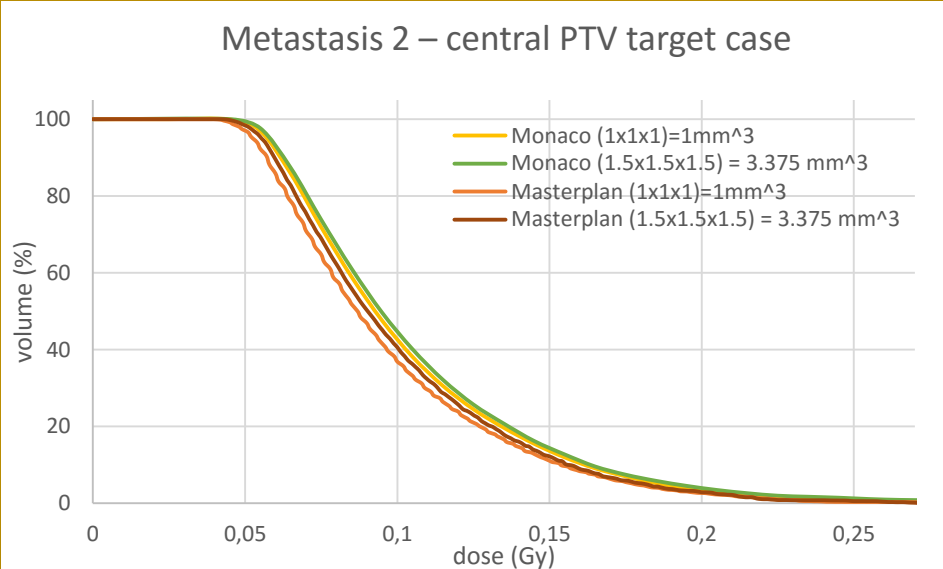
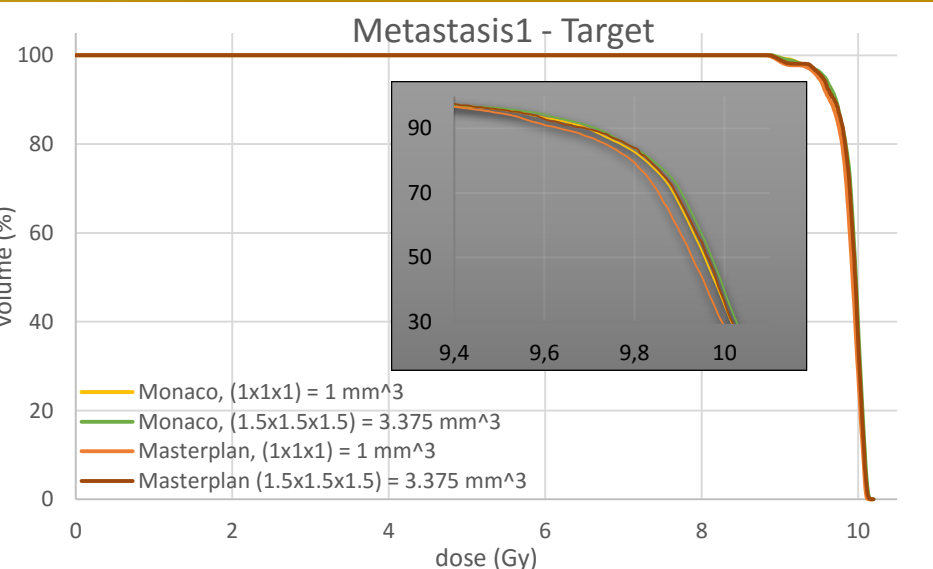
Comparing DVHs for several structures as OARs when calculated using different dose calculation grid in the Treatment Planning System.



Results V

DVHs for two structures (metastasis1 and metastasis2) from two different TPSs (Oncentra Masterplan, Monaco), using the same planned dose distributions, as calculated by one TPS (Masterplan) and DICOM imported to the other one (Monaco).

The calculated DVH presents a small systematic trend due to small uncertainties induced by the volume calculation algorithm of each TPS.



Conclusions



- ✓ Overall uncertainty induced by TPS volume calculation discrepancies in DVH clinical indices is present, but relatively small in clinical context
- ✓ Maximum deviations are being observed for smaller anatomical structures, thus the size of structures matters
- ✓ The shape of anatomical structures plays major role in the induced uncertainties in calculated DVHs
- ✓ Dose calculation grid resolution influences the uncertainty of the TPS calculated DVHs, especially with regard to structures' shape and size
- ✓ Different TPS algorithmic implementations seem to be giving systematically small deviations
- ✓ Slice thickness seems to be, otherwise, affecting DVH calculation accuracy

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