# Accuracy of Dose-Volume Metric Calculation for Small Volume Radiosurgery Targets

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## INTRODUCTION

For stereotactic radiosurgery (SRS), accurate evaluation of dose-volume metrics for small structures is crucial. One of the most common and extensively utilized plan evaluation tools is the dose-volume histogram (DVH). The DVH is an efficient method of quantifying and visualizing dose coverage for targets and organs at risk (OAR) by converting 3D information into a two-dimensional curve for each object and is currently a standard feature in every treatment planning system. Clinical trials and protocols rely on DVH analysis to determine compliance and evaluate treatments, and guidelines for reporting DVH metrics were recently published in The Report of AAPM Task Group 263: Standardizing Nomenclatures in Radiation Oncology.

Previous studies have evaluated the capabilities and accuracy of DVH calculations with varying grid resolutions, bin width/size capabilities, and large complex targets. SRS treatment planning offers a unique set of challenges, namely high doses with steep gradients and very small structures, which can present a challenge for accurate DVH evaluations. This study aimed to expand on the previously published literature to quantitatively compare the DVH analysis capabilities of software commonly used for SRS plan evaluation and provide a freely available and downloadable analytically derived set of ground truth DICOM dose and structure files for the use of radiotherapy clinics.

## METHODS

DICOM RTdose and RTstructure set files created using MATLAB were imported and evaluated in each of the tools. Each structure set consisted of 50 randomly placed spherical targets. The dose distributions were created on a 1 mm grid using an analytic model such that the dose-volume metrics of the spheres were known. Structure sets were created for 3, 5, 10, 15, and 20 mm diameter spheres. The reported structure volume, V100% [cc], and V50% [cc], and the RTOG conformity index and Paddick Gradient Index, were compared with the analytical values.

**Table 1: The average difference and total range between the reported structure volume and the analytically derived volume for each of the evaluated systems.**

| Target Size (mm) | | TPS 1 ΔV [cc] Range [%] | TPS 2 ΔV [cc] Range [%] | TPS 3 ΔV [cc] Range [%] | TPS 4 ΔV [cc] Range [%] | TPS 5 ΔV [cc] Range [%] |
|---|---|---|---|---|---|---|
| 0.5 mm slice spacing | 3 | -9.8 (-16.4, -6.9) | 0.1 (-10.9,8.2) | -1.5 (-12.1 , 7.0) | -5.4 (-8.0 , -1.0) | -1.0 (-1.0 , -1.0) |
| | 5 | -3.1 (-5.7 , -2.2) | -0.1 (-2.1 , 1.8) | -0.4 (-2.6 , 1.5) | -4.0 (-6.8 , -2.2) | -0.5 (-0.7 , 0.8) |
| | 10 | -1.3 (-2.6 , -0.9) | 0.1 (-1.2 , 1.2) | -0.1 (-1.3 , 1.1) | -1.6 (-3.1 , 0.2) | -0.1 (-0.3 , 0.2) |
| | 15 | -0.4 (-1.0 , -0.3) | -0.0 (-1.1 , 0.5) | -0.1 (-1.1 , 0.5) | -0.2 (-1.1 , 1.0) | 0.0 (-0.3 , 0.1) |
| | 20 | -0.1 (-0.3 , 0.0) | -0.0 (-0.4 , 0.2) | -0.0 (-0.4 , 0.2) | -0.5 (-1.5 , 0.2) | 0.0 (-0.2 , -0.0) |
| 1 mm slice spacing | 3 | -23.7 (-33.2,-20.1) | 1.3 (-8.3 , 9.5) | -1.3 (-10.9 , 7.0) | -10.7 (-22.2 , -1.0) | -2.4 (-15.1 , 13.2) |
| | 5 | -9.6 (-14.0 , -7.4) | 0.0 (-5.4 , 4.0) | -0.6 (-5.9, 3.4) | -6.6 (-14.4 , -0.7) | -3.8 (-9.9 , 0.8) |
| | 10 | -5.4 (-9.5 , -3.9) | -0.1 (-2.4 , 2.4) | -0.5 (-3.2 , 2.0) | -5.1 (-8.1 , -3.1) | -3.1 (-5.9 , -0.9) |
| | 15 | -2.2 (-3.6 , -1.8) | 0.0 (-1.2 , 1.0) | -0.1 (-1.3 , 0.7) | -1.8 (-3.4 , -0.3) | -1.4 (-3.2 , -0.3) |
| | 20 | -0.9 (-1.8 , -0.7) | -0.0 (-0.5 , 0.6) | -0.1 (-0.7 , 0.5) | -0.1 (-1.9 , 0.7) | -0.9 (-1.6 , -0.2) |

**Table 2: The average difference and total range between the reported V100% [cc] (V20Gy [cc]) and the analytically derived dose volume for each of the evaluated systems.**

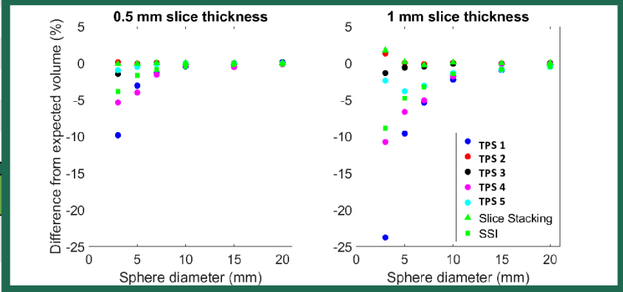
| Target Size (mm) | | TPS 1 ΔV [cc] Range [%] | TPS 2 ΔV [cc] Range [%] | TPS 3 ΔV [cc] Range [%] | TPS 4 ΔV [cc] Range [%] | TPS 5 ΔV [cc] Range [%] |
|---|---|---|---|---|---|---|
| 0.5 mm slice spacing | 3 | -0.2 (-24.5,9.8) | -12.4 (-19.8,-5.8) | -13.1 (-20.7,-6.8) | 6.3 (-37.9,22.3) | 0.2 (-22.2,13.2) |
| | 5 | 0.0 (-6.5,6.2) | -3.5 (-6.5,-2.1) | -3.9 (-7.1,-2.4) | -13.6 (-16.2,0.6) | -0.2 (-3.7,7.0) |
| | 10 | 0.1 (-3.0,2.1) | -1.3 (-2.5,0.3) | -1.5 (-2.8,-0.0) | 6.1 (1.5,12.8) | -0.2 (-3.7,3.0) |
| | 15 | 0.4 (-2.1,1.0) | -0.3 (-1.4,0.3) | -0.5 (-1.5,0.1) | -11.6 (-12.7,-7.1) | 0.2 (-2.6,1.0) |
| | 20 | 0.3 (-0.2,0.7) | 0.1 (-0.4,0.2) | -0.2 (-0.6,0.1) | 2.8 (-2.2,7.3) | 0.1 (-0.7,0.7) |
| 1 mm slice spacing | 3 | -4.3 (-24.5,2.7) | -10.6 (-23.6,-0.7) | -10.8 (-23.6,-0.7) | -6.8 (-37.9,24.4) | 2.0 (-36.3,20.3) |
| | 5 | -1.4 (-7.2,5.4) | -3.4 (-7.8,0.1) | -3.6 (-8.1,-0.1) | 4.5 (-16.2,34.2) | -0.5 (-16.0,10.0) |
| | 10 | -0.5 (-3.9,1.6) | -1.5 (-4.2,1.1) | -1.8 (-4.3,0.6) | 2.3 (-2.3,12.8) | -0.5 (-5.9,3.6) |
| | 15 | 0.2 (-2.3,0.7) | -0.3 (-1.6,0.8) | -0.5 (-1.8,0.5) | -1.9 (-12.7,3.2) | 0.2 (-4.7,4.7) |
| | 20 | 0.2 (-0.2,0.8) | 0.0 (-0.5,0.7) | -0.2 (-0.7,0.4) | 0.0 (-2.2,1.4) | 0.1 (-1.3,1.2) |

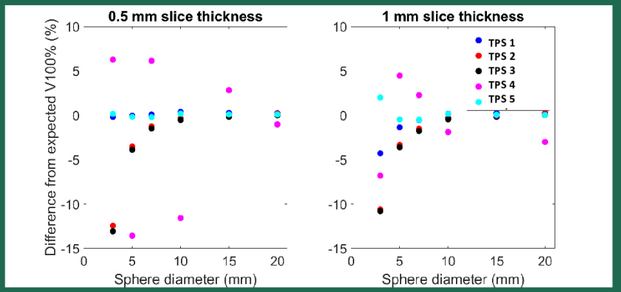
**Table 3: The average difference and total range between the reported V50% [cc] (V10Gy [cc]) and the analytically derived dose volume for each of the evaluated systems.**

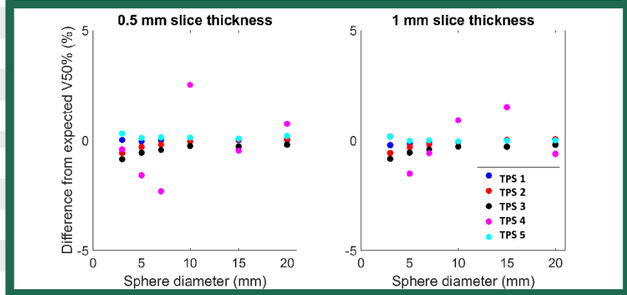
| Target Size (mm) | | TPS 1 ΔV [cc] Range [%] | TPS 2 ΔV [cc] Range [%] | TPS 3 ΔV [cc] Range [%] | TPS 4 ΔV [cc] Range [%] | TPS 5 ΔV [cc] Range [%] |
|---|---|---|---|---|---|---|
| 0.5 mm slice spacing | 3 | 0.0 (-0.7,0.6) | -0.6 (-1.2,0.2) | -0.9 (-1.3,-0.2) | -0.4 (-1.9,2.6) | 0.3 (-0.6,1.6) |
| | 5 | 0.0 (-0.5,0.5) | -0.3 (-0.9,0.5) | -0.6 (-1.2,0.2) | -1.6 (-2.7,0.9) | 0.1 (-1.1,0.9) |
| | 10 | 0.0 (-0.3,0.3) | -0.2 (-0.5,0.4) | -0.4 (-0.7,0.1) | -2.3 (-4.5,-0.4) | 0.1 (-0.2,0.6) |
| | 15 | 0.0 (-0.3,0.3) | -0.1 (-0.3,0.1) | -0.3 (-0.4,-0.1) | 2.5 (1.2,3.3) | 0.1 (-0.4,0.8) |
| | 20 | 0.0 (-0.1,0.2) | 0.0 (-0.1,0.1) | -0.3 (-0.4,-0.1) | -0.5 (-1.9,1.9) | 0.1 (-0.2,0.3) |
| 1 mm slice spacing | 3 | -0.2 (-0.8,0.4) | -0.6 (-1.2,0.1) | -0.8 (-1.4,-0.0) | 0.2 (-1.9,2.3) | 0.2 (-1.1,2.7) |
| | 5 | -0.2 (-0.6,0.4) | -0.3 (-0.7,0.1) | -0.6 (-1.0,-0.1) | -1.5 (-6.1,0.7) | 0.0 (-1.4,1.1) |
| | 10 | -0.1 (-0.4,0.3) | -0.2 (-0.5,0.5) | -0.4 (-0.7,0.3) | -0.6 (-1.0,0.1) | 0.0 (-0.7,0.7) |
| | 15 | -0.1 (-0.3,0.3) | -0.1 (-0.4,0.3) | -0.3 (-0.6,-0.0) | 0.9 (-0.7,2.8) | 0.0 (-0.6,0.7) |
| | 20 | 0.0 (-0.2,0.2) | 0.0 (-0.1,0.3) | -0.3 (-0.4,-0.1) | 1.5 (0.2,2.1) | 0.0 (-0.5,0.3) |

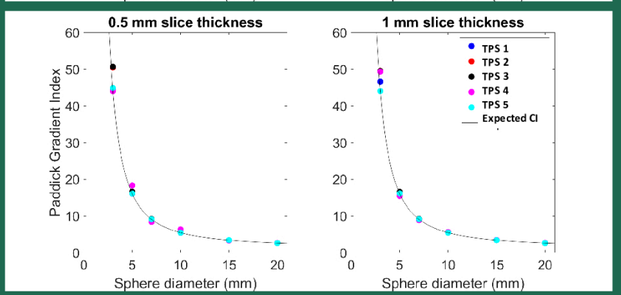
## RESULTS

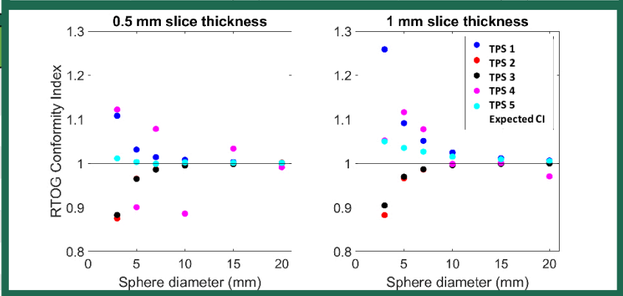
Tables 1-3 show the average difference and range of each of the evaluated systems for the reported structure volume, V100% [cc] (V20Gy [cc]), and V50% [cc] (V10Gy [cc]), respectively. Figures 1-3 show the average difference of the reported structure volume, V100% [cc] (V20Gy [cc]), and V50% [cc] (V10Gy [cc]), respectively. Additionally, each system was compared against slice stacking and the improved slice stacking (SSI) methodology as described by Ma et al in 2012. Using this information, the Paddick index, shown in figure 45, and the RTOG conformity indices, shown in figure 5, (analytical CI=1) were calculated.




## CONCLUSIONS

This study expanded on the previously published literature to quantitatively compare the DVH analysis capabilities of software commonly used for SRS plan evaluation and provides freely available and downloadable analytically derived set of ground truth DICOM dose and structure files for the use of radiotherapy clinics. The differences between systems highlight the need for standardization and/or transparency between systems, especially when evaluating plan quality for multi-institutional clinical trials.

## CONTACT INFORMATION

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