# Accuracy Evaluation of Oncentra™ TPS in HDR Brachytherapy of Nasopharynx Cancer Using EGSnrc Monte Carlo Code

Hadad K.[1], Zohrevand M.[1]*, Faghihi R.[1], Sedighi Pashaki A.[2]

[1]Nuclear Engineering Department, Faculty of Mechanical Engineering, Shiraz University, Shiraz, Iran
[2]Mahdieh M.R.I Center, Hamedan, Iran

## ABSTRACT

**Background:** HDR brachytherapy is one of the commonest methods of nasopharyngeal cancer treatment. In this method, depending on how advanced one tumor is, 2 to 6 Gy dose as intracavitary brachytherapy is prescribed. Due to high dose rate and tumor location, accuracy evaluation of treatment planning system (TPS) is particularly important. Common methods used in TPS dosimetry are based on computations in a homogeneous phantom. Heterogeneous phantoms, especially patient-specific voxel phantoms can increase dosimetric accuracy.

**Materials and Methods:** In this study, using CT images taken from a patient and ctcreate-which is a part of the DOSXYZnrc computational code, patient-specific phantom was made. Dose distribution was plotted by DOSXYZnrc and compared with TPS one. Also, by extracting the voxels absorbed dose in treatment volume, dose-volume histograms (DVH) was plotted and compared with Oncentra™ TPS DVHs.

**Results:** The results from calculations were compared with data from Oncentra™ treatment planning system and it was observed that TPS calculation predicts lower dose in areas near the source, and higher dose in areas far from the source relative to MC code. Absorbed dose values in the voxels also showed that TPS reports D90 value is 40% higher than the Monte Carlo method.

**Conclusion:** Today, most treatment planning systems use TG-43 protocol. This protocol may results in errors such as neglecting tissue heterogeneity, scattered radiation as well as applicator attenuation. Due to these errors, AAPM emphasized departing from TG-43 protocol and approaching new brachytherapy protocol TG-186 in which patient-specific phantom is used and heterogeneities are affected in dosimetry.

## Keywords

EGSnrc, Nasopharynx, TPS, Voxel-based Phantom

## Introduction

Nasopharyngeal cavity is a somewhat cuboid space, which communicates anteriorly with the nasal cavities through the choanae and inferiorly with the oropharynx. Sphenoid body limits it superiorly, the first two vertebrae posteriorly, and the soft palate inferiorly [1].

To treat nasopharyngeal cancer, a combination of radiotherapy and chemotherapy are used. In radiotherapy, cancer can be removed or prevented from spreading using photons (in the form of external radiotherapy or brachytherapy). Typically, in nasopharyngeal radiotherapy, 18 Gy in 6 fractions are prescribed to the tumor through brachytherapy and 46-60 Gy by external irradiation [2].

Regarding the source high dose rate and tumor location, accuracy of calculating TPS is very important. There are three main ways to assess

*Corresponding author: M. Zohrevand
Nuclear Engineering Department, Faculty of Mechanical Engineering, Shiraz University, Shiraz, Iran
E-mail: zohrevandmajid@yahoo.com

the accuracy of treatment planning systems in radiotherapy:

1. Practical and laboratory procedures using radiation detectors
2. Computational methods, using formulas, tables and radiation laws
3. Computer simulation methods [3].

For some reason, using laboratory and practical methods is limited:

1. In the field of internal dosimetry in radiotherapy, using practical and laboratory methods to determine the dose is often impossible.
2. Using this method can result in high measurement error, which is due to issues related to radiation detection devices.
3. Reaching the final result of measurement by some means of radiation measurement may take a long time.
4. Another limitation is its cost. Hence, using computer simulations can be considered as a powerful tool with high capabilities to investigate the dosimetry inside and outside the body [4].

One of the computer methods that its use is growing in dosimetric calculations in radiotherapy is Monte Carlo method. The method is based on the statistical processes like nucleon interaction probability during the transversal of a path in the substance [5].

EGSnrc code is a Monte Carlo multipurpose simulation package of photon and electron collisions in the arbitrary geometry. Particle energy in code ranges from 1 Kev to 10 Gev. Of course this energy range depends on the target substance atomic number [6].

EGSnrc is the best code for calculations related to medical physics and calculations of absorbed dose in radiotherapy as compared to other Monte Carlo codes, it is more convenient to use complex geometries and actual patient anatomy can be converted into a Voxel-Based Phantom [6]. In EGSnrc creating CT phantoms from CT data is done using ctcreate independent code.

Considering high dose rate and tumor location, calculation accuracy of treatment planning system is of particular importance.

In this study, Iridium source (Ir -192) will move in applicator and stand in several places to deliver appropriate dose to the treatment volume. The final goal is to calculate the dose delivered to the treatment volume due to source dwelling in different places using DOSXYZnrc. These calculations will lead to plotting isodose diagrams and dose-volume histograms and comparing them with treatment planning systems.

## Materials And Methods

To create virtual phantom, 51 CT images of a 42-year-old man in DICOM format and dimensions 512×512 with Rotterdam applicator were used. The prescribed dose was 3 Gy. This operation was performed in radiotherapy ward of Mahdieh M.R.I Center using Flexitron produced by Microselectron®. CT images were converted to virtual phantom using ctcreate. Virtual phantom dimensions were 33×33×30 and each voxel size was determined as 0.2 × 0.2 × 0.2 $cm^3$.

Simulation was carried out using DOSXYZnrc which is a part of BEAM project. ECUT and PCUT were selected 0.513MeV and 0.01MeV, respectively. In simulating the source mHDR-v2r, source number 6 was used (rectangular isotropic parallelepiped source). Source geometry was estimated using a cube with dimensions 0.1 cm and Ir-192 Microselectron spectra. (Result of reliability of this estimation is presented in section 3.1).

In afterloaders, shielded source is connected to the end of a cable. After determining CTV and prescribed dose by oncologist, TPS calculates the source dwell position and dwell time for delivering prescribed dose to CTV. Each dwell position has its particular dwell time. In this study, source had 56 dwell positions in applicator, and voxels absorbed doses of each dwell position and dwell time were gathered and eventually a 3D dose profile (3D dose file) was obtained.

In addition to CT phantom, a water phantom

was created in DOSXYZnrc similar to dimensions and size of the virtual phantom, and treatment plan was performed on it. This phantom does not contain applicator and heterogeneity, and it is only created to compare Oncentra™ TPS and EGSnrc Monte Carlo Code in water phantom. Dosxyz_Show Program was used to display the geometry and dose profiles in EGSnrc.

By extracting absorbed doses of CTV voxels, dose volume histogram (DVH) was calculated and plotted. As previously mentioned, voxels size contains cubes with 2 mm side. In calculating dose volume histogram, voxels that more than half of which are in CTV were used in DVH calculations.

## Results

### Results of Source 6 DOSXYZnrc Validation

Validation result includes comparison parameters of Ir-192 source mHDR-v2 model and source 6 DOSXYZnrc. It must be said that this validation is only done to compare two source parameters to explain the differences in dose volume histogram and dose profile of TPS and Monte Carlo Code. The aim of this study was not determining the accuracy of these parameters though. Results of comparison of dose rate constant Ir-192 source and source 6 DOSXYZnrc are presented in Table 1.

Data of radial dose function for Ir-192 model mHDR-v2 was taken from Papagiannis et al. [7], and was compared with source 6 DOSXYZnrc radial dose function. Results indicate a good agreement of radial dose functions for these two sources in low distance as given in Figure 1.

Due to small volume of treatment area ($2.6cm^3$), simulation error of Ir-192 source version mHDR-v2 with source 6 DOSXYZnrc with 0.1 cm side in treatment area is less than 3%.

**Table 1:** Dose Rate Constant Comparison

| | |
|---|---|
| Ir-192 Dose Rate Constant Model mHDR-v2r [7] | $\Lambda = 1.108 \pm 13\%\ cGy.h^{-1}.U^{-1}$ |
| Source 6 DOSXYZnrc Dose Rate Constant | $\Lambda = 1.05 \pm 21\%\ cGy.h^{-1}.U^{-1}$ |

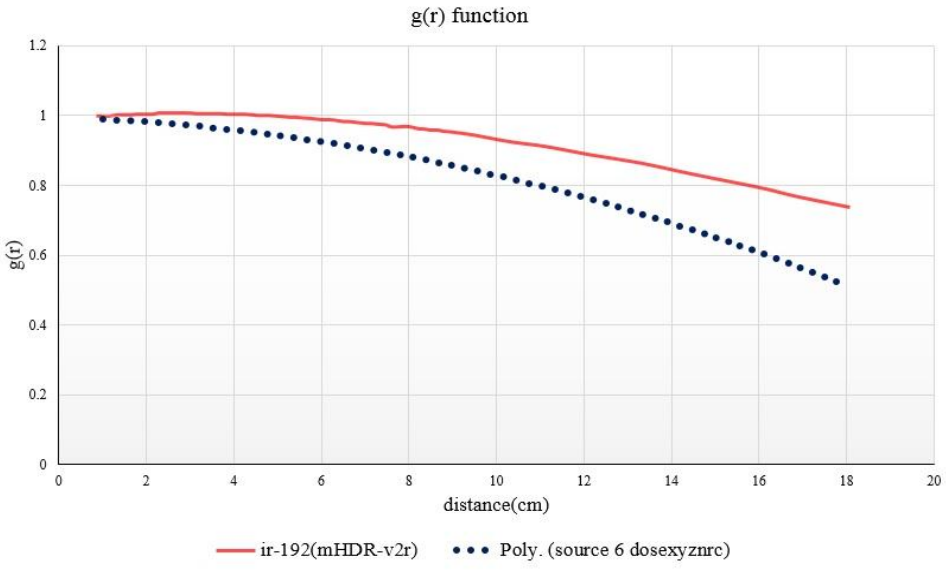


**Figure 1:** Comparison of Radial Dose Function for Ir-192 Version mHDR-v2 and Source 6 DOSXYZnrc

## Comparison of Dose Volume Histogram Functions

Figure 2 displays a comparison of cumulative dose volume histograms of Monte Carlo method and TPS. As seen below, for a specific volume ratio of CTV, TPS estimates more doses than MC method. Also the diagram calculated by Monte Carlo drops in lower doses than TPS. This sharp drop means that difference in voxels absorbed dose in Monte Carlo method is higher.

Figure 3 shows the comparison between histogram of differential dose volume between MC and TPS. These diagrams are obtained by deriving cumulative dose volume histogram and normalizing the numbers.

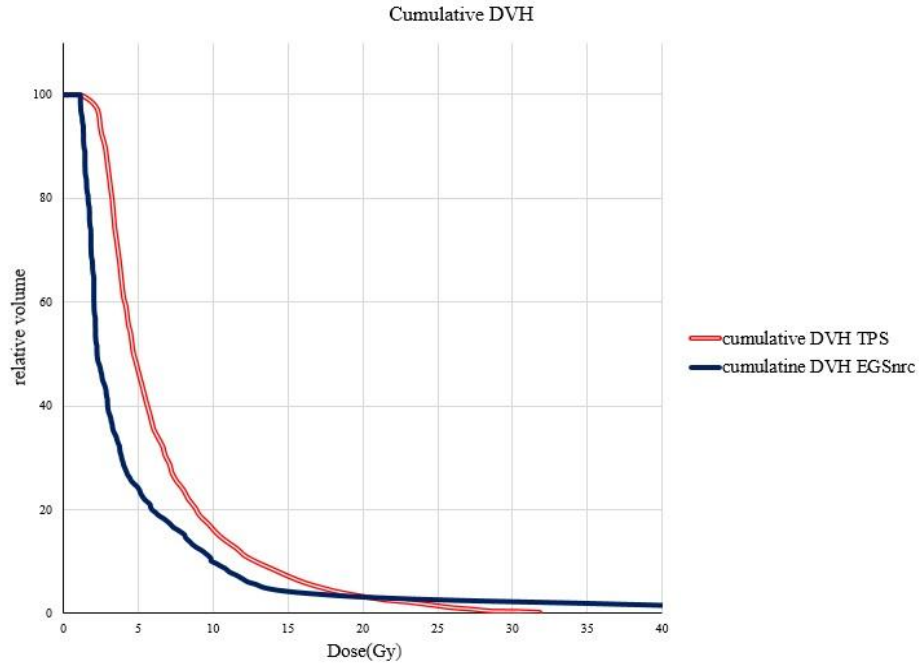


**Figure 2:** Cumulative DVH in TPS and Monte Carlo Calculation

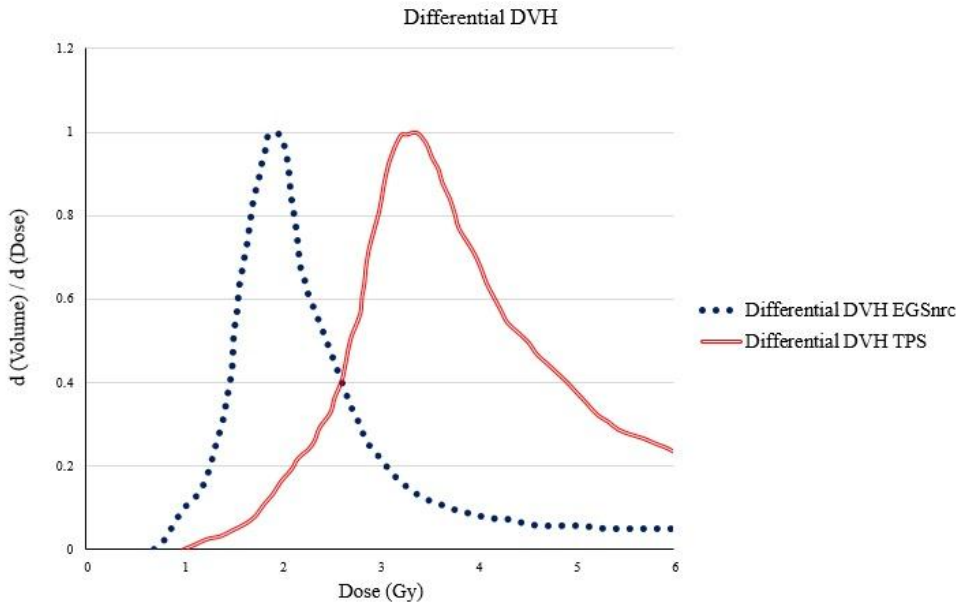


**Figure 3:** Differential DVH in TPS and Monte Carlo Calculation

### Dose Profiles

In figures 4 and 5, dose profile comparison is done in two 0.25 Gy and 1Gy doses in two sets of 27 and 37 slices. It can be seen that in water phantom, the results of comparing doses shows good agreement. So, dose difference in CT phantom is due to heterogeneities of tissue and applicator attenuation.

## Discussion

The purpose of this study is to evaluate the dosimetric accuracy for Oncentra™ treatment planning system. In nasopharynx brachytherapy, treatment area consists of three matters, soft tissue, bone and air. TPS, in dose calculations, considers all the materials as water. Here, we made patient-specific phantom using patient CT images and we involved inhomoge-

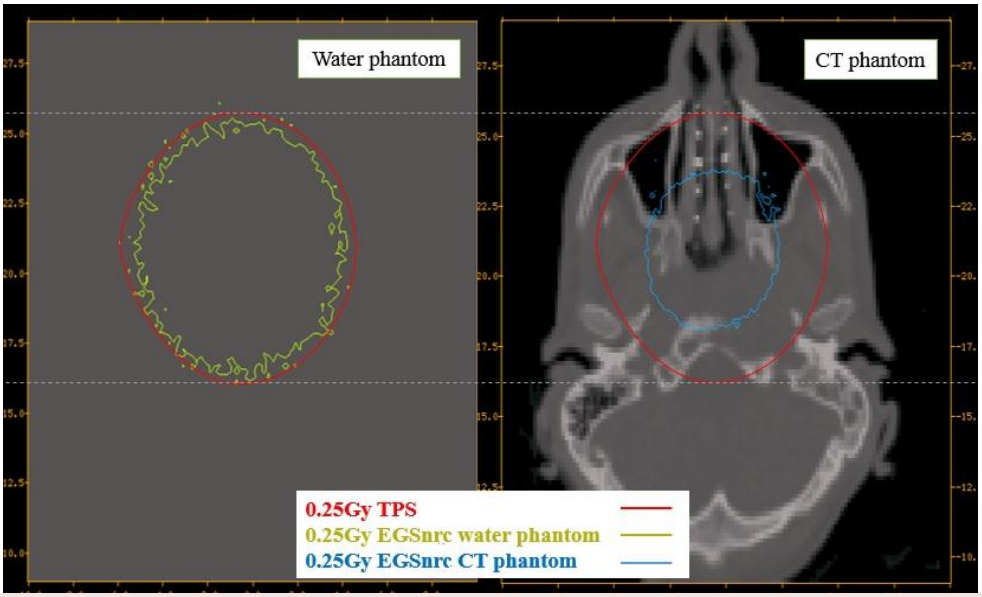


**Figure 4:** Comparison of 0.25 Gy Dose in Water Phantom and CT Phantom

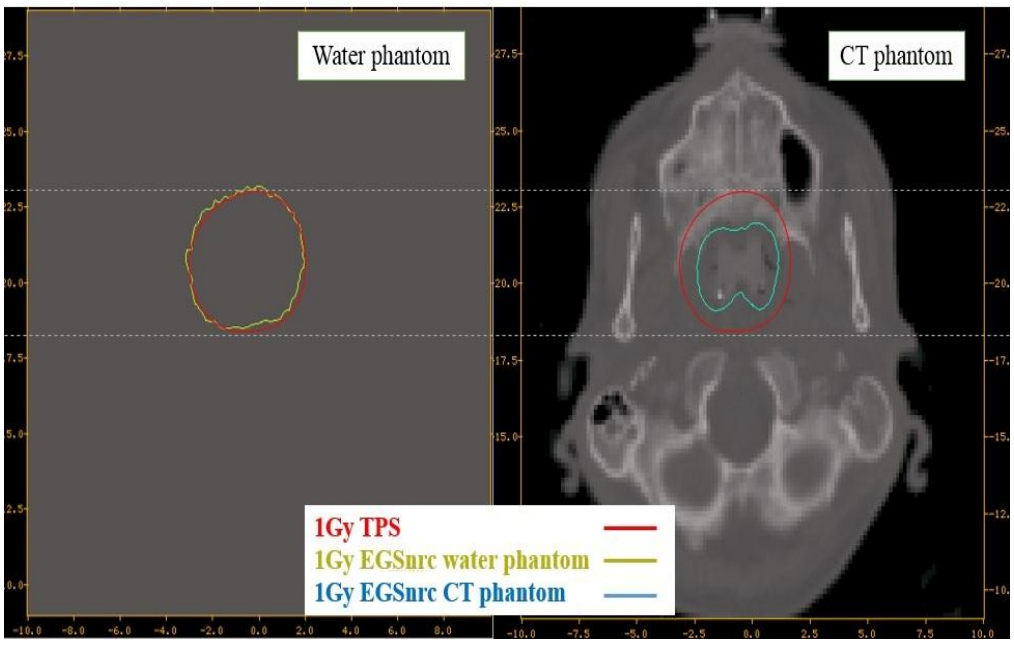


**Figure 5:** Comparison of 1 Gy Dose in Water Phantom and CT Phantom

neity. As can be seen in Figures 4 and 5, considering actual heterogeneities, a difference occurs between absorbed doses in voxels. In areas that voxel constituent is air, the difference reaches its maximum value, because the attenuation coefficient and density of air and water are very different.

Due to the fact that simulations results of water phantom in DOSXYZnrc and TPS have shown good agreement, dose differences observed in voxels of CT phantom can all be attributed to heterogeneities and applicator attenuation.

DVHs suggest that in the presence of tissue heterogeneity, greater heterogeneity is observed in voxels absorbed dose. The difference is due to the fact that in the presence of heterogeneity and ir-192 low energy photons, the photoelectric effect dominates and bones absorbed dose is more than air and soft tissue. Cumulative dose-volume histograms showed a sharper drop in MC method. Although, due to the rarity of nasopharyngeal cancer, no study is available on nasopharyngeal brachytherapy QA, by the agreement between TPS and MC simulation in water phantom, we can ensure the accuracy of our calculations in CT phantom.

Today, most treatment planning systems use TG-43 protocol. This protocol may results in errors such as neglecting tissue heterogeneity, scattered radiation as well as applicator attenuation. Due to these errors, AAPM emphasized departure from TG-43 protocol and approaching new brachytherapy protocol TG-186 in which patient-specific phantom is used and heterogeneities are affected in dosimetry.

## Acknowledgement

Author would like to thank Dr. A. Sedighi and the staff of Mahdieh M.R.I Center in Hamedan, Iran for sincere cooperation to conduct this study. This work is extracted from M.S. thesis NO.900329.

## Conflict of Interest

None

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