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Use of High Definition Multileaf Colimator for the Treatment of Trigeminal Neuralgia

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Abstract

In the present work, a treatment technique for trigeminal neuralgia (TN) using LINAC radiosurgery is shown. The technique is based on the optimization of ten static arcs in such a way as to minimize the overlapping of the treatment fields with the brainstem. We will call this technique brainstem-optimized (BO). The results are compared with another technique described in the literature known as a virtual cone (VC). The comparison of dosimetry results that have been carried out essentially shows that the doses in the brainstem V12Gy-brainstem, D0.5cm^3-brainstem and D0.035 cm^3-brainstem are lower in the BO versus VC technique, and with the parameters V50% (whole brain) and V12Gy-cerebrum higher in BO versus VC. Our goal is to keep the dose to the brainstem as low as possible and, if possible, at most between 12 Gy and 15 Gy. The BO technique meets our purposes and is considered clinically acceptable at our institution.

Keywords

Trigeminal Neuralgia, Radiosurgery, Brainstem, Brainstem-Optimized Technique (BO), Virtual Cone (VC)

1. Introduction

Trigeminal neuralgia (TN) is a nerve disorder that causes facial pain in affected patients. In most cases, the cause is focal demyelination of the nerve produced by vascular compression. The three main treatment modalities for TN are drug treatment, surgery, and cranial radiosurgery (SRS-NT) [1].

Historically, linear accelerator radiosurgery treatment has been performed with small circular cones, whose diameter was 4 or 5 mm [2]. The development

of high definition multileaf collimators (MLCs), whose geometric accuracy is comparable to that of physical cones, has allowed the development of alternative techniques to produce similar dose distributions. Popple *et al.* show a way to generate a virtual cone (VC) from a high definition MLC, generating a spherical dose distribution [3] [4]. Other treatment techniques can also reproduce this type of dose distribution [5] [6].

In our case, we have developed a treatment technique based on arcs with 5 mm × 5 mm shaped fields, and a 2.5 mm width MLC. We do not use spherical dose distributions, as our goal is to leave the brainstem dose as low as possible. In this work, we compare dosimetry data obtained by means of our technique with those obtained by means of the virtual cone technique and relate the results with the appearance of adverse effects. In brain irradiations, the volume of the isodose of 12 Gy (V12Gy) is related to the risk of adverse, reversible and irreversible effects [7]. Therefore, although in the case of TN irradiation, V12Gy is small, it has been considered this parameter to estimate the probability of occurrence of these effects [8].

2. Material and Methods

A retrogasserian target point on the trigeminal nerve was determined by neurosurgeons of our institution [9] [10]. For this purpose, three high-resolution MRI studies with neuronavigation protocols were used: T1-incoherent (FSPGR), fast spoiled gradient echo (FSPGR) method of three-dimensional magnetic resonance data that improve anatomical visualization of the structures of the grooves of the hemispherical convexities, T1-balanced sequenced (FIESTA) and T2-FSE, FIESTA (Fast Imaging Employing Steady-state Acquisition) is the GE name for a balanced steady-state gradient echo sequence, this sequence may be affected by phase shift errors across the image that produce banding artifacts, is currently the sequence of choice for CSF-cisternography for visualizing cranial nerves at the skull base. When used in the 3D mode, it provides a high signal from CSF based on T2/T1 contrast and high spatial resolution. Furthermore, like FIESTA/TrueFISP, it has inherent flow compensation because of its perfectly balanced gradients. (Signa Artist 1.5 T, GE). In addition, a high-resolution sterotactic head CT scan (Philips Bigbore Brilliance) was performed as the basis for planning. Axial slices on MRI were 0.7 mm wide and 1 mm wide on CT. All these images were transferred to the planning system (TPS Eclipse 15.6 Varian Medical Systems) and matched by rigid registration (Mutual Information Algorithm).

The organs at risk (brainstem, chiasm, optic nerves) were outlined. The plans were calculated with the Acuros 13.5 dose algorithm. The calculation grid was 1 mm.

The SRS-TN was carried out on an Edge Linear Accelerator, equipped with a 120-leaf NDS120HD MLC, having a leaf width of 2.5 mm in the central 8 cm and 5 mm in the outer 14 cm. The energy used was 6 MV flattening filter free, rate 1400 UM/min. Treatments can be completed in about 20 minutes, from the

time the patient is positioned following the acquisition of a Cone Beam CT.

The prescribed dose at the target point is 90 Gy [11]. We have conducted treatment plans aimed at optimizing the dose in the brainstem (BO). It is prioritized that the dose received in the brainstem be minimal, if possible, around 12 Gy or less [12]. To do this, we restrict the amplitudes of the irradiation arcs, avoiding the entry into the brainstem, through the Beam Eye's View (BEV) tool. We used ten non-coplanar fields with 5 mm × 5 mm static MLC apertures static, separated by ten-degree couch, distributed in the quadrant corresponding to the location of the lesion. We rotate the collimator to orient the leaves axe direction tangent to the brainstem. In this way, irradiation of the brainstem due to interleaf leakage is avoided (**Figure 1**).

In **Figure 2**, we can see the dose half profiles in TPS for each direction. In the direction of the axis perpendicular to the movement of the leaves, the dose profile has a faster fall than in the parallel axis.

We compared the BO resulting dose distributions with those that would be obtained using the VC (**Figure 3** and **Figure 4**) in the six patients for whom we have performed the SRS-TN since it was implemented in our hospital in November 2019.

We verified treatment prior to treatment using the SRS MapCHECK measurement equipment on the phantom StereoPHAN phantom (Sun Nuclear Corporation) [13]. Although using static fields, well characterized dosimetrically in the commissioning phase, we consider that this verification would be necessary, as significant deviations from the calculated dose distribution could be expected due to any mechanical inaccuracies.

3. Results

For plans evaluation, we have used five parameters: the brainstem volume covered

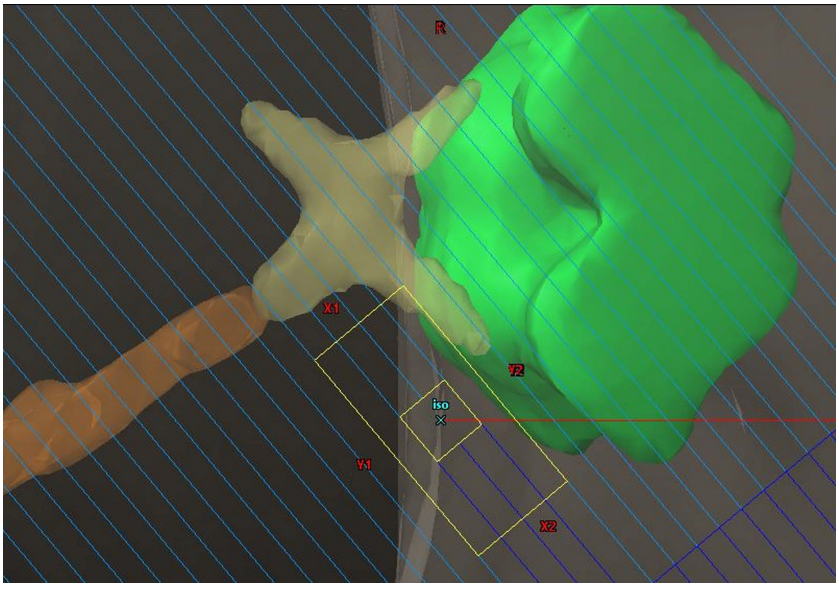

Figure 1. BEV with optimized collimator angle relative to the brainstem.

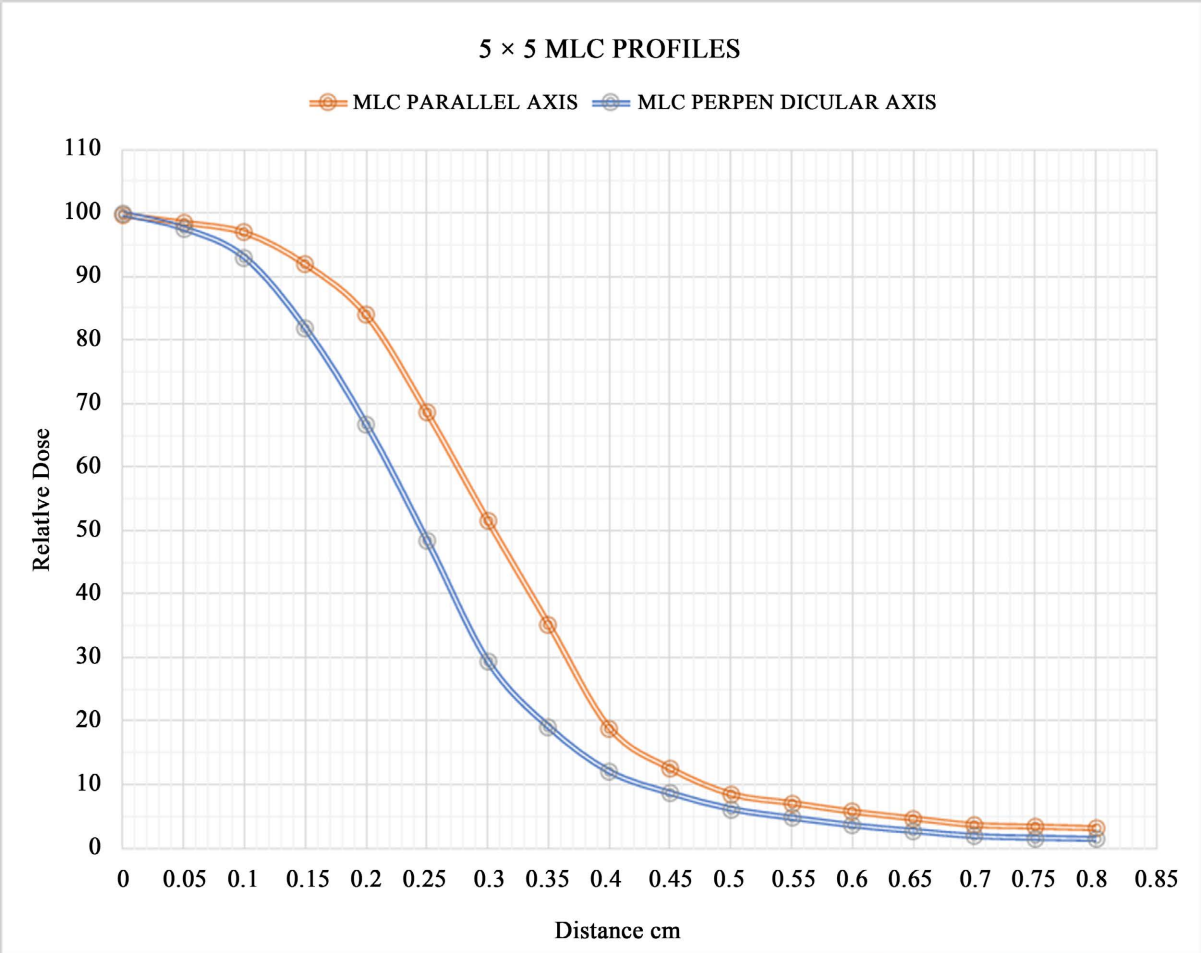

Figure 2. Half dose profiles, parallel and perpendicular to leaves movement.

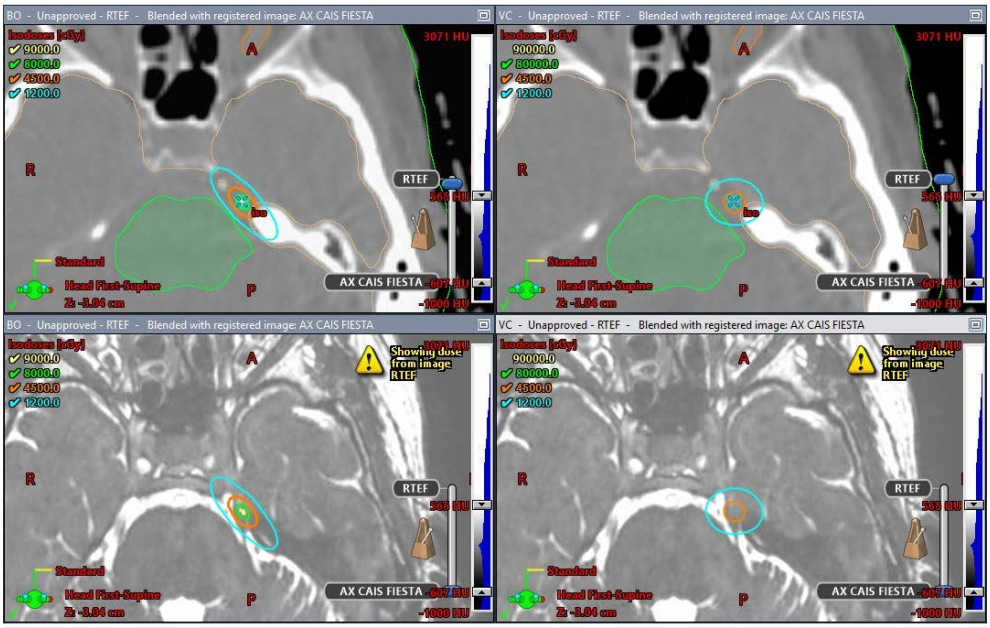

Figure 3. Upper left: CT BO isodoses, Lower left: MR BO isodoses projection, Upper right: CT VC isodoses, Lower right: MR VC isodoses projection.

by 12 Gy or more in cm^3 (V12Gy-brainstem), idem for the brain (V12Gy- Cerebrum), the near maximum dose in the brainstem (D0.035cm^3-brainstem), the dose delivered at 0.5 cm^3 or less of the brainstem (D0.5cm^3-brainstem), and the volume of brain irradiated by the 50% isodose (V50%cm^3). Table 1 and Table 2 show these results.

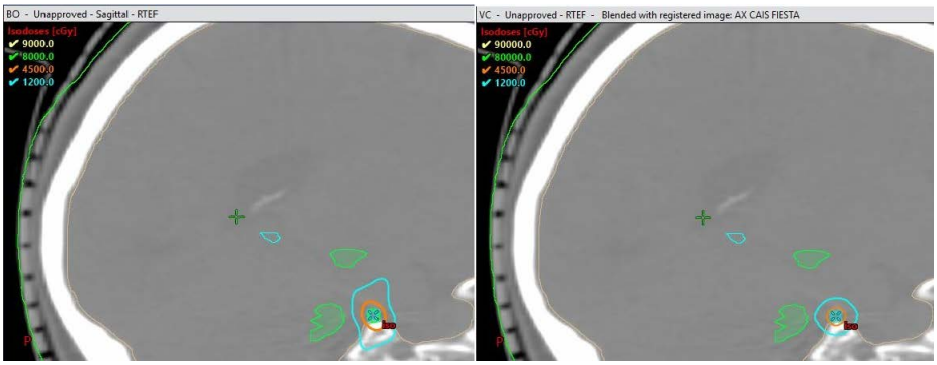

Figure 4. Sagittal reconstruction of CT dose distribution. Left BO, right VC.

Table 1. Dosimetric results for the BO technique.

BRAINSTEM-OPTIMICED (BO)					
CASE ID	V12cm^3-cerebrum	V50% cm^3	D0.5cm^3-brainstem (Gy)	D0.035cm^3-brainstem (Gy)	V12cm^3-brainstem
1	2.83	0.27	2.98	7.24	0
2	3.35	0.27	4.16	14.8	0.06
3	3.69	0.27	3.57	13.7	0.06
4	3.33	0.3	1.82	4.5	0
5	3.53	0.26	3.62	8.4	0
6	2.2	0.23	3.77	7.1	0
Average	3.155	0.267	3.320	9.290	0.020
Typical dev.	0.550	0.023	0.828	4.063	0.031

Table 2. Dosimetric results for the VC technique.

VIRTUAL CONE (VC)					
CASE ID	V12cm^3-cerebrum	V50% cm^3	D0.5cm^3-brainstem (Gy)	D0.035cm^3-brainstem (Gy)	V12cm^3-brainstem
1	0.88	0.084	5.87	20.5	0.05
2	1.08	0.101	7.55	18.5	0.15
3	0.88	0.088	6.63	17.5	0.12
4	1.01	0.096	5.7	11.7	0.03
5	1.02	0.098	6.18	14.3	0.08
6	1.05	0.095	4.8	9.57	0.01
Average	0.987	0.094	6.122	15.345	0.073
Typical dev.	0.086	0.006	0.926	4.217	0.054

D0.035cm^3-brainstem in the BO vs. VC is significantly lower in BO.

This does is highly dependent on the anatomy of the patient. Patients with large cisterns have the retrogasserian target farther from the brainstem. The D0.5cm^3-brainstem and the V12Gy-brainstem are also substantially smaller. On the other hand, V50% and V12cm^3-cerebrum are three times greater in the B.O technique than in V.C. (Table 1 and Table 2).

Below we show the results graphically (Figures 5-9).

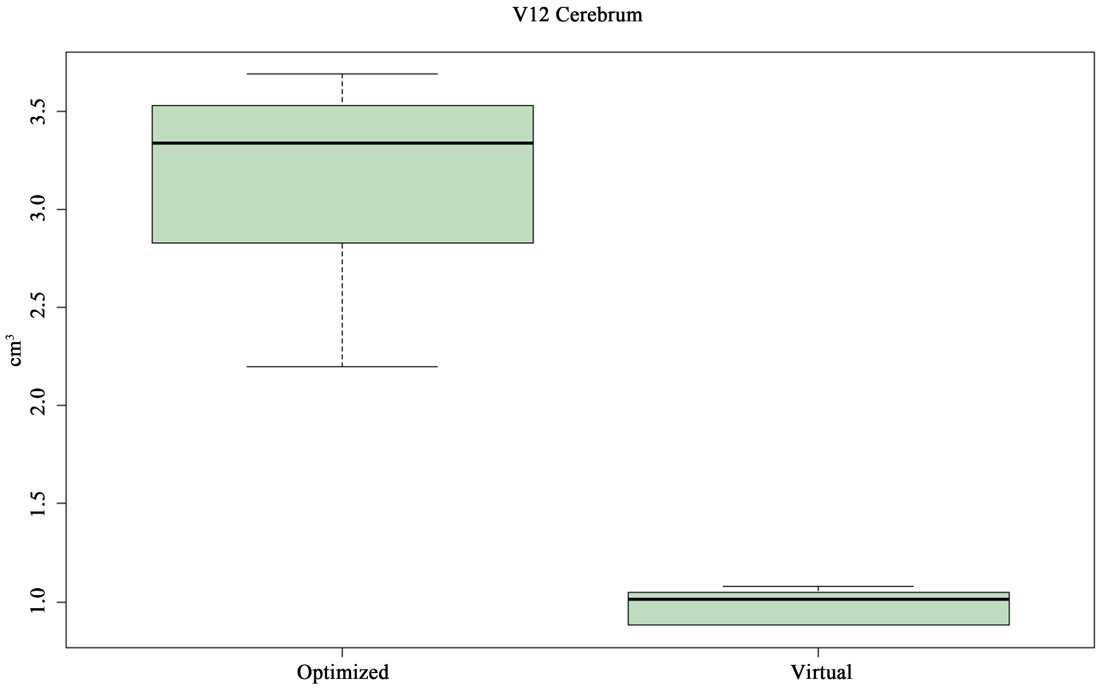

Figure 5. V12Gy-cerebrum BO vs. VC.

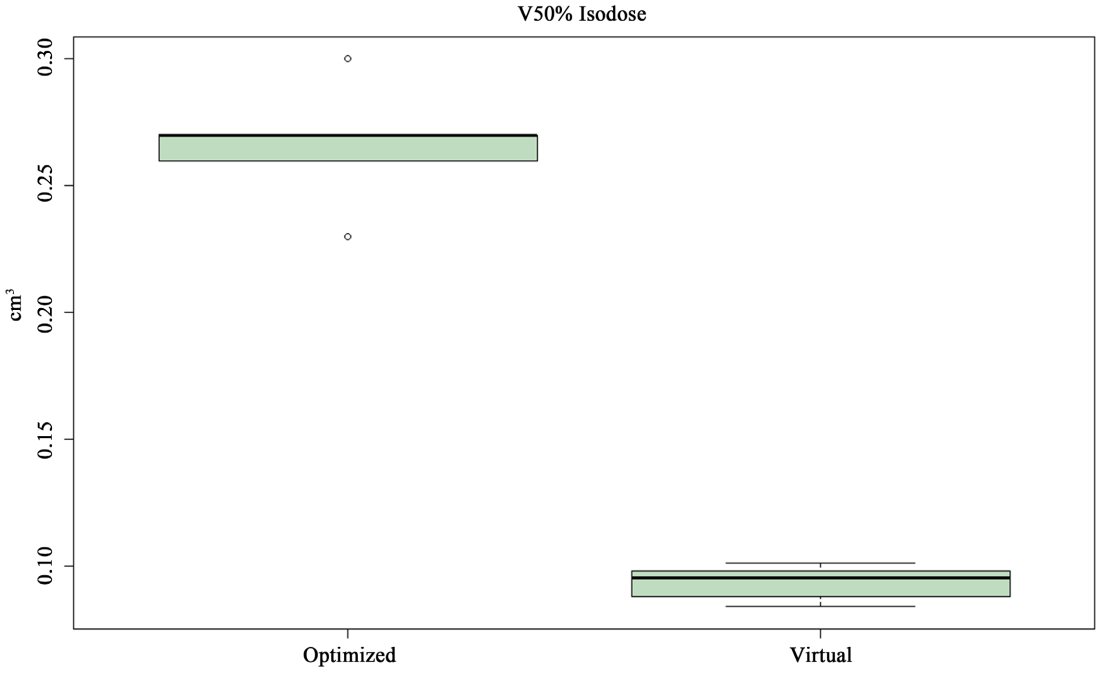

Figure 6. V50% BO vs. VC.

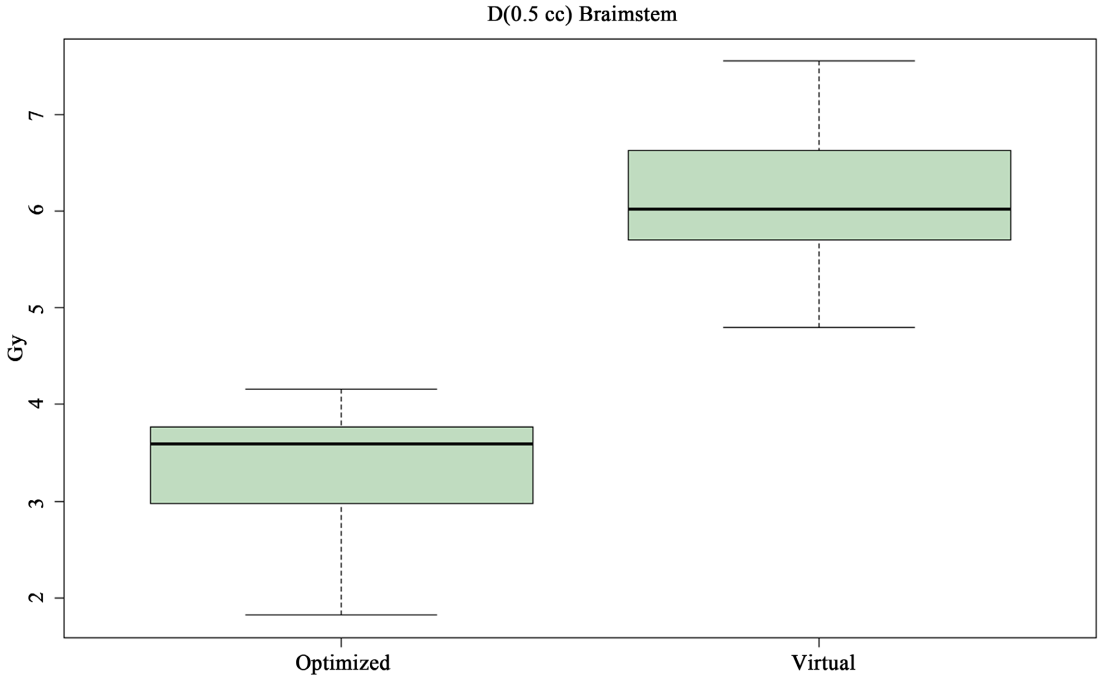

Figure 7. D0.5cm^3-brainstem BO vs. VC.

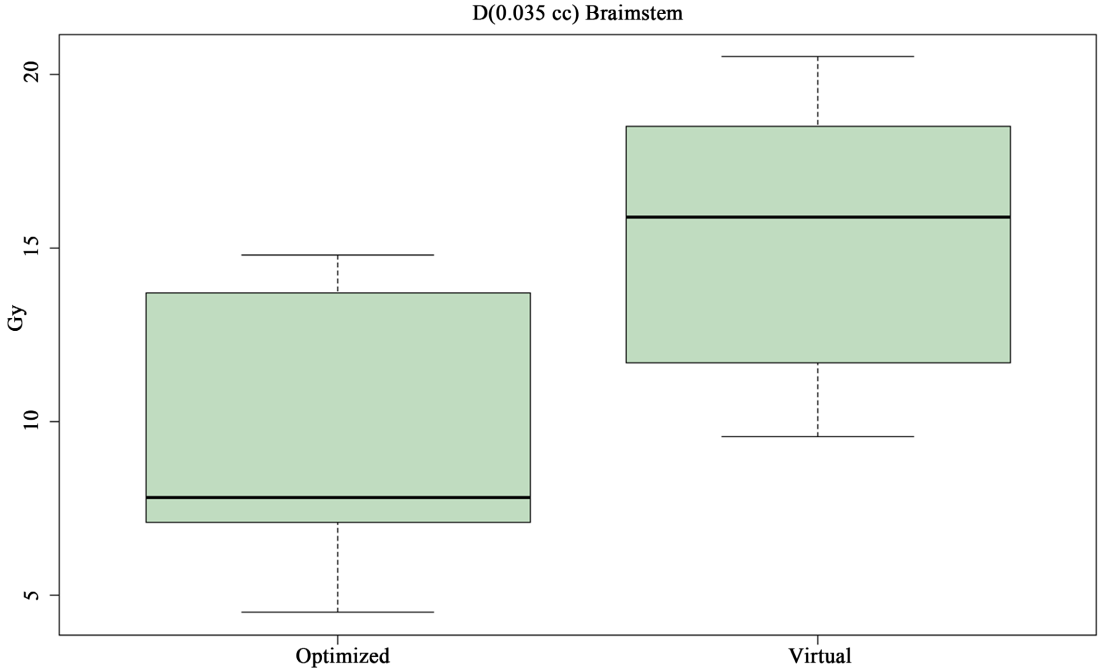

Figure 8. D0.035cm^3-brainstem BO vs. VC.

If we compare with other works in which for the same treatment conditions (6 MV FFF and 5 × 5 MLC opening), we find values of D0.5 cm^3 of 4.94 Gy compared to 3.32 Gy on average in the present work [4].

The verification of the treatments with SRS MapCHECK (Sun Nuclear Corporation) gave gamma indices (1%, 1 mm, 10% dose threshold, absolute dose) [14] with results above 95% (**Figure 10**).

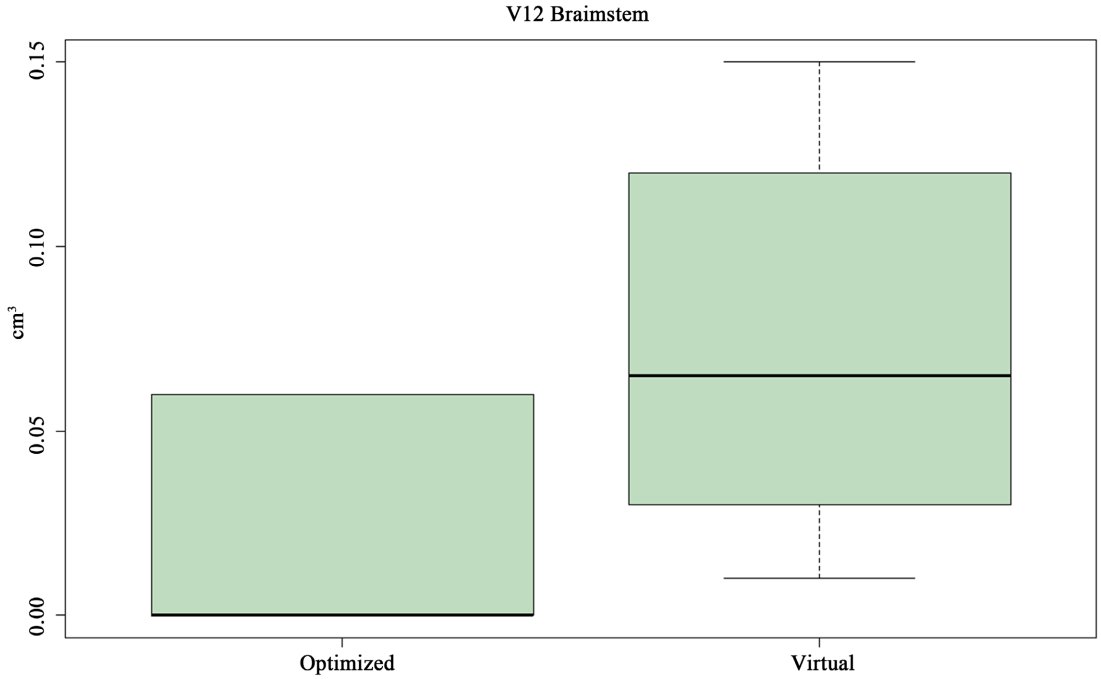

Figure 9. V12Gy-brainstem BO vs. VC.

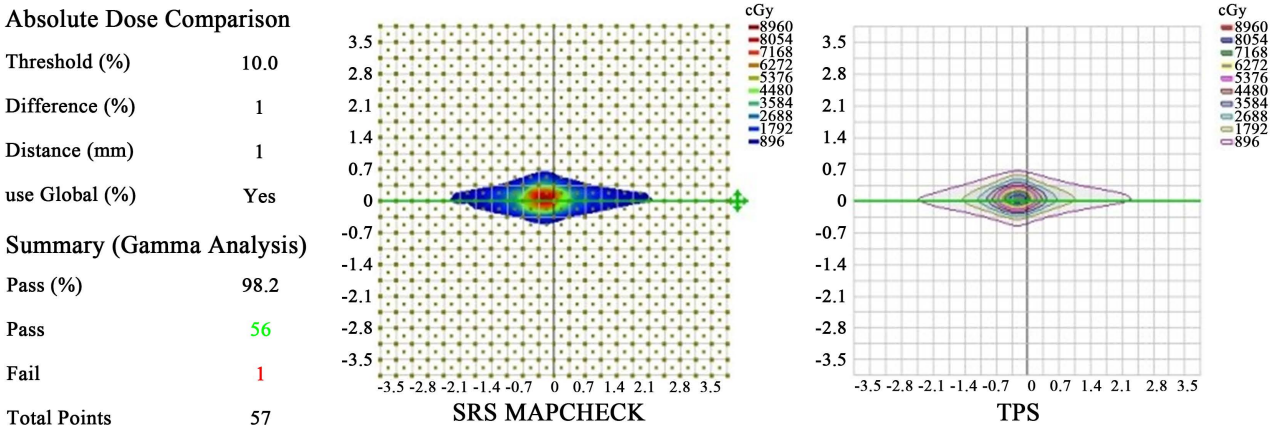

Figure 10. Example of case verification report.

During the follow-up of the patients (every 6 months), no noteworthy adverse effect has been observed. In all cases, improvement in perceived pain was observed.

4. Discussion

The CV technique generates an isotropic dose distribution with a maximum average gradient. It is also a very consistent technique because it always produces the same dose distribution. However, it is not optimized to limit the dose to the brainstem. The BO technique optimizes the dose to the brainstem, limiting it in all the cases that we have analyzed to around 12 Gy or less, but the irradiated volume of the brain (V50%) is 3 times greater. Kano *et al.* [7] shows that for V12cm^3-cerebrum less than 5 cm^3, the probability of the appearance of irreversi-

ble symptomatic adverse effects is practically nil and acute ones are below the threshold of 5%. In contrast, for any V12cm^3-brainstem, there is a 10% probability of adverse effects, both acute and irreversible. Furthermore, the probability of these effects occurring grows much faster in the case of the brainstem.

Therefore, the BO is preferable in most cases due to its lower toxicity. However, in patients whose target point is far from the brainstem (e.g., case 6) the CV may be preferable.

From our point of view, we can conclude that the choice of technique to be used is subject to the dose limits reached in the brain stem. In our center, both neurosurgeons and radiation oncologists, establish a maximum dose limit between 12 and 15 Gy. Therefore, in all cases, we must optimize the BEV of the arcs used. However, we insist that everything depends on the clinical decisions made in each institution. The limitations of this technique in our institution are patients with small cisterns, due to the dose limits described above.

5. Conclusions

We consider that the BO technique described here, aimed at dose restriction in the brainstem, is adequate for the treatment of TN. A priori is the one that produces less toxicity in the most number of cases. It is efficient, reliable, simple to plan, quick and easy to apply in a high-performance LINAC provided with a 6D couch and a high-definition MLC. Since it is not an intensity-modulated radiotherapy treatment, issues regarding the validity and consistency of the dose calculated by the TPS and the associated quality control are simplified. Although the number of patients we have treated is small, the results have been encouraging, both in terms of pain reduction and toxicity.

We conclude that the BO technique is a useful treatment option, showing a theoretical advantage over the virtual cone technique if the retrogasserian target point is close enough to the brainstem, which is the case in most patients.

Contribution

All authors declare to have reviewed the work and contributed to its height.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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