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DOSIMETRIC COMPARISON OF HELICAL TOMOTHERAPY AND DYNAMIC CONFORMAL ARC THERAPY IN STEREOTACTIC RADIOSURGERY FOR VESTIBULAR SCHWANNOMAS

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Abstract—The dosimetric results of stereotactic radiosurgery (SRS) for vestibular schwannoma (VS) performed using dynamic conformal arc therapy (DCAT) with the Novalis system and helical TomoTherapy (HT) were compared using plan quality indices. The HT plans were created for 10 consecutive patients with VS previously treated with SRS using the Novalis system. The dosimetric indices used to compare the techniques included the conformity index (CI) and homogeneity index (HI) for the planned target volume (PTV), the comprehensive quality index (CQI) for nine organs at risk (OARs), gradient score index (GSI) for the dose drop-off outside the PTV, and plan quality index (PQI), which was verified using the plan quality discerning power (PQDP) to incorporate 3 plan indices, to evaluate the rival plans. The PTV ranged from 0.27−19.99 cm^3 (median 3.39 cm^3), with minimum required PTV prescribed doses of 10−16 Gy (median 12 Gy). Both systems satisfied the minimum required PTV prescription doses. HT conformed better to the PTV (CI: 1.51 ± 0.23 *vs*. 1.94 ± 0.34; $p < 0.01$), but had a worse drop-off outside the PTV (GSI: 40.3 ± 10.9 *vs*. 64.9 ± 13.6; $p < 0.01$) compared with DCAT. No significant difference in PTV homogeneity was observed (HI: 1.08 ± 0.03 *vs*. 1.09 ± 0.02; $p = 0.20$). HT had a significantly lower maximum dose in 4 OARs and significant lower mean dose in 1 OAR; by contrast, DCAT had a significantly lower maximum dose in 1 OAR and significant lower mean dose in 2 OARs, with the CQI of the 9 OARs = 0.92 ± 0.45. Plan analysis using PQI (HT 0.37 ± 0.12 *vs*. DCAT 0.65 ± 0.08; $p < 0.01$), and verified using the PQDP, confirmed the dosimetric advantage of HT. However, the HT system had a longer beam-on time (33.2 ± 7.4 *vs*. 4.6 ± 0.9 min; $p < 0.01$) and consumed more monitor units (16772 ± 3803 *vs*. 1776 ± 356.3; $p < 0.01$). HT had a better dose conformity and similar dose homogeneity but worse dose gradient than DCAT. Plan analysis confirmed the dosimetric advantage of HT, although not all indices revealed a better outcome for HT. Whether this dosimetric advantage translates into a clinical benefit deserves further investigation.

Key Words: **Helical TomoTherapy, Dynamic conformal arc therapy, Novalis, Vestibular schwannoma, Dosimetry.**

INTRODUCTION

Stereotactic radiosurgery (SRS) is an alternative to microsurgery in the treatment of vestibular schwannomas (VSs); it confers lower morbidity and comparable local control.[1,2] There have been technical developments in the delivery of radiation beams using linac-based SRS with progress from the conventional circular arc, static conformal beam to dynamic conformal arc or intensity-modulated therapy. During beam delivery, the radiation can be shaped by circular collimators of variable size or a micromultileaf collimator (mMLC). Dynamic conformal arc therapy (DCAT), which combines the concept of a circular arc and mMLC beam shaping, shapes radiation by changing the mMLC patterns along the arc pathway of a single isocenter.[3,4] In our department, we use the DCAT technique to treat VS using the Novalis system. The DCAT technique has been used to treat intracranial tumors, and a comparable dosimetric result was obtained in relation to intensity-modulated radiotherapy (IMRT).[5,6]

IMRT constitutes an advanced form of the conformal technique and uses inverse planning algorithms and iterative computer-driven optimization to generate treatment fields with varying beam intensity. IMRT has the ability to produce custom-tailored conformal dose distributions around the tumor, although most studies have examined large tumors.[7] With commercial motorized mMLC systems, IMRT can be extended to smaller intracranial tumors.[8] IMRT can be delivered using linac or Hi-Art Helical TomoTherapy (HT) (TomoTherapy, Madison, WI).[9–11] Compared with step-and-shoot IMRT, helical IMRT is capable of calculating the MLC position

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every 7° of rotation; it also creates a more uniform target dose and improves critical organ sparing.[12,13]

Dosimetric comparisons of HT with the gamma knife or conventional linac-based SRS have been performed for small intracranial or skull base tumors.[14–16] To our knowledge, however, no dosimetric comparisons of IMRT delivered using HT with DCAT using the Novalis system in VS have been made. This study compared the 2 techniques in VS quantitatively, by using several indices for the dosimetric comparisons, including the conformity index (CI) and homogeneity index (HI) for the planned target volume (PTV), quality index (QI) and comprehensive quality index (CQI) for 9 organs at risk (OARs), gradient score index (GSI) for the dose drop-off outside the PTV, and plan quality index (PQI) to incorporate 3 plan indices to evaluate the plans quantitatively.[12,13,17–21] To investigate the discerning power between the indices, the plan quality discerning power (PQDP) was used to check the discrimination between PQI and other indices, such as conformation number (CN) and conformation index (COIN).[19] The beam-on time[22] and monitor units (MUs) used by the 2 techniques were also measured and compared.

MATERIALS AND METHODS

Study population

Ten consecutive patients (6 females, 4 males) with VS and treated using SRS with the Novalis system between March 2007 and October 2008 were enrolled. The patient characteristics and tumor descriptions are presented in Table 1. The median age at SRS was 58 years (range 29–86). The tumor was located on the right vestibular nerve in 3 patients and on the left in seven.

Novalis and HT

The Novalis system, a dedicated linac-based SRS modality, is integrated with an m_3-mMLC system, working on a 6-MV photon beam with stringent isocentricity standards (BrainLAB, Heimstetten, Germany, and Varian Medical Systems, Palo Alto, CA).[23] There are three different leaf widths in the m_3-mMLC, which has 26 pairs of tungsten alloy (95% W, 3.4% Ni and 1.6% Fe) leaves (14 × 3, 6 × 4.5, and 6 × 5.5 mm, with a maximum useful field of 9.8 × 9.8 cm^2). In addition, the system is combined with ExacTrac® X-Ray 6D (BrainLAB, Heimstetten, Germany), an infrared (IR) camera, a kV stereoscopic x-ray imaging system, a relocatable stereotactic frame system, a noninvasive mask system, and ExacTrac® Robotics, for patient positioning in all 6D of freedom.[24]

Helical TomoTherapy combines an intensity-modulated fan beam with the helical motion of the gantry, relative to the patient. In the HT system, a 6-MV linac is mounted on a circular gantry that rotates in the transverse plane of the patient, while the patient couch moves into the gantry bore. The fan beam is modulated by a 64-leaf binary MLC (6.25-mm leaf-width at the isocenter) throughout gantry rotation.[10,11]

The 10 patients were treated with the Novalis system, and a standard 5-arc noncoplanar DCAT was delivered. For the dosimetric comparison with HT, the computed tomography (CT) images and associated contours were transferred to the HT system (version 2.1) *via* the DICOM-RT protocol format. The same optimization parameters and prescribed doses were used in the HT as in the Novalis treatment plan system (TPS). In the HT plans, the operator must choose 3 main parameters: the field width (one of 1, 2.5, or 5 cm); pitch (range 0.01–20); and modulation factor (range 1–10); this is unique to HT. Briefly, the field width is defined as the slice thickness of the radiation field projected at the isocenter along the gantry rotation axis. The pitch is defined as the couch movement relative to the field width during one gantry rotation. The modulation factor is defined as the ratio of the maximum number of opening leaves and the average number of opening leaves in active gantry rotations.[11,18] A 1-cm field width, a pitch of 0.3, and a modulation factor of 2 were used in all of the HT plans in this study. The choices of these 3 parameter values were based on preliminary planning exercises that showed this choice was a good balance between ability at dose sculpting and efficiency of the treatment, in terms of treatment duration and feasibility for routine use. In general, small field dimensions, small pitch, and large modulation factors mean longer irradiation times and a better ability for the

Table 1. Patient and tumor characteristics (n = 10)

Patient No.	Planned Target Volume (cm^3)	Prescription Dose (Gy)	Tumor Site Treated	Gender	Age (y)
1	1.13	15	Right	M	53
2	3.77	12	Left	F	69
3	1.45	16	Left	F	29
4	5.83	10	Left	M	74
5	3.01	10	Left	F	33
6	6.64	10	Right	M	67
7	0.27	12	Left	F	86
8	4.35	12	Left	M	59
9	19.99	10	Right	F	39
10	1.42	12	Left	F	68
Mean ± SD (range)	4.73 ± 5.72 (0.27–19.99)	12 (10–16)			58 (29–86)