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Gamma Knife radiosurgery for intracranial meningiomas: Do we need to treat the dural tail? A single-center retrospective analysis and an overview of the literature

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Abstract

Background: The dural tail (DT) has been described as a common feature in meningiomas. There is a great variation of tumor invasion and extent of tumor cells in the DT. Therefore, the necessity to include the whole DT in Gamma Knife radiosurgery is not clear, since inclusion increases the target volume and therefore increases the risk of complications. In this analysis, we evaluated whether the complete tail should be included as part of the target in Gamma Knife radiosurgery for meningiomas.

Methods: Between June 2002 and December 2010, Gamma Knife radiosurgery was performed in 160 patients with 203 meningiomas with a DT. In 105 tumors, the diagnosis was based on magnetic resonance imaging (MRI) characteristics, and in 98 tumors, the diagnosis was confirmed by histopathologic examination after surgery. The median volume of the tumors was 3.55 cc. All tumors were treated with Gamma Knife radiosurgery with a median prescribed dose of 13 Gy (range 11-15), resulting in a median marginal dose of 11 Gy (range 10-15). Only the part of the DT closely related to the tumor mass was included in the target. The median follow-up period was 41 months (range 12-123).

Results: In image-based meningiomas, the overall local control rate was 96.2% with 2- and 5-year control rates of 98.0% and 95.1%, respectively. In WHO grade I tumors, the overall local control rate was 85.9% with 2- and 5-year control rates of 94.5% and 88.0%, respectively. The overall local control rate in World Health Organization (WHO) grade II tumors was 70.6% with control rates of 83.4% and 64.4% after 2 and 5 years, respectively. The growth of all new tumors was found in the radiation target area. No tumor growth was observed in the part of the DT that had been excluded from the target volume.

Conclusion: We found in this study that routinely excluding the DT from the target does not lead to out-of-field tumor progression. Given the possibility that the DT is infiltrated with tumor cells, regular follow-up is needed.

Key Words: Dural tail, Gamma Knife radiosurgery, meningioma

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INTRODUCTION

The dural tail sign (DTS) was first described in 1989 as a gadolinium-enhanced thickening of the adjacent dura of meningiomas, especially on T1-weighted magnetic resonance imaging (MRI).[25] Initially, the DTS was only considered to be pathognomonic for meningiomas. However, a DTS is also shown in various types of extra- and intracranial tumors, infections, and autoimmune diseases.[9] Nonetheless, diagnosis of meningiomas by DTS has a sensitivity of 58.6% and a specificity of 94.02%; therefore, presence of DTS can be suggestive for a meningioma.[22,23]

The particular nature of dural tail (DT) in meningiomas is not well understood. The DT has been described as a hyperproliferation of connective tissue with signs of angiogenesis, indicating a vascular effect inside the dura.[1] However, some studies found that the DT consists of tumor cells.[20] A recent study by Qi *et al.* classified the DT into five subtypes (smooth, mixed, nodular, symmetrical, and asymmetrical multipolar), based on radiological features such as smooth enhancement of the DT, nodular hyperplasia in the DT, or a combination of these features.[18] On histopathologic evaluation, they found significant differences between the subtypes. Dural invasion of tumor cells was found, especially in smooth and mixed types to the extent of 43.8% and 94.0%, respectively. The extent of dural invasion was found within 3 cm of the meningioma. Although this study confirmed infiltration of tumor cells in the DT, no follow-up data of the resected tumors was published. Therefore, the clinical consequences remain unclear. In more recent literature, no clear evidence can be found about the prognostic relevance of tumor cell invasion in the DT; therefore, the question remains whether or not to include the DT as a target for radiosurgery.

Only a few studies have addressed this issue.[4,14,19] Including the DT may increase the target volume considerably, which possibly increases the risk for early or delayed toxicity after radiosurgery.

Because of the unknown nature of the DT and radiosurgical adverse consequences, we deliberately chose not to include the complete DT in the treatment plan. This could have resulted in a lower tumor control rate, especially in the part of the untreated DT. We have evaluated this concept in intracranial meningiomas with a DT treated in our center between June 2002 and December 2010. The aim was to evaluate a possible tumor growth in the untreated part of the DT.

MATERIALS AND METHODS

Between June 2002 and December 2010, 395 patients with 471 intracranial meningiomas were treated with Gamma Knife radiosurgery. In this group, 203 (43%) tumors in 160 patients (40.5%) showed a DT. Only this group was included in this study.

The mean age of the patients was 59.3 ± 13.4 years. There was a female predominance of 72.5% (116 females vs. 44 males). The median follow-up period was 41 months (range 12-122). The median tumor volume was 3.55 cc (range 0.06-22.0). The location of the treated tumors with a DT is shown in Table 1.

The MR diagnosis of a meningioma including a DT was based on known characteristics of meningiomas [Table 2].[24]

The DT was classified based on the criteria of Goldsher.[8] These are: (1) presence on at least two consecutive sections through the tumor at the same site and in more than one plane; (2) greatest thickness adjacent to the tumor and tapering away from it; and (3) enhancement greater than tumor mass itself. The DTs were further subclassified according to Qi *et al.*[18] [Table 3].

Table 1: Anatomical location of treated tumors

Site	Number of meningiomas	Site	Number
Anterior fossa	14	Posterior fossa	33
Parasellar	3	Cerebral pontine angle	13
Planum sphenoidale	1	(Petro) clival	6
Frontobasal	4	Petrous bone	6
Olfactory groove	3	Foramen magnum	1
Orbital	1	Other	7
Anterior clinoid	1		
Other	1	Convexity	60
Middle fossa	32	Other	64
Cavernous sinus	21	Falcine	27
Sphenoid wing	10	Tentorial	17
Meckels's cave	1	Parasagittal	20

Table 2: MRI characteristics of meningioma

Well-defined extra-axial mass
Iso- or hypointense on T1-weighted images
Hyperintense on T2-weighted images
Strong homogenous enhancement after gadolinium
Dural tail (most meningiomas)

Table 3: Classification of the dural tail

	Image based	WHO I	WHO II	Total
Smooth	48	31	16	95
Nodular	15	6	6	27
Mixed	4	4	5	13
Symmetric multipolar	32	15	3	50
Asymmetric multipolar	6	8	4	18
	105	64	34	203

WHO: World Health Organization

Only the part of the dura adjacent to the tumor was included in the planning [Figures 1 and 2].

Patients were divided into two groups. Group A was based exclusively on MRI criteria. This group consisted of 88 patients with 105 meningiomas with a DT. The indication for treatment was proven growth during follow-up MRI. Group B was based on the histopathologic diagnosis of meningiomas after surgery. This group consisted of 72 patients with 98 meningiomas with a DT. In these patients, a total or partial resection of the meningiomas was performed before radiosurgery and the histopathologic diagnosis of the tumor was established consecutively. Sixty-four (65.3%) of these tumors were classified as World Health Organization (WHO) grade I and 34 tumors as WHO grade II (34.7%).

The indication for radiosurgery was local recurrence after complete resection in 18 meningiomas (18.0%) and progression after subtotal resection of 80 tumors (81.6%). All meningiomas with a WHO grade II had radiosurgery as soon as possible after surgery.

Treatment planning was performed with Leksell Gamma Plan® based on high-resolution contrast-enhanced stereotactic planning MRI scan.

A median dose of 13 Gy (11-15 Gy) was prescribed to that isodose covering 90-100% of the target volume (including the part of the DT adjacent to the tumor) resulting in a median marginal dose of 11 Gy (10-15 Gy).

Initial follow-up imaging studies after radiosurgery were performed at 6 months. Subsequently, follow-up continued every year for the first 2 years and thereafter every 3-4 years. Patients with WHO grade II meningioma received more frequent follow-up.

Out-of-field progression was defined as tumor growth outside the target volume in the DT in the axial planes.

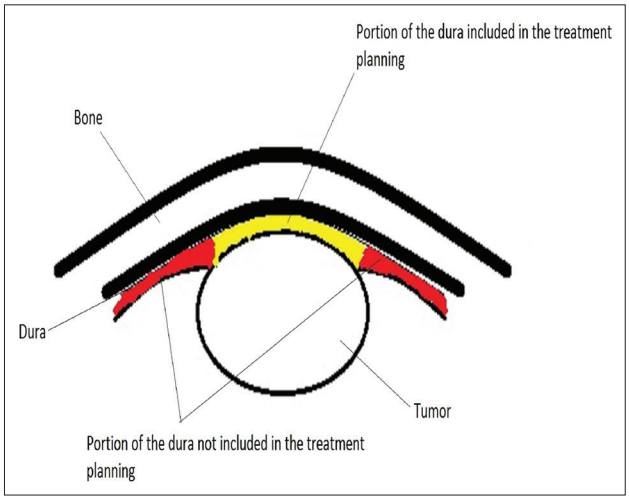

Figure 1: Schematic figure illustrating which part of the dural tail was included in the treatment planning

If progression was observed inside the treated volume, it was classified as an in-field progression.

Statistical analysis

Analysis of local control was performed by using the Kaplan and Meier method. Univariate analysis was performed using the log-rank test for non-continuous variables and Cox proportional hazard analysis for continuous variables. A multivariate analysis was carried out by using Cox regression analysis. Only the factors that were proven relevant in the univariate analysis were evaluated in multivariate analysis. A $P < 0.05$ was considered significant.

Statistical analysis was processed with the statistical package for the social sciences (version 19; SPSS, Chicago, IL, USA) computer software for Windows.

RESULTS

Group A

Four of the 105 tumors (3.8%) showed an increase in volume after radiosurgery. The overall local control rate was 96.2% with 2- and 5-year control rates of 98.0% and 95.1%, respectively. The median time to progression was 29.5 months (range 24-42). The median prescribed dose was 13 Gy (range 12-13 Gy) with a median marginal dose of 11.7 Gy (range 10-12 Gy). The median volume of these tumors was 8.2 cc (range 5-11.3).

The growth of all tumors was classified as an in-field progression. No out-of-field tumor growth was found.

Group B

Nine of the 64 (13.1%) WHO grade I tumors showed

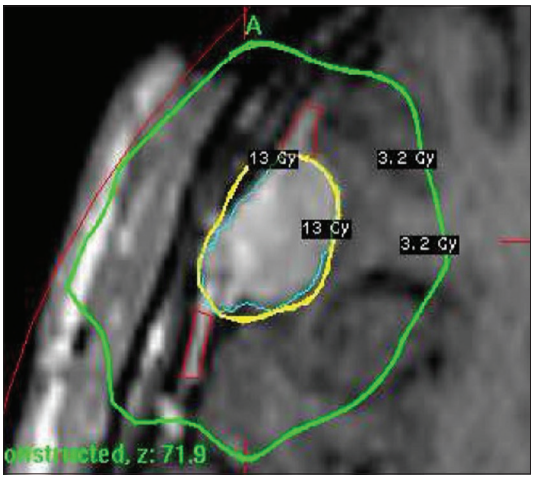

Figure 2: Axial MRI T1-weighted image with gadolinium showing an example of the treatment planning of a WHO grade I meningioma located right frontal. The size of the tumor was 3.2 cm³. The prescribed dose was 13 Gy. The coverage was 99% with a selectivity of 77%. The part of the dural tail not included in the treatment volume is delineated with the red line. The volume of the untreated part of the dural tail was 0.31 cm³. The minimum dose that the untreated part of dural tail received was 3.2 Gy. This tumor showed no in-field or out-of-field progression within 48 months

local growth. This resulted in 85.9% overall tumor control and 2- and 5-year control rates of 94.5% and 88.0%, respectively. The median time to progression was 48 months (range 13-66). The median prescribed dose was 13 Gy (range 11-13.2) with a median minimal dose of 11 Gy (range 10-11.8). The median volume of these tumors was 5.6 cc (range 1.4-9.4).

The WHO grade II meningiomas showed progression in 10 out of 34 tumors. The overall local control rate was 70.6% with control rates of 83.5% and 64.4% after 2 and 5 years, respectively. The median prescribed dose to these meningiomas was 13 Gy (range 11-15). The median minimal dose was 11 Gy (range 10-15). The median volume of these tumors was 4.0 cc (range 1.4-8.6).

The growth of all tumors was classified as an in-field progression. No out-of-field tumor progression was found.

Univariate and subsequent multivariate analysis showed that WHO grade II [odds ratio (OR): 11.8, $P \leq 0.05$] was an independent predictor for local progression. Male gender was a significant factor with univariate analysis, but not with multivariate analysis.

Other factors included in the analysis were tumor volume, age, number of tumors treated, location of the tumor, prescribed dose, and marginal dose. None of those factors were an independent predictor for local recurrence.

Complications

Two patients developed transient neurological complications after treatment: One patient with epilepsy suffered a partial seizure caused by edema 2 weeks after treatment. This patient received dexamethasone and additional epilepsy medication as treatment and recovered. The other patient, who was treated for multiple (8) tumors, had speech impairments caused by edema. The patient recovered after receiving dexamethasone.

DISCUSSION

This study shows high local tumor control rates with low morbidity after Gamma Knife radiosurgery for image-based meningiomas as well as for histopathologically diagnosed WHO grade I meningiomas. Our findings correspond well with the literature reports.[2,6,12,13,16,21]

WHO grade II tumors have lower tumor control rates, which is in concordance with the current literature on the subject.[3,11] Our median marginal dose is lower compared to other series.[5,10,17] Based on our own results and the available literature, we have increased the median marginal dose in the treatment of higher-grade meningiomas.

With regard to the DT, we observed that excluding the DT from the target volume is not associated with an increased risk of tumor growth originating from the untreated part of the DT, not even in WHO grade II tumors. This could be explained by the fact that the DT has received a low dose that may be sufficient enough to obtain local tumor control in the DT during the follow-up of our study.

In our series, there was no significant difference in distribution of the subtypes of DT as described by Qi *et al*. [Table 3][18] Smooth DT was the most identified subtype in our analysis, which may explain the absence of tumor growth in the untreated part of the DT, since this subtype has relatively the least invasion of tumor cells.[18] In contrast, symmetric multipolar DT is the second most common subtype in our group. This type has an invasion rate of tumor cells of about 80%.[18] However, no progression was observed in this subtype of DT in this study during follow-up.

Infiltration of meningoma in a DT cannot be excluded. Therefore, the question remains whether the DT should be included in the treatment planning for radiosurgery. One study showed that inclusion of the DT in benign meningiomas was a significant factor for better local tumor control.[4] The authors found a higher 5-year disease-free survival than without inclusion of the tail (96% vs. 77.9%, $P = 0.038$). However, this relation was not significant after multivariate analysis. The authors also reported a significantly lower conformity index ($P = 0.04$), indicating a disadvantage of including the DT in the treatment plan. In addition, the definition of the DT was not clear and the location of the local progression (in-field or out-of-field) was not specified.

Rogers *et al*.[19] described that routine inclusion of the DT will lead to larger treatment volumes, increasing the complication rates without improving local control. Furthermore, since tumor invasion in a DT can extend up to 3 cm from the base of the meningioma,[18] the inclusion of the whole DT would increase the treatment volume significantly, which increases adverse effects such as cerebral edema–related complications.[7,15]

Based on the heterogeneity of the histology of the DT and our findings in the present study, we advise to only include the DT directly adjacent to the tumor. The conformity index will remain as optimal as possible and the chance of treatment-related complications as low as possible. However, there might be an increased risk of out-of-field recurrence within the DT in the higher-grade meningiomas, which requires more frequent MRI investigations.

The main limitation in our study is the relatively short follow-up duration. The portion of the DT not included in the treatment volume has received a lower dose that may be sufficient enough for tumor control in the short

term. Therefore, a longer follow-up of this patient cohort is needed to evaluate our policy regarding the DT.

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