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Outcomes of medium choroidal melanomas treated with ruthenium brachytherapy guided by three-dimensional pretreatment modeling

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ABSTRACT

PURPOSE: The Collaborative Ocular Melanoma Study (COMS) established iodine-125 (I-125) plaque brachytherapy for eye preserving treatment of medium-sized choroidal melanomas in the United States. Eye Physics I-125 plaque treatment modeled with Plaque Simulator (PS) software yields similar results to COMS. Herein, we report results from a series of 15 patients treated with ruthenium-106 (Ru-106) plaque brachytherapy using PS pretreatment modeling for plaque localization and dosimetry.

METHODS AND MATERIALS: Fifteen patients with medium-sized choroidal melanomas (2.84−5.5 mm in apical height and a basal diameter of 7.8−12.6 mm) treated with ruthenium brachytherapy from 2003 to 2005 were evaluated retrospectively. Baseline and followup data were evaluated for tumor height, best corrected visual acuity, radiation retinopathy, radiation optic neuropathy, postradiation cataract formation, diplopia, and ptosis. Tumor response for both Ru-106 and I-125 plaques planned using the same PS pretreatment modeling was evaluated and compared.

RESULTS: Isotope-specific radiation profiles were compared, and rates of local treatment failure (0%), optic neuropathy (6.7%), retinopathy (20%), and cataracts (33%) were evaluated. Five year−treated tumor heights were approximately 0.61 ± 0.29 (I-125, $n = 16$) and 0.53 ± 0.17 (Ru-106, $n = 6$) of their heights at diagnosis.

CONCLUSIONS: This patient subset had background characteristics very similar to those of the COMS and patients treated at our institution with I-125 plaques. Treatment response was equivalent although radiation complications occurred slightly less frequently in the Ru-106 group compared with those treated with I-125. Image-guided three-dimensional pretreatment modeling for plaque localization and dosimetry seems to work equally as well for Ru as for I-125 plaques and justifies more extensive investigation.

Keywords: Uveal; Melanoma; Plaque; Brachytherapy; Toxicity; Ruthenium

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Conflict of interest: Dr Astrahan holds an ownership position in Eye Physics LLC, which was incorporated in 2007 to continue development of the Plaque Simulator software and Eye Physics plaques after Dr Astrahan's emeritus retirement from the University of Southern California (USC) in 2010. During 1990−2010, no outside funding for development or material support for any of his contributions was received by USC. No compensation was received for any patient in this study. From 1995 to 2010, USC and Dr Astrahan shared a royalty derived from licensed distribution of the Plaque Simulator software to other institutions. No other disclosures were reported.

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Introduction

Episceral plaque brachytherapy is a well-established and effective treatment for medium-sized choroidal melanomas. The Collaborative Ocular Melanoma Study (COMS) showed that treatment with plaques loaded with iodine-125 (I-125) achieved survival rates equal to enucleation (1). I-125 brachytherapy has become the standard approach to globe preservation in the treatment of medium-sized choroidal melanomas in the United States.

Various surgical techniques have been described to localize COMS plaques on the episcleral surface, including scleral transillumination, indirect ophthalmoscopy with scleral depression, scleral diathermy, and ultrasonographic confirmation of plaque localization (2). An alternative brachytherapy system to the COMS plaques using preoperative localization has been previously described (3–7). The Eye Physics (EP) plaques are thin plaques with custom, conformal radiation profiles that are configured using Plaque Simulator (PS) software (6). The PS software constructs a three-dimensional model of the eye and tumor from a fusion of fundus photography, ultrasound, and computed tomography or magnetic resonance imaging. PS provides coordinates for plaque placement preoperatively, which obviates the need for significant intraoperative localization. The PS software also enables selection of seed positions to customize radiation profiles for a variety of tumor shapes and sizes. EP I-125 brachytherapy has been shown to have similar long-term clinical outcomes as compared with the COMS plaques and has the additional benefit of enabling most of the treatment planning to be performed preoperatively rather than intraoperatively (8).

Plaque brachytherapy for uveal melanoma can be administered using gamma radiation emitters such as I-125 or Palladium-103 or primarily beta radiation emitters such as ruthenium-106 (Ru-106/Rh-106). In the 1980s, I-125 became the *de facto* radionuclide used for uveal melanomas of medium size by the COMS because, for tumors >5 mm in apical height, I-125 delivers much better dose penetration compared with ruthenium. However, the caveat is that the radiation dose gradient surrounding I-125 plaques is not as steep as the gradient surrounding the beta-emitting Ru-106. Therefore, the benefits of a more homogeneous dose to the tumor and its immediate environs by I-125 may, at times, be offset by increased radiation to distal critical eye structures such as the macula, optic nerve, or lens.

A dosimetric comparison of I-125 vs. Ru-106 plaques has shown that Ru plaques can provide adequate radiation dose to small tumors although sparing critical nearby structures more effectively than I-125 (9). Wilkinson *et al.* showed that the use of Ru plaques could potentially reduce radiation dose to the macula, optic disc, and lens by 18%, 53%, and 89%, respectively. The primarily beta-emitting radiation properties of Ru-106/Rh-106 decay are responsible for this steep dose gradient; the surface dose rate near the peripheral edge of a Ru Plaque drops to about 70% of its central strength and about 2 mm beyond the edge the radiation dose rate drops to <5%. Because of this dosimetric advantage for small uveal melanomas (<5.5 mm in apical height), Ru plaques were recently reintroduced as a potentially safer radiation source for brachytherapy in the United States. Several groups have reviewed their experience with Ru plaques for small and medium uveal melanoma in both anterior and posterior locations (10–12). Barker *et al.* (13) have further suggested that planning for Ru-106 plaque brachytherapy should be performed carefully at centers with experience in COMS protocols with the possible need for special consideration to ensure sufficient dose delivery to tumor margins given the specific dosimetric considerations with Ru-106.

Herein, we report results from a series of 15 patients with posterior choroidal melanomas treated with Ru plaque brachytherapy using PS for preoperative planning, at the University of Southern California (USC) from 2003 to 2005. We further compare the radiation profiles with previously published results from similar tumors treated at our institution with I-125 EP plaques (8, 14).

Methods

This is a retrospective review of all patients who underwent episcleral plaque brachytherapy with Ru-106 for medium-sized choroidal melanomas at the USC between January 1, 2003 and December 31, 2005. This study was approved by the Institutional Review Board at USC.

Patient eligibility

Eligible patients were older than 18 years of age and were diagnosed by an ocular oncologist (ALM) with a primary, medium-sized choroidal melanoma with an apical height of less than 5.5 mm and maximum basal diameter of less than 16.0 mm (15). Large, diffuse, ill-defined tumors, tumors contiguous with the optic nerve for more than 3 clock-hours, tumors primarily involving the ciliary body or iris, and tumors with extrascleral extension were not treated with brachytherapy.

All patients were educated on treatment options including observation, enucleation, and proton beam therapy. Patients who chose brachytherapy were treated with Ru-106 plaques (Bebig GmbH, Berlin, Germany) with a prescribed dose of 85 Gy to the tumor apex (average dose rate range 61.7–220.9 cGy/h).

Data collection and patient followup

At diagnosis, complete history and examination with measurement of visual acuity (VA) with pinhole or manifest refraction, slit lamp examination, and fundoscopy of both eyes were completed. Tumors were characterized with

A-scan echography, B-scan echography (internal reflectivity, apical height, base diameter, and circumference), and color fundus photography at initial and followup examinations. Orbital imaging with computed tomography or magnetic resonance imaging was obtained, and systemic evaluation was performed by an internist or oncologist at the time of diagnosis and biannually (liver function serology and liver imaging as per the recommendations of the internist). Followup was performed after surgery at 3 months (range, 2–4 months), 6 months (range, 5–8 months), and 12 months (range, 9–14 months) and subsequently at 6- to 12-month intervals.

Adverse effects of radiation (blepharoptosis, strabismus, cataract, radiation retinopathy/vitreous hemorrhage, optic neuropathy, phthisis with/without pain, and local failure/recurrence) were evaluated at each visit. As with the COMS, local failure was defined by growth (>15% increase in tumor size on ultrasound; >250-μm increase in tumor border), extrascleral extension (>2 mm), or evidence of orbital recurrence (1). Primary outcome measures included local recurrence, enucleation, and death. Secondary outcome measures were plaque-related adverse side effects and change in VA. Histopathology was completed for all enucleated specimens.

Plaque protocol

The plaque planning and placement protocol has been described previously (8). Briefly, a single radiation physicist (MA American Board of Radiology authorized user) and a single ocular oncologist (ALM) completed all treatment plans and surgical procedures. The PS (Bebig GmbH) software was used for pretreatment planning using a single model CCD (serial number 241) Ru plaque with a 17.8 mm diameter (16) (Fig. 1). The coordinates of episcleral plaque fixation were planned to cover the tumor apex, base, and about a 2-mm retinal margin surrounding the base within a prescribed isodose of 85 Gy to the apex of the tumor. The prescribed dose was delivered over a varying number of days depending on the tumor height and the dose rate of the plaque at the Rx point at the time of implant. No pretreatment diagnostic biopsies were performed. All 15 treated patients had protocols available for review. Radiation doses to critical ocular structures were calculated with PS software based on plaque location and treatment time.

Statistical analysis

Snellen VA was recorded and converted to logarithm of the minimal angle of resolution format. Mean, median, range, and SDs were computed using Microsoft Excel (Redmond, WA, USA) functions. *p*-Values were calculated using the $\chi 2$ function.

Results

Patient population

Fifteen patients were treated using a Bebig model CCD Ru-106 plaque with placement protocols designed using PS software (16). The baseline patient demographics and clinical features are summarized in Table 1. Five patients (33.3%) were male, and 10 patients were female (66.7%). The median age at the time of treatment was 63 years (range, 42–82 years). Four patients (26.6%) had tumor in the right eye, and 11 patients had tumor in the left eye. All patients (100%) were caucasian (self-designation). Tumor height at diagnosis ranged from 2.8 to 5.5 mm with average (SD) apical height of 3.8 (0.8) mm. Basal diameter at diagnosis ranged from 7.8 to 15.3 mm with an average (SD) of 11.0 (2.0) mm. All tumors were located in the posterior pole, with the posterior border behind the equator in all (100%) patients. The median followup was 33.0 months (range, 10–120 months). Fourteen patients (93.3%) had more than 1-year followup, and seven patients (46.6%) had more than 3-year followup. After treatment, 14 patients (93.3%) retained their eyes. One treated eye (6.7%) was eventually enucleated because of a blind painful eye secondary to neovascularization with vitreous hemorrhage. This case was one of two tumors, which involved the ciliary body. There were no cases of local tumor recurrence. Data regarding long-term survival or metastasis are incomplete; however, no patient is known to have suffered metastatic disease or death related to their melanoma.

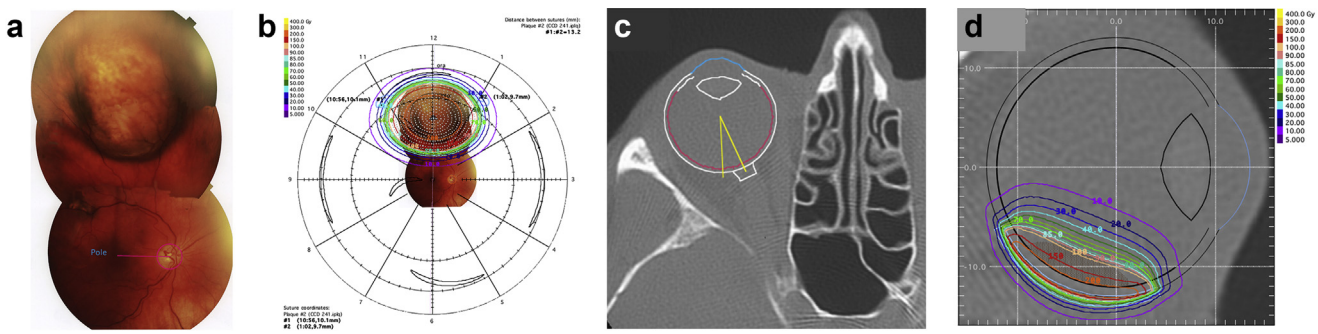

Fig. 1. Eye Physics treatment methodology. (a) fundus photograph of melanoma, (b) fundus photograph over a fundus landmark map with isodose profiles, (c) orbital CT of affected eye, (d) radiation profile mapped over CT image. CT = computed tomography.

Table 1
Patient's baseline characteristics

Characteristic	No.	(%)
Sex		
Male	5	33
Female	10	67
Age, y		
<50	2	13
50–69	5	33
≥70	8	53
Race/ethnicity		
White	15	100
Other	0	0%
Laterality of affected eye		
Right	11	73
Left	4	27
Visual acuity at diagnosis		
>20/20–20/40	8	53
20/50–20/150	4	27
≤20/200	3	20
Tumor apical height, mm		
<3	2	13
3–4	7	47
>4	6	40
Tumor basal dimension, mm		
4.5–8.0	1	7
8.1–11.0	6	40
11.1–14.0	8	53
Location of anterior border		
Ciliary body	2	13
Anterior to equator	5	33
Posterior equator	8	53
Location of posterior border		
Anterior to equator	0	0
Posterior to equator	15	100
Followup, mo		
6–14	3	20
15–24	4	27
25–36	1	7
37–48	0	0
≥60	7	47

The average dose to the tumor apex prescribed by PS software was 85.2 Gy (range, 84.2–86.7 Gy). The average dose to critical anatomical locations included optic nerve 9.2 Gy (range, 0.75–33.6 Gy), macula 30.2 (range, 0.03–131.9), and lens 0.74 Gy (range, 0–4.9 Gy) (Table 2).

Radiation dose and related adverse effects

Preoperative planning for any given tumor is dependent on the size and location of the tumor, available sources of radiation, and the ability to limit radiation exposure to critical ocular structures while treating the tumor apex to 85 Gy. At USC, Ru plaque usage was limited to tumors <5.5 mm in thickness owing to the steep dose gradient of Ru-106. The goal of using Ru-106 over I-125 was to possibly spare dose to the macula and/or optic nerve and the opposite side of the eye when treating these smaller tumors.

Table 2
Tumor response and clinical outcomes: comparison of patients from this study, with I-125 treated patients published previously (8)

Clinical characteristics and outcomes	Ru-106 University of Southern California	EP I-125 University of Southern California	COMS I-125
Baseline clinical characteristics			
Patients, No	15	82	638
Median followup, mo	33	47	67
Patients, %			
White	27	94	98
Male	73	60	50
Mean tumor height, mm	3.8	4.6	4.2
Mean basal diameter, mm	11.0	10.7	11.5
Anterior border posterior to equator, %	33	57	55
Tumor control			
Dose to tumor apex, Gy	85.2	85	85
Dose to optic nerve, Gy	9.2	46.6	52.1
Dose to macula/fovea, Gy	30.2	66.6	79.0
Dose to lens, Gy	0.7	15.2	15.6
Kap/Meier		3	10
Enucleation at 5 y, no	1	3	13
Metastatic disease at 5 y, %	NA	11	10
Visual and ocular outcomes, %			
Preoperative visual acuity			
20/40 or better	46.7	63	70
20/200 or worse	13.3	18	10
Postoperative visual acuity			
20/40 or better	33	35	34
20/200 or worse	33	43	43
Optic neuropathy	6.7	15	27
Radiation retinopathy	20	38	49
Cataracts	33	32	83

Ru-106 = ruthenium-106; EP = Eye Physics; COMS = Collaborative Ocular Melanoma Study; NA = not available.

Figure 2 presents isodose lines and dose area histograms for radiation emitted from Bebig Ru-106, EP I-125, and COMS I-125 plaques. It shows that the beta emitter, Ru-106, has a much more rapid dose drop off than I-125. Therefore, Ru-106 allows for treatment of thinner tumors with a prescribed dose of 85 Gy to the apex and a lower dose to other critical structures in the eye. Because of this shallow isodose profile, larger tumors require much higher doses at the base of the tumor when treated with Ru-106, and this can cause scleral necrosis. Demonstrated in Fig. 2, 90% of the tumor base (brown lines) treated with ruthenium receives about 225 Gy, whereas with iodine, 90% of the tumor base receives about 120 Gy. However, the macula and optic disc receive a dose close to 0 Gy with Ru-106 and a dose of about 20 Gy with I-125. The steep dose gradient of the Ru-106/Rh-106 emissions has the theoretical benefit of reducing radiation-related side effects postbrachytherapy. Incidences of adverse radiation effects included cataracts (33%), retinopathy (20%), and optic neuropathy (6.7%), which were comparable or less than rates of radiation toxicity from EP I-125 plaques (31.7%, 37.8%, and 14.6%, respectively) and COMS plaques (8).

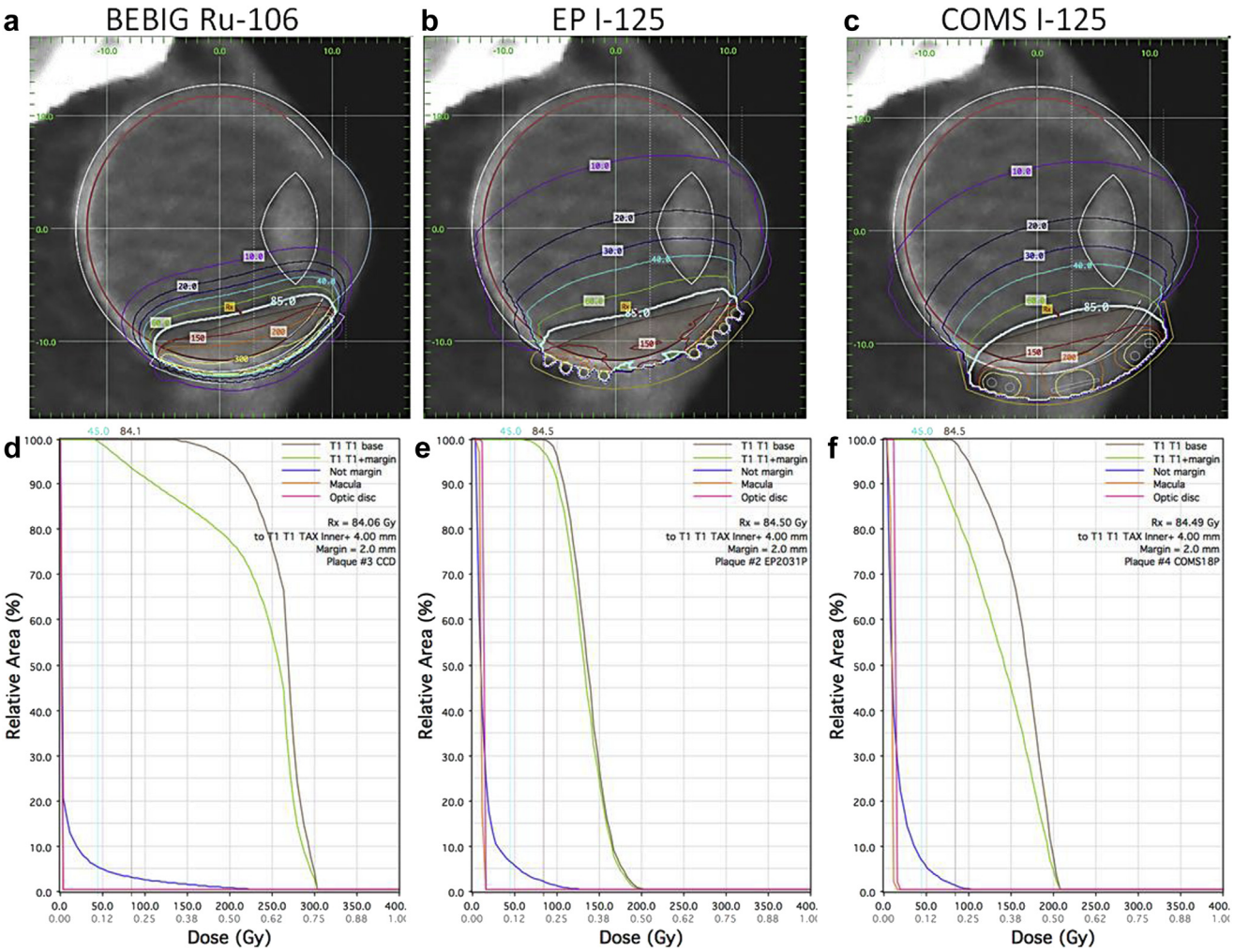

Fig. 2. PS comparison of (a–c) isodose lines on a meridian plane bisecting the eye through the tumor apex (each with a prescription point of 85 Gy to a 4-mm apex) and (d–f) dose area histograms for the tumor potentially treated with Bebig Ru-106 (a, d), EP I-125 (b, e), or COMS I-125 (c, f) plaques. PS = Plaque Simulator; EP = Eye Physics; COMS = Collaborative Ocular Melanoma Study.

The average dose to the optic disc was 9.17 Gy (range, 0.75–33.56 Gy, only one received >55 Gy to the nerve). The average dose to the macula was 30.21 Gy (range, 0.03–131.9 Gy, three received >55 to the macula).

Vision

Snellen VA was measured at time of diagnosis and at each followup visit. Eight (53%) patients had VA better than or equal to 20 of 40, and 12 patients had VA better than 20 of 200 (80%) at the time of diagnosis. Changes in VA compared with the initial visit and at each followup are plotted with color coding for those patients who experienced radiation-related cataract, retinopathy, or optic neuropathy (Fig. 3). Seven patients (46.7%) lost vision after brachytherapy, of which three patients experienced concomitant adverse effects from radiation. Four patients (26.7%) experienced improved vision, of which two patients experienced a concomitant adverse effect from radiation. Three patients (20.0%) experienced no change in vision. The presence of an adverse side effect was neither inclusive nor exclusive of vision loss.

Tumor height

Tumor height after therapy demonstrated regression profiles equivalent to tumors treated with I-125 plaques. Five-year tumor heights for radiation-treated tumors were approximately 61% ± 29% (I-125, n = 16) and 53% ± 17% (Ru-106, n = 6) relative to their heights at diagnosis (Fig. 4). The tumor response regardless of radiation source or eventual metastasis is equivalent.

Discussion

Results of posterior uveal melanomas treated with Ru plaque brachytherapy monotherapy in the literature are summarized in Table 3 and support the utility of ruthenium for globe-sparing therapy in the treatment of medium choroidal melanomas less than 5.5 mm in height.

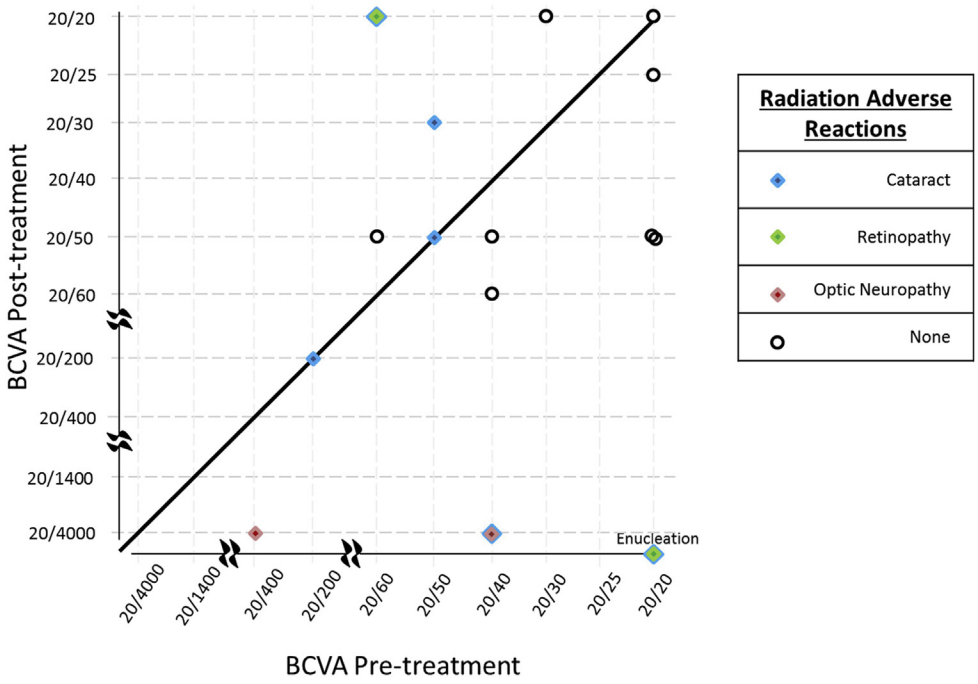

Fig. 3. Changes in each patient's visual acuity from before treatment to after treatment. Colors indicate concomitant radiation adverse reactions. BCVA = best corrected visual acuity.

Comparing EP I-125 plaques with Ru-106 plaques, the percentage of patients who dropped below 20 of 40 vision after treatment were 28.0% and 13.7%, respectively. Similarly, the percentage with vision worse than 20 of 200 increased for EP I-125 plaques and Ru-106 plaques by 24.7% and 20.0%, respectively.

Although this series of patients is limited by the number of patients treated, comparing melanoma treated by PS planned treatments with EP I-125 plaques or Bebig Ru-106 show that half as many patients treated with ruthenium plaques, when compared with iodine plaques, experienced a decline below 20 of 40 vision. This observation should be evaluated in the context of PS planning for I-125 treatments, which produces similar outcomes to COMS therapy (8). Larger studies in the future may reveal that the differing radiation profiles of COMS, EP I-125, and Bebig Ru-106 account for differences in adverse visual outcomes.

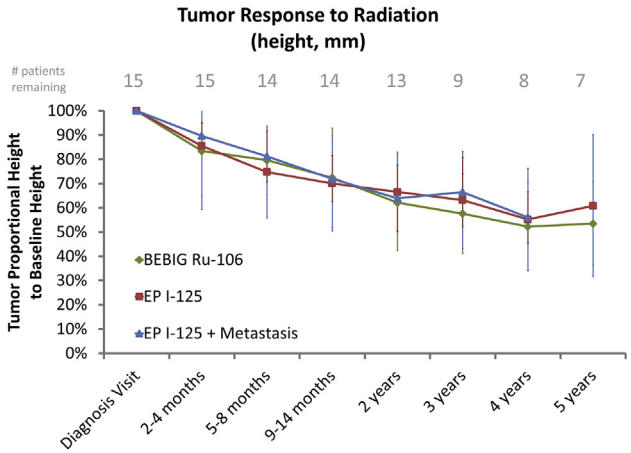

Fig. 4. Tumor response to plaque brachytherapy with EP I-125 (red) and Bebig Ru-106 (green). The subgroup of patients who were treated with EP I-125 and developed metastasis is plotted in blue. EP = Eye Physics. (For interpretation of references to color in this figure legend, the reader is referred to the web version of this article.).

Patient selection is probably an important factor for the success of ruthenium plaque brachytherapy. The tallest tumor treated in our series was 5.5 mm. To deliver 85 Gy at the tumor apex, the much steeper dose gradient of Ru-106 compared with I-125 requires that a notably higher dose be delivered to sclera in contact with the concave face of the Ru plaque compared with using an I-125 plaque. For this reason, when given a choice between ruthenium and iodine in the setting of taller tumors (i.e., >5.5 mm apical height), I-125 has been the conventionally recommended radionuclide. We adhered to this conventional recommendation.

The location of the tumor is also likely to be an important consideration. When the tumor overlies or is adjacent to the optic disc or macula, these critical regions will be irradiated to some extent during brachytherapy no matter the radiation source. Collimation is probably the best way to spare these posterior sites when they are located immediately adjacent to a plaque. On the other hand, in the treatment of anteriorly located tumors, beta-emitting Ru-106 may spare these critical posterior structures to a greater extent than the more penetrating gamma-emitting sources.

Perri *et al.* (11) demonstrated an unexpectedly high tumor recurrence rate with Ru-106 brachytherapy, but there was a note that surgeon experience with inserting the

Table 3
Summary of outcomes for posterior uveal melanoma treated ruthenium-106 plaque brachytherapy

	Number of patients	Years	Size	Apex dose[a]	Plaque margin	Survivor median followup	Progression -free survival (%)	Enucleation-free survival (%)
(Bergman, Nilsson *et al.* 2005)	579	1979–2003		100 Gy to 1 mm above apex	NA	82	86 (3 y)	82 (3 y)
(Damato, Patel *et al.* 2005)	458	1993–2001		80–100 Gy	≥2 mm	46.8	98 (5 y)	98 (4 y)
(Verschueren, Creutzberg *et al.* 2010)	425	1993–2004		100–150 Gy	NA	50	96 (5 y)	96 (5 y)
(Perri, Fiorica *et al.* 2012)	142	1990–2009	Small, medium	80–100 Gy	2 mm		84 (5 y), 76 (15 y)	93[b]
(Marconi, de Castro *et al.* 2013)	83	2004–2008	Small, medium, few large	100 Gy	2–4 mm	>36 mo	94 (5 y)	84 (5 y)
(Isager, Ehlers *et al.* 2006)	55	1988–2000	Small, medium, large	100 Gy at 6-mm apex	NA		73 (5 y)	72 (5 y)
(Takiar, Gombos *et al.* 2014)	40	2003–2007	Small, medium	90 Gy (range, 85–90)	NA	67 mo	94.4 (5 y)	100
(Barker, Francis *et al.* 2014)	28	2000–2008	Small, medium	Range, 75.0–75.5 Gy	2 mm	71 (10–95)	59 (5 y)	84 (5 y)
(Dias, Giordani *et al.* 2007)	20	2002–2003	Small, medium	Range, 55.8–104.8 Gy	NA	19 mo	75 (19 mo)	100 (19 mo)
Present study	15	2003–2005	Medium	85.2 Gy	2 mm	33 (range, 10–120)	100 (5 y)	93 (5 y)

NA = not available.
[a] Dose is reported as described in the primary source.
[b] No enucleations from radiation complications.

plaque may have impacted local failure. Barker et al. indicated that outcomes when using Ru-106 therapy may be best achieved at centers with COMS experience and when users give special consideration to dose applied to tumor margins (13). Furthermore, it has been reported that the use of intraoperative ultrasound may further help to decrease local recurrences (17). In comparison with these recommendations, our results using three-dimensional pretreatment modeling showed no recurrences in 15 consecutive patients with a low complication rate from radiation. Distinguishing between the dosimetric footprint produced by a plaque compared with that plaque's physical footprint is important, and using pretreatment modeling may account, in part, for the difference in recurrence by assuring precisely situated plaques with adequate dosimetric margins, which encompass the tumor and margin within the prescribed radiation isodose surface. Intraoperative ultrasound was not used in our study; however, scleral depression was used to visually confirm the plaque location and physical margins. Additionally, this study is limited in similar fashion to other studies by its small cohort size and retrospective nature (10, 11, 13, 18, 19); however, the efficacy and safety results are similar across large and small studies (20–22).

The cost of radionuclide chosen for plaque brachytherapy is a significant consideration, particularly in the current health care era. Ru-106 plaques ($4000 in 2003 and $7000 in 2015) have a much higher initial cost per plaque than I-125 plaques ($60–100 per seed), with an average of 15 but overall variable number of seeds per plaque (and roughly $1200–1500 per treatment). However, Ru-106 also has a much longer half-life (approximately 1 year) than I-125 (approximately 60 days). This allows the Ru plaques a longer useful lifetime (9) and hence the ability to reuse them for multiple treatments. This reduces the cost per patient when compared with I-125 plaques, which are generally intended for single use. Some institutions do reuse I-125 seeds to reduce costs; however, the treatment time can be significantly extended. Based on the longer half-life, ruthenium plaques can be reused for multiple patients for approximately 2 years after purchase (23). It should be noted, however, that whereas the delivered dose rate for I-125 plaques is easily configurable to fit a standardized prescription and treatment duration protocol (e.g., 85 Gy in 7 days), the Ru plaque steadily decays over its useful lifetime with the result that every treatment requires a different implant duration as a function of the prescribed dose, tumor height, and the strength of the plaque at the time of insertion. Fili *et al.* (24) have reported that dose rate of ruthenium did not affect patient outcomes only the treatment time for the plaque to be in place. Therefore, in a busy ocular oncology service, there may well be a financial advantage to use of ruthenium. However, despite this possible financial advantage, ruthenium is not appropriate for all tumors. Ruthenium offers theoretical protection of distal critical structures when treating small and anterior

tumors but creates logistical issues as it decays and probably offers little advantage compared with collimated I-125 for larger tumors or tumors adjacent the optic disc or fovea.

Conclusions

Treatment of medium-sized choroidal melanomas with a maximum apex height of 5.5 mm can be accomplished effectively with PS pretreatment modeling and ruthenium plaques. These Ru plaques have been shown effective for the treatment of choroidal melanomas in multiple studies; additionally, in appropriate clinical scenarios, Ru plaques may more effectively spare critical structures such as the optic disc and macula while still delivering the prescribed dose to the base, margin, and apex of the tumor.

The patient subset reported herein had background characteristics similar to those reported in the COMS studies and patients treated with EP I-125 plaques. Treatment response was equivalent, and radiation complications occurred slightly less frequently than those patients treated with I-125 radiation. These results, although promising, justify the need for a larger study using our method for preoperative planning and ruthenium plaque brachytherapy to verify this observation. At 5 years, tumors treated with brachytherapy shrink to about 50−60% of their initial height at diagnosis regardless of the radionuclide used.

PS image-guided pretreatment modeling for plaque brachytherapy is an effective method and demonstrates similar results compared with COMS results regardless of radiation source. Ru plaques show similar efficacy as COMS plaques for small uveal melanomas (<5 mm apical height) although evidently reducing radiation toxicities. With new imaging technologies allowing detection of uveal melanomas at an earlier stage, we may see a rise in the interest of Ru-106 plaque use.

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