American Brachytherapy Society radiation oncology alternative payment model task force: Quality measures and metrics for brachytherapy

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ABSTRACT

PURPOSE: Brachytherapy is an essential technique to deliver radiation therapy and is involved in the treatment of multiple disease sites as monotherapy or as an adjunct to external beam radiation therapy. With a growing focus on the cost and value of cancer treatments as well as new payment models, it is essential that standardized quality measures and metrics exist to allow for straightforward assessment of brachytherapy quality and for the development of clinically significant and relevant clinical data elements. We present the American Brachytherapy Society consensus statement on quality measures and metrics for brachytherapy as well as suggested clinical data elements.

METHODS AND MATERIALS: Members of the American Brachytherapy Society with expertise in disease site specific brachytherapy created a consensus statement based on a literature review and clinical experience.

RESULTS: Key quality measures (ex. workup, clinical indications), dosimetric metrics, and clinical data elements for brachytherapy were evaluated for each modality including breast cancer, cervical cancer, endometrial cancer, prostate cancer, keratinocyte carcinoma, soft tissue sarcoma, and uveal melanoma.

CONCLUSIONS: This consensus statement provides standardized quality measures and dosimetric quality metrics as well as clinical data elements for each disease site to allow for standardized assessments of brachytherapy quality. Moving forward, a similar paradigm can be considered for external beam radiation therapy as well, providing comprehensive radiation therapy quality measures, metrics, and clinical data elements that can be incorporated into new payment models. © 2021 American Brachytherapy Society. Published by Elsevier Inc. All rights reserved.

Keywords: Brachytherapy; Radiation; Quality assurance; Metrics
Introduction

Brachytherapy represents a key component in the treatment paradigm of many cancers and can improve outcomes (ex. cervical cancer), reduce toxicities (ex. prostate brachytherapy), shorten treatment duration (ex. breast cancer), and even allow for re-treatment in the setting of recurrence (ex. soft tissue sarcoma). An important aspect of any procedural technique, including brachytherapy, is a dedicated focus on quality assurance (QA) and improvement, something that has been demonstrated with surgical procedures (1). At the patient level, QA programs and procedures ensure that each patient’s procedure is delivered with the highest level of quality and safety possible. At the programmatic level, pooled data from QA programs allows for teams to identify areas of success and areas for improvement, with quality improvement programs allowing for constant iteration and change over time. However, one challenge facing such programs is defining standardized quality metrics that are externally validated.

At this time, paralleling the focus on quality and safety, is a growing focus on cost and value in healthcare and in particular cancer care, with the costs of treatment expected to substantially increase in the years to come (2). One approach to addressing these rising costs has been the consideration of new payment models that fix costs and tie reimbursement in some cases to quality metrics (3). While radiation oncology represents a small component in the total cost of care, the Centers for Medicare and Medicaid Services (CMS) has finalized an alternative payment model (APM) that will provide episodic bundled payments for 16 disease sites, irrespective of the treatment modality utilized or the number of treatments delivered within an episode of care; while brachytherapy was initially included, it has subsequently removed from the model (3). A primary goal of this model is to reduce Medicare expenditures while preserving or enhancing the quality of care as it pertains to radiation oncology. However, a major challenge for new payment models is how to define and monitor the quality and safety of care, given the lack of standardized metrics that can help to define high quality and safe care (4). Similar to QA programs, one solution is development of a standardized set of quality metrics by disease site. Additionally, moving forward, payors may look to identify clinical data elements (CDEs) by asking providers to submit data from their practices, which can be quite onerous for practices. We therefore present the American Brachytherapy Society (ABS) consensus statement for quality measures and metrics in brachytherapy as well as CDEs by disease site.

Methods

The ABS Board of Directors appointed a group of physicians with expertise in brachytherapy for each respective disease site to provide a consensus statement. Previous ABS publications were incorporated into the present guideline. A literature review was performed to evaluate human clinical studies available in English language evaluating brachytherapy for each disease site to assist with QA measures and metrics; of note this guideline was not based on a systematic review but rather focused on published guidelines and studies that evaluated brachytherapy metrics. The goal of the guidelines, based on the literature review and clinical expertise, is to provide a set of standardized quality measures and metrics that can be incorporated for each disease site and indication of brachytherapy; of note, this guideline’s primary focus was brachytherapy and as such does not incorporate QA measure/metrics with respect to work-up/staging and/or external beam radiation therapy. Additionally, CDEs that are part of best practice for each disease site were created. Levels of evidence for CDE’s were provided based on the Center for Evidence-Based Medicine: IA: Systematic review (with homogeneity) of randomized trials, IB: Individual randomized trial with narrow confidence intervals, IC: All or none study, IIA: Systematic review with homogeneity of cohort studies, IIB: Individual cohort study (including low quality randomized trials), IIC: outcomes research, IIIA: systematic review with homogeneity of case-control studies, IIB: individual case-control study, IV case series, and V expert opinion without explicit critical appraisal or based on physiology bench research or “first principles.”(5) Prior to publication, the consensus statement was approved by the ABS Board of Directors.

Results

Breast

Adjuvant radiation therapy following breast conserving surgery is associated with a reduction in local recurrence as well as improved breast cancer mortality (6). While traditionally delivered as whole breast irradiation (WBI) delivered with external beam radiation therapy (EBRT), more recently, partial breast irradiation (PBI) has emerged as a standard of care approach for appropriately selected women with early stage breast cancer; most randomized studies have shown no difference in rates of local recurrence with PBI though NSABP B-39 did not meet its threshold for equivalence (7–9). PBI can be delivered with EBRT or brachytherapy, with indications and quality measures/metrics provided in Table 1 (7–9). At this time, multiple consensus guidelines are available for patient selection for PBI with current ABS guidelines supporting its use in women 45 years or older with T1–2 (≤ 3 cm) cancers that are node negative with negative surgical margins and no LVI/S present (7).

Brachytherapy based PBI can be delivered with interstitial or applicator based techniques with multiple dose and fractionation regimens available (7,10). For interstitial PBI,
common dose and fractionation regimens include 34 Gy in 10 fractions delivered twice daily, 32 Gy in 8 fractions delivered twice daily, and 30.2/36.4 Gy in 7 fractions delivered twice daily (7, 10). Hypofractionated fractionation regimens have also been studied (11). Target volumes for interstitial PBI should include delineation of the lumpectomy cavity with a 1.5–2.5 cm expansion; with this technique the CTV=PTV=PTV_EVAL and is limited 0.5 cm from the skin and from beyond the posterior extent of breast tissue. For applicator based PBI, the most common regimen is 34 Gy in 10 fractions delivered twice daily, though 32 Gy in 8 fractions twice daily can also be considered (7, 10).

For applicator brachytherapy the expansion from the applicator surface is 1 cm, limited 0.5 cm from the skin and from beyond the posterior extent of breast tissue; it should be noted that this expansion is smaller than that seen with interstitial or external PBI regimens but it is what has consistently been utilized in randomized and prospective studies (10). With respect to intraoperative radiation, at this time, it is not considered a standard PBI approach and should not be utilized outside of prospective studies (7, 8, 12). As such, it should not be considered an approved technique to deliver adjuvant radiation as part of current payment models.

**Quality Measures:** A key measure is the multidisciplinary evaluation of breast cancer patients including breast surgeon, medical oncology, and/or a radiation oncologist or alternatively a discussion at a multidisciplinary tumor board. With respect to patient selection for PBI, it is recommended that clinicians utilize current guidelines for patient selection or trial criteria (7–9).

**Quality Metrics:** NSABP B-39/RTOG 0413 was recently published with long-term outcomes (10). Dosimetric quality metrics from the study are provided in Table 1. For interstitial and applicator brachytherapy, V150/V200 should be minimized while preserving PTV coverage V90% ≥ 90% (Level of Evidence: IB).

### Cervical Cancer

Brachytherapy is an integral part of definitive treatment for patients with locally advanced cervical cancer and can be performed with high dose rate (HDR), pulsed dose rate (PDR) or low dose rate (LDR) technique (16–21). For patients with a positive vaginal margin after radical hysterectomy, brachytherapy is conditionally recommended in the postoperative setting (21). The commonly used applicators for cervical cancer in the definitive setting are tandem and ring or tandem and ovoids. Hybrid applicators or interstitial brachytherapy may be required to improve coverage of the target volume and reduce dose to organs at risk, particularly when the High Risk Clinical Target Volume (HRCTV) is greater than 30 cc or geometry is not suitable for intracavitary brachytherapy alone (21, 22).

Real-time image guidance, such as ultrasound imaging, is recommended for placement of a tandem in order to decrease the probability of creating a false track or uterine perforation and to ensure adequate coverage of the tumor (23) A sleeve can be placed to facilitate tandem insertion. With respect to treatment planning, 3D image-based brachytherapy is recommended with either MRI or CT scan used for imaging to help conform dose to target volumes while reducing dose to critical organs (17, 21, 22, 24).

Multiple prospective and single institution studies have shown improved local control and reduced morbidity with 3D brachytherapy in comparison to 2D-based planning (21, 22, 24). In the largest prospective study (EMBRACE-1) 5-year local control was 92% with actuarial cumulative 5-year incidence of Grade 3–5 morbidity of 6.8% GU, 8.5% GI, and 5.7% vaginal events (25). 3D imaging should be performed at each fraction with the applicator in place to account for changes in applicator placement, target volumes or position of critical organs (17, 21, 22, 24).

The most common dose schedules used for HDR brachytherapy are 27.5–30 Gy in 5 fractions or 28 Gy in 4 fractions as part of definitive treatment with EBRT (18, 21, 26). The most common doses for LDR or PDR

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Quality measures and metrics for partial breast irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quality measures</strong></td>
<td><strong>Metrics</strong></td>
</tr>
<tr>
<td>Multidisciplinary evaluation with a breast surgeon, a medical oncologist, and/or radiation oncologist or discussion at a multidisciplinary tumor board</td>
<td><strong>Interstitial Brachytherapy:</strong></td>
</tr>
<tr>
<td></td>
<td>PTV_EVAL: V90% ≥ 90%</td>
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<tr>
<td></td>
<td>V150% ≤ 70 cc</td>
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<td></td>
<td>V200% ≤ 20 cc</td>
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<tr>
<td></td>
<td>Dose Homogeneity Index ≥ 0.75</td>
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<tr>
<td></td>
<td>Uninvolved breast: V50% &lt; 60%</td>
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<tr>
<td></td>
<td><strong>Applicator Brachytherapy:</strong></td>
</tr>
<tr>
<td></td>
<td>PTV_EVAL: V90% ≥ 90%</td>
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<tr>
<td></td>
<td>Air/fluid subtracted from PTV_EVAL dose coverage &lt; 10% of total PTV_EVAL volume</td>
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<tr>
<td></td>
<td>Maximum skin ≤ 100% (acceptable ≤ 125%)</td>
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<tr>
<td></td>
<td>V150 ≤ 50 cc</td>
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<tr>
<td></td>
<td>V200 ≤ 10 cc</td>
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<tr>
<td></td>
<td>Uninvolved breast: V50% &lt; 60%</td>
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</table>
is 30–45 Gy depending on the external beam dose to deliver a total dose of 80–90 Gy (19,21,26). In the postoperative setting, the technique is either single channel or multiple channel vaginal cylinder based on location with a range of dose/fractionation schedules based on margin status and presence/absence of residual disease (21,26). If disease depth is greater than 5 mm, interstitial brachytherapy should be considered.

Quality Measures: All patients with locally advanced disease should be evaluated by a multidisciplinary team and, if appropriate candidates, offered definitive treatment with external beam, concurrent cisplatin based chemotherapy, and brachytherapy.

Quality Metrics: Coordination of care should focus on completing radiation therapy (external beam and brachytherapy) within 8 weeks when possible; there may be instances outside the practitioner’s control or clinical factors (ex. persistent neutropenia or thrombocytopenia, etc.) where delaying care is appropriate. Reduction in target doses may be necessary to meet normal tissue tolerances; however, informed discussion with patients regarding risks and/or benefits of dose reduction versus exceeding normal tissue tolerances and maintaining prescription dose should occur when appropriate. The target D90 to the HR-CTV should be ≥ 85 Gy. If necessary to meet normal tissue dose constraints, a lower target dose of ≥ 80 Gy for tumors with ≤ 4 cm of disease at the time of brachytherapy may be appropriate. The rectal D2cc constraint was traditionally 70–75 Gy while recent data has supported a lower dose of 65 Gy (17-19,21,22,25); as such, the guidelines in Table 2 reflect the modern goal of 65 Gy, while accepting a maximum of 75 Gy. Similarly, with respect to the bladder D2cc constraint, traditionally higher dose up to 90 Gy were accepted, but modern data support a constraint of 80 Gy (17-19,21,22,25).

Endometrial cancer

Brachytherapy can be utilized in the management of endometrial cancer as adjuvant therapy or definitively for medically inoperable patients (27). Postoperatively, treatment recommendations can vary from observation, vaginal brachytherapy alone, EBRT alone or a combination of EBRT plus HDR brachytherapy with indications for adjuvant radiation based on the prognostic risk group after surgical staging and cervical stroma involvement (27–29). For vaginal cuff recurrences with no prior RT, the combination of EBRT plus HDR brachytherapy is recommended (26). For medically inoperable patients treatments options are EBRT plus brachytherapy or brachytherapy alone based on grade and extent of disease (30).

When delivering adjuvant brachytherapy, vaginal examination is recommended prior to initiating therapy to ensure the vaginal cuff is healed and to assess the size of the vagina for cylinder size selection. Most commonly, a single channel vaginal cylinder is utilized but other applicators can be used, depending on the patient’s anatomy (31). The target volume includes the upper part of the vagina (2–4 cm in length). CT simulation is recommended to ensure adequate placement of the applicator abutting the apex with no significant air gaps (28). The most common adjuvant HDR brachytherapy alone dose schedules are 7 Gy x 3 prescribed to 5 mm depth or 6 Gy x 5 prescribed to the vaginal surface (26,28). Other schedules are also available (26). For patients receiving post-operative EBRT with brachytherapy, commonly used schedules include 5–6 Gy x 2–3 fractions prescribed to the vaginal surface (26). In patients with inoperable endometrial cancer, the dose for HDR brachytherapy after 45 Gy in 25 fractions with EBRT is variable with a range of dose and fractionation schedules being reported (26,30). EQD2 of the CTV D90 is recommended to be in the 65–75 Gy range for Stage I and 70–75 Gy for Stage II-III patients (30). The same normal tissue tolerances used in cervical cancer should be applied in the setting of inoperable endometrial cancer.

In patients with recurrent disease, the brachytherapy technique options include either a single or multichannel cylinder or interstitial implant based on the location and extent of residual disease following EBRT. In the setting of recurrent disease, 3D image-based planning with CT scan or MRI is recommended with dose to organs at risk similar to those utilized in cervical cancer (21,22,24,31,32). Dose and fractionation include 45 Gy in 25 fractions with EBRT...
followed by a brachytherapy boost to achieve an EQD2 > 70 Gy prescribed to the residual tumor volume (26).

Quality Measures: All patients should be evaluated in a multidisciplinary setting. For adjuvant vaginal cuff brachytherapy all patients should have a documented vaginal examination prior to initiating brachytherapy (Table 3). Brachytherapy should be utilized instead of pelvic external radiation in appropriately selected patients.

Quality Metrics: Adjuvant brachytherapy should start ≤ 9–12 weeks after surgery (Table 3). A CT scan or kV imaging with fiducials should be performed to confirm appropriate cylinder placement and to ensure no significant air gaps.

Table 3
Quality measures and metrics for brachytherapy in endometrial cancer

<table>
<thead>
<tr>
<th>Quality measures</th>
<th>Metrics</th>
<th>Level of evidence</th>
<th>Source of data</th>
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<tbody>
<tr>
<td>Multidisciplinary evaluation with a gynecologic oncologist</td>
<td>Adjuvant Brachytherapy:</td>
<td>IB</td>
<td>NCCN Guidelines (27)</td>
</tr>
<tr>
<td>surgical oncologist, medical oncologist, and/or radiation oncologist or discussion at a multi-disciplinary tumor board</td>
<td>Start adjuvant treatment within 9–12 weeks after surgery</td>
<td>IB</td>
<td>Klopp et al (28)</td>
</tr>
<tr>
<td>Vaginal examination prior to initiating brachytherapy</td>
<td>CT scan for confirmation of placement and ensure no significant air gaps</td>
<td>IB</td>
<td>Meyer et al (29)</td>
</tr>
<tr>
<td>Utilization of vaginal cuff brachytherapy in appropriately selected postoperative patients</td>
<td>EBRT and brachytherapy:</td>
<td>IB</td>
<td>Schwarz et al (30)</td>
</tr>
<tr>
<td>(Consider ASTRO, EMBRACE and ABS Guidelines)</td>
<td>D90 ≥ 70–80 Gy</td>
<td></td>
<td>Small et al (31)</td>
</tr>
<tr>
<td></td>
<td>D2 cc of rectum &lt; 65 Gy (maximum &lt; 75 Gy)</td>
<td></td>
<td>Cattaneo et al (33)</td>
</tr>
<tr>
<td></td>
<td>D 2 cc of bladder &lt; 80 Gy (maximum &lt; 90 Gy)</td>
<td></td>
<td>Potter et al (34)</td>
</tr>
<tr>
<td></td>
<td>D 2 cc of sigmoid &lt; 70 Gy (maximum &lt; 75 Gy)</td>
<td></td>
<td>Kamrava et al (35)</td>
</tr>
<tr>
<td></td>
<td>Rectovaginal point &lt; 65 Gy (maximum 75 Gy)</td>
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Prostate cancer

Radiation therapy is a standard of care treatment for prostate cancer (36–38). Brachytherapy is a radiation technique used in the definitive management of prostate cancer for all prostate risk groups; brachytherapy can be delivered either with LDR (permanent seed: Iodine-125, Palladium-103, Cesium-131) or HDR (temporary Iridium-192 (Ir-192) source placement) brachytherapy and can be delivered alone as monotherapy or in conjunction with EBRT. The dosing and sequencing are dependent on risk stratification (36,39).

Brachytherapy as monotherapy is recommended for patients with low-risk to favorable intermediate-risk prostate cancer (36). Long-term outcomes with LDR and HDR monotherapy have demonstrated excellent rates of biochemical control with low-rates of acute and chronic toxicity with long-term follow-up (40–45). Recently, a prospective study (RTOG 0232) found less toxicity with no significant PFS difference with brachytherapy alone in comparison to the combination of external beam radiotherapy and brachytherapy (41). When utilizing permanent seed LDR brachytherapy as monotherapy a dose of 140–160 Gy, 110–125 Gy and 100–115 Gy is utilized with I-125, Pd-103, and Cs-131, respectively (46). In controlled studies, there does not appear to be differences in outcome or toxicity between the three radionuclides (47,48). Postoperative imaging and dosimetry is essential for every LDR prostate seed implant given the association between dosimetry and oncologic success (46). MRI has superior soft-tissue delineation than ultrasound and CT and can be incorporated into each step of the quality assurance process from diagnosis, treatment planning, treatment, and post-implant quality assessment, depending on availability and access (49,50). With HDR brachytherapy, treatment is delivered over 15–20-minutes using a high activity Ir-192 source using ultrasound-, CT-, or MR-based planning with an afterloader delivery platform (51). Commonly used monotherapy regimens include 43.5 Gy in 6 fractions, 38 Gy in 4 fractions, 31.5 Gy in 3 fractions, and 27 Gy in 2 fractions (51). Single fraction HDR has been evaluated but initial outcomes raised concerns of elevated biochemical failure rates (52).

For men with unfavorable intermediate risk to very high-risk prostate cancer, prospective, randomized trials have compared the addition of LDR or HDR prostate brachytherapy delivered as a boost with EBRT to EBRT alone. These trials have consistently demonstrated statistically significant improvements in biochemical failure with the addition of brachytherapy boost (53–55). ASCENDE-RT compared现代 external beam radiotherapy with IMRT alone versus the addition of LDR boost to IMRT. All men received 1 year of androgen deprivation therapy. At a medium follow-up of 6.5 years, EBRT + LDR boost was associated with an improved biochemical progression free survival with a moderate increase in both GU/GI late toxicity (53). A nuance of the study design is that once a patient failed, which was twice as likely without boost, toxicities stopped being recorded. Therefore, comparison data is truly not known for all survivors, though patient reported quality life outcomes in 9 of 11 scales were not significantly different between arms prior to censoring (56,57). In the prospective, multi-institutional cooperative group study RTOG 0321, HDR was utilized as a boost with
EBRT and demonstrated excellent long-term clinical outcomes with very low rates of toxicity (58). Finally, Hoskin et al. reported on a randomized comparison of HDR boost combined with EBRT compared to EBRT alone. This study showed HDR boost significantly improved 10-year biochemical survival rates with no additional toxicity (54). When utilizing permanent seed LDR brachytherapy as a boost, 108–110 Gy, 90–100 Gy, and 70–85 Gy is utilized with I-125, Pd-103, and Cs-131, respectively (59). With HDR brachytherapy boost, 15 Gy in 1 fraction is commonly utilized as are two fraction approaches (54,58,59).

Quality Measures: Patients diagnosed with prostate cancer should be evaluated in a multidisciplinary setting including a urologist and radiation oncologist with or without a medical oncologist as indicated. Currently patients should be stratified by risk criteria (i.e., National Comprehensive Cancer Network Risk Criteria) to aid treatment decision making (36). Brachytherapy monotherapy should be considered in patients with low-risk prostate cancer elective not to proceed with active surveillance and also in patients with favorable intermediate risk disease. Brachytherapy as a boost in addition to EBRT should be considered in patients with unfavorable intermediate- to very-high risk disease. In patients with prostate volume ≥60 cc, International Prostate Symptom Score (IPSS) ≥20, or prior transurethral resection defect, the benefit of brachytherapy should be weighed against the possibility of increased urinary symptoms (39). If available, MRI should be incorporated into each step of the quality assurance process to facilitate a consistent high-quality implant with precise dosimetric feedback to the clinical team (49,50,60,61).

Quality metrics

For both LDR and HDR prostate brachytherapy, dosimetric recommendations are presented in Table 4 for brachytherapy as both monotherapy and a boost. Table 5 presents constraints by isotope for LDR brachytherapy. Postimplant quality assurance for LDR brachytherapy should be performed as soon as possible after the implant and not to exceed 30 days, if necessary, to permit resolution of edema.

Skin cancer

Multiple techniques exist to treat non-melanomatous skin cancer (i.e., keratinocyte carcinoma (KC)) including surgery and radiation therapy (62,63). Amongst radiation therapy techniques utilized to treat KC, brachytherapy is a well-established treatment for appropriately selected KC’s with indications, dose and fractionation regimens, and metrics provided in Table 6 (64,65). For patients receiving skin brachytherapy it is recommended that the GTV should be marked out clinically at the time of simulation using all available information; the lesion may then be outlined with radio-opaque markers for reference (64). Radionuclide based applicators are commonly utilized for small skin cancers with limited depth of invasion (no more than 3–4 mm) for lesions located on a regular surface (64). With this technique the GTV is defined as the tumor with a CTV of 5–10 mm for BCC and 7–20 mm for SCC with a PTV expansion of 2–5 mm radially and 1 mm in depth (64). Molds and flaps can be used for larger lesions with a depth of invasion up to 5 mm and can be used on irregular or curved surfaces (64). The GTV is defined as the tumor with a CTV expansion of 10 mm. In such cases the CTV and PTV are the same (64). Interstitial brachytherapy can be utilized when greater depth is needed or for larger areas with similar target volumes to molds/flaps (64). CT based dosimetry should be utilized for mold/flap and interstitial brachytherapy (64). Regardless of technique, at the time of treatment, care should be taken to ensure no air gaps exist between the applicator/mold/flap and the treated lesion (64).

With respect to dose and fractionation, brachytherapy allows for hypofractionated regimens; however, more protracted regimens can be utilized in sensitive areas.
(Table 6) (64). Electronic brachytherapy typically works in the 50–70 kVp range and has been evaluated to treat superficial skin cancers; however, while initial data are promising, further study with long term follow-up is needed before being utilized outside of prospective studies (64,66). Additional concerns include dose calculations in tissues and a lack of consensus dosimetry (66).

**Quality Measures:** Patients with a diagnosis of KC should undergo multi-disciplinary evaluation or discussion at tumor board. Lesions considered for brachytherapy with applicators should be small (<2 cm) and shallow (≤4 mm) though molds/flaps or interstitial brachytherapy can be used for larger and deeper lesions. Brachytherapy should not be utilized when lesion has invasion beyond subcutaneous fat, bone invasion, clinical PNI, or in patients with select genetic conditions.

**Quality Metrics:** Standardized dose/fractionation regimens by brachytherapy technique are presented in Table 6. In general, the 100% isodose line should cover the PTV regardless of technique with minimization of hot spots and surface dose.

### Sarcoma

Adjuvant radiation therapy following limb-sparing surgery has been shown to reduce rates of local recurrence when delivered with EBRT or brachytherapy (67–69). Brachytherapy can be considered for soft tissue sarcomas of the extremity and trunk and can be used as monotherapy or as a boost with EBRT (70). Brachytherapy monotherapy can be considered in patients with intermediate or high grade sarcomas <10 cm in size excised with negative margins, or in locally recurrent cases requiring re-irradiation after excision (70). Brachytherapy boost should be considered in higher-risk cases including tumors >10 cm, close/positive margins, or for recurrent disease not previously radiated (70). For monotherapy, HDR brachytherapy dose and fraction regimens include 30-54 Gy (2-4 Gy/fraction delivered twice daily) and when utilizing LDR brachytherapy, a dose of 45-50 Gy (0.45-0.5 Gy/hr) is prescribed (70). If HDR brachytherapy is utilized as a boost with EBRT, a dose of 12-20 Gy (2.4 Gy/fraction delivered twice daily) is delivered while a dose of 15-25 Gy (0.45-0.5 Gy/hr) is used with LDR brachytherapy when delivered with 45-50 Gy of EBRT (70). While HDR and LDR brachytherapy are the most well studies, there is a role for IORT in the management of sarcomas. An IORT boost of 10-20 Gy in a single fraction can be considered in select retroperitoneal sarcoma cases treated with EBRT pre- or post-operatively (12,70).

**Quality Measures:** Patients with a diagnosis of soft tissue sarcoma should undergo multidisciplinary evaluation by physicians specializing in the treatment of soft tissue sarcoma, or at minimum, discussion by a multidisciplinary tumor board. Brachytherapy as monotherapy should be considered for intermediate and/or high grade sarcomas less than 10 cm resected with negative margins and can be considered in cases of reirradiation. Brachytherapy as a boost should be considered for intermediate and/or high grade sarcomas greater than 10 cm, those with close and/or positive margins, and recurrences having not previously received RT.

**Quality Metrics:** The prescription isodose line should cover 90% or more of the treatment volume while minimizing V150 and V200 hot spots. Skin, bone, blood vessel, and major nerve dose constraints are provided in Table 7.

### Uveal melanoma

Plaque brachytherapy is commonly utilized to treat uveal melanomas with mature cancer control outcomes and visual preservation data available (71–73). Utilizing plaque brachytherapy, rates of local control range from 70% to 96%, though visual acuity may diminish to >20/200 in upwards of 67% of patients (71–76). Beyond diminished visual acuity, other toxicities of plaque brachytherapy in-
clude cataracts, vitreous hemorrhage, neovascular glaucoma, radiation maculopathy, optic nerve atrophy, and radiation retinopathy (71–73). For instance, neovascular glaucoma can be difficult to treat and may require enucleation for management; ciliary body involvement increases this risk. Of note, patients with peripapillary and subfoveal lesions as we all those with exudative retinal detachments have been found to have worse clinical outcomes and visual acuity outcomes (72,73). $^{125}$I is the most common isotope used, though other isotopes include $^{103}$Pd, $^{131}$Cs, and $^{106}$Ru (73). Since $^{106}$Ru is beta emitting with lower depth of penetration and more rapid dose fall off, it is used for tumors $\leq 5$ mm in apical thickness in the United States (78) Given the more rapid dose falloff, toxicities are less for tumors $\leq 5$ mm compared to $^{125}$I(79). While smaller lesions can be treated at the specialist’s discretion, observation is also appropriate for T1 melanomas with thickness $< 2$ mm without subretinal exudative fluid or superficial organ pigment lipofuscin (80). With respect to contraindications, plaque brachytherapy is not recommended for cases with gross extraocular extension (T4e), tumors that cannot be adequately covered with a plaque, as well as for cases where patients have no light perception in the affected eye or have blind, painful eyes (72,73). Dose recommended is $\geq 70$ Gy (when calculated assuming all aqueous materials and medium) prescribed to the apex or point of maximal thickness (72,73).

Following placement, patients may be admitted or discharged home. A radiation survey of the patient at one meter should be performed after the procedure to measure the exposure rate and determine whether NRC release criteria have been met. If NRC release criteria are not met, patients should be admitted to a hospital room (either alone or share a room with another eye plaque patient) and are not allowed to leave the room until removal (81). Lead lined eye glasses are given to reduce the radiation exposure to staff and visitors. A leaded container is kept at the bedside in case the eye plaque falls out or needs to be urgently removed. Guests are allowed, but are instructed to stay no more than 3 hours in a given day and be as far as reasonably possible, ideally at least 6 feet, to limit exposure. Children (18 year old or less) and pregnant women are restricted from visiting. For patients who are discharged, they are asked to follow similar rules at home as a precaution (e.g., ALARA: As Low As Reasonably Achievable). They are instructed to limit exposure to those around them and sleep in a separate room from their partner. Ideal patients that can go home are those who are reliable in following these directions and do not live too far from the hospital in case additional care is needed.

**Quality Measures:** Patients with a diagnosis of uveal melanoma should undergo multidisciplinary evaluation (preferably with a retina specialist) or discussion at tumor board. Clinical indications include T1-T4a tumors.

**Quality Metrics:** The prescription point should be the tumor apex or point of maximal thickness. The prescription isodose line should cover the entire lesion (Table 8).

**Discussion**

Brachytherapy represents a standard approach for a large number of malignancies. It is a procedural based technique and as such, traditional quality measures and metrics used for EBRT may not apply or be appropriate. The current guideline presents a set of evidence-based quality measures and metrics for treatment site specific
procedures that can be utilized as a template for individual programs and/or institutions QA programs but also has implications for future payment models. A major component of the such models, beyond cost savings, is to “enhance the quality of care.” A component of this is to look for new outcome measures in radiation oncology that impact quality; for example, though brachytherapy has now been removed from the RO-APM, the Innovation Center is looking for CDEs in order to identify measures and metrics for radiation therapy. The present manuscript provides CDEs that can be utilized by payors as quality measures. This is significant as the American Society for Radiation Oncology (ASTRO) has noted that the plans to collect CDEs to identify quality endpoints (ex. as part of upcoming RO-APM) is fraught with limitations including the large amount of data practices are required to submit and the lack of specificity of the requests rendering these requests a substantial burden; for example, DVH parameters are mentioned but no specific dosimetric endpoints.

APMs are likely to grow in the years to come. The present guidelines provide consensus evidence-based metrics that are of clinical significance; this is important as without such information, APMs can request information that may or may not have clinical significance or a tie to quality despite the burden associated with collecting them. Additionally, it should be noted that most of the metrics provided are based on data from prospective studies and existing guidelines; in contrast, the CMS plan for unspecified CDEs would represent a retrospective analysis searching for quality metrics, a nonstandard way to approach outcomes while representing a substantial burden to the specialty. It is our hope that organizations will consider evaluating the present quality measures and metrics and work with radiation oncology associations such as the ABS and ASTRO to develop similar measures and metrics for EBRT. Additionally, it is important that, based on clinical situations, that these measures may not be achievable in 100% of instances and as such, APMs must account for outlier clinical scenarios and not penalize radiation oncologists in these situations.

At this time, in light of the concerns noted above, payors and those adopting APMs should consider a consensus data set that would allow for automated solutions to data collection of CDEs from electronic medical records and treatment planning systems; this would allow for initial data collection and subsequent monitoring. Initially, a limited CDE set would be recommended to decrease the burden on practices; for example, a patient ID, performance status, treatment site, treatment intent, prior radiation, and stage of disease with broadening of CDEs occurring over time. Such initial and continuing monitoring will require standardization as well as collaboration between special-

### Table 7 Quality measures and metrics for sarcoma brachytherapy

<table>
<thead>
<tr>
<th>Quality measures</th>
<th>Dosimetry</th>
<th>Level of evidence</th>
<th>Source of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multidisciplinary evaluation with an orthoped oncologist, medical oncologist, and/or radiation oncologist or discussion at a multidisciplinary tumor board</td>
<td>CTV: V100 ≥ 90%; V150 ≤ 50%; D90 ≥ 90%</td>
<td>IIA</td>
<td>ABS Guidelines (70)</td>
</tr>
<tr>
<td><strong>Monotherapy indications:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate/high grade sarcoma, 10 cm, negative margins</td>
<td>D 0.1 cc &lt; 40Gy, D 2 cc &lt; 37Gy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low grade, deep, &gt; 5 cm</td>
<td>Wound edges &lt; 100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Close/positive margins</td>
<td>Bone: D 0.1 cc &lt; 43Gy, D 2 cc &lt; 35Gy, Blood Vessel: D 0.1 cc &lt; 53Gy, D 2 cc &lt; 47Gy, Nerve: D 0.1 cc &lt; 32Gy, D 2 cc &lt; 30 Gy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recurrent disease not previously irradiated</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

### Table 8 Quality measures and metrics for plaque brachytherapy

<table>
<thead>
<tr>
<th>Quality measures</th>
<th>Metrics</th>
<th>Level of evidence</th>
<th>Source of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multidisciplinary evaluation with ophthalmologist (retina specialist preferred), and/or radiation oncologist or discussion at a multidisciplinary tumor board</td>
<td>Prescription point: tumor apex or point of maximal thickness</td>
<td>IB</td>
<td>ABS Guidelines (72,73), COMS (71,82)</td>
</tr>
<tr>
<td>Utilization of brachytherapy per current guidelines:</td>
<td>Coverage: Prescription isodose line should cover entire tumor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage: T1-T4a-d (39)</td>
<td>(39)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dose: ≥ 70Gy to apex (typically 85Gy) (39)</td>
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</tbody>
</table>
ties, vendors, and payors to finalize endpoints. It is also important to recognize that these endpoints may change over time with new data and techniques emerging. With collaboration and discussion, automated processes that use standard coding (ex. HL7 FHIR, SNOMED, etc.) could be utilized by practices to report these endpoints.

While the goal of this manuscript was to provide evidence and/or guideline based measures and metrics, it is important to recognize that many of these metrics are derived from expert opinion. Additionally, correlative dosimetric endpoints have been derived and should also be considered when examining quality and safety of brachythrapy procedures.

Conclusions

With new payment models facing radiation oncology, a greater focus will be placed on ensuring quality and safety using standardized measures and metrics. The current consensus guideline presents clinical and dosimetry guidelines for commonly used brachytherapy procedures by disease site as a tool for standardized assessment of brachytherapy quality as well as providing possible clinical data elements. Moving forward, it is our hope that payors looking to incorporate alternative payment models that include quality measures work with radiation oncology organizations to create evidence-based metrics that do not overly burden practices.

References


