Clinical Oncology 31 (2019) 844–849

Contents lists available at ScienceDirect

Clinical Oncology

journal homepage: www.clinicaloncologyonline.net

Original Article

Clinical Outcome of Exclusively Radiographer-led Delivery of Postoperative Vaginal Vault Brachytherapy for Endometrial Cancer – The Addenbrooke's Experience

H. Buckley, K. Bradshaw, D. Gregory, S. Prewett, L.T. Tan

Addenbrooke's Hospital, Cambridge University Hospitals NHS Foundation Trust, Cambridge, UK

Received 3 May 2019; received in revised form 29 May 2019; accepted 30 May 2019

Abstract

Aims: Postoperative vaginal vault brachytherapy (VBT) reduces local recurrence in operable endometrial cancer. Radiographer-led delivery of VBT, carried out without image guidance, was implemented at Addenbrooke's in 2010 to maximise skills mix and to improve service delivery. The purpose of this study was to evaluate the safety and effectiveness of this service.

Materials and methods: This was a single-centre retrospective study of endometrial cancer patients treated with postoperative high dose rate VBT ± external beam radiotherapy (EBRT) between January 2010 and December 2016.

Results: In total, 414 patients were analysed: 307 received adjuvant VBT alone and 107 patients received pelvic EBRT followed by VBT. Thirty-seven per cent of patients receiving VBT alone were high risk according to ESMO-ESGO-ESTRO criteria. After a median follow-up of 59 months (range 2–118), 9/414 (2.2%) patients had isolated vaginal recurrences, 15/414 (3.6%) had locoregional recurrence (vaginal, pelvic node or both), whereas 62/414 (15%) patients had distant recurrence. The 5-year actuarial isolated vaginal recurrence rate was 2.3% (VBT alone 2.1%, EBRT + VBT 3.0%). Grade 3 urinary or bowel toxicity occurred in 2/414 (0.6%) patients treated with EBRT and VBT. None of the patients treated with VBT alone had grade 3 complications.

Conclusion: Radiographer-led delivery of VBT, without the use of image guidance, is a safe and effective service.

Key words: Brachytherapy; endometrial; radiographer-led; vaginal

Introduction

Postoperative radiotherapy has been shown to reduce the risk of local recurrence in operable endometrial cancer but does not improve survival [1–3]. Radiotherapy can be delivered as external beam radiotherapy (EBRT) to the pelvis with or without vaginal vault brachytherapy (VBT), or as VBT alone. In patients with high–intermediate risk of recurrence, VBT has been shown to be equivalent to EBRT in terms of local and locoregional recurrence while causing significantly less gastrointestinal toxicity [4].

The NHS Cancer Plan [5], published in September 2000, outlined the Government's plans for investment and reform to improve cancer services in England. A key proposal in the document was for a four-tier skills mix model for radiographers, which will lead to a more flexible workforce. At Addenbrooke's Hospital (Cambridge, UK), VBT delivery was chosen as the ideal service to pilot this model.

The Addenbrooke's radiographer-led VBT service was implemented in 2007. Initially, assessment and applicator placement for the first VBT treatment was carried out by an oncologist; subsequent treatments were carried out by radiographers independently. Since 2010, the entire service, including the initial assessment and all treatments, has been conducted by radiographers without an oncologist present.

The aim of this study was to evaluate the safety and effectiveness of exclusively radiographer-led delivery of VBT without image guidance. To our knowledge, this is the first series to report clinical outcomes after VBT as adjuvant treatment for endometrial cancer delivered entirely within a radiographer-led service.

Author for correspondence: L.T. Tan, Oncology Centre (Box 193), Addenbrooke's Hospital, Hills Road, Cambridge, CB2 0QQ, UK. Tel.: +44-1223-217074.

E-mail address: litee.tan@addenbrookes.nhs.uk (L.T. Tan).

https://doi.org/10.1016/j.clon.2019.06.018

Materials and Methods

Study Population

This was a single-centre retrospective study of patients with stage I–IIIC1 endometrial carcinoma receiving adjuvant high dose rate VBT, delivered entirely by a radiographer, between 1 January 2010 and 31 December 2016. Eligible patients were identified from an electronic radiotherapy database. Patients with IIIC2 disease, carcinosarcoma or recurrent disease, and those requiring whole vaginal brachytherapy, were excluded.

All patients were surgically staged according to the 2009 International Federation of Gynaecology and Obstetrics (FIGO) classification. Routine pelvic lymphadenectomy was not carried out; however, clinically suspicious pelvic or para-aortic nodes were removed.

The standard protocol was to offer VBT alone to patients who met the PORTEC-1 criteria of 'high risk', i.e. age $\geq$60 years with stage IB grade 1–2 tumours or any patient with IA grade 3 disease [1]. Patients with stage IB, grade 3, stage II–IIIC1 and non-endometrioid histology were offered adjuvant pelvic EBRT + VBT (from 2015, only patients with cervical stromal involvement were offered VBT after EBRT). Patients with non-endometrioid cancers (serous, clear cell or mixed) were also offered adjuvant chemotherapy. The final choice of treatment for each patient was agreed through shared decision-making.

Radiotherapy

Pelvic EBRT was delivered using a four-field technique defined on bony landmarks. The standard target volume extended from the L5/S1 junction superiorly to the lower border of the pubic symphysis inferiorly. Laterally, the target volume extended to 1 cm beyond the pelvic brim. The anterior border of the target volume was mid-pubis symphysis, whereas the posterior border was 2–3 cm anterior to the sacral hollow, with a maximum width of about 10 cm. The total dose was 45 Gy in 1.8 Gy fractions delivered over 5 weeks.

VBT was delivered using a single channel, vaginal cylinder applicator. Treatment was delivered using standard plans, treating the proximal 2 cm of the vaginal vault. The dose was 21 Gy in three fractions over 2 weeks for VBT alone or 7 Gy as a single fraction if given after pelvic EBRT, prescribed to 0.5 cm from the surface of the applicator. The choice of applicator diameter and length was decided clinically at the first insertion by vaginal examination and the use of vaginal sizers. No imaging was undertaken during the entire process.

Competency Package

An educational package was designed in collaboration with a higher education institute to provide evidence of academic knowledge, skills and expert practice at a master's degree level. In-house training for vaginal examination and brachytherapy applicator sizing and insertion was provided by the oncologist; as part of the training, radiographers were required to observe five insertions and then to carry out five insertions under supervision followed by five unsupervised mentored cases. The scope of practice was limited to standard treatments only, i.e. adjuvant treatments to the top 2 cm of the vaginal vault.

Initially, the competency package was confined to advanced and consultant radiographer practice only. In 2012, the programme was extended to include band 7 radiographers, on a rotational placement of 1 year or more, and responsibility for training and assessment was delegated to the advanced practitioner. Radiographers were required to update their knowledge and skills annually and to undertake a refresher if there was a gap in practice of more than 6 months.

Follow-up

The planned follow-up schedule for patients receiving VBT alone was every 3 months in year 1 and every 6 months in years 2 and 3. For patients receiving EBRT + VBT, the follow-up was 3 months, 6 months and 12 months. At each follow-up visit, vaginal and rectal examinations were carried out and toxicity was recorded. Patients were discharged after the planned follow-up but were able to request a further follow-up if they developed symptoms of recurrence or toxicity.

All patients were seen at Addenbrooke's for the first follow-up visit. Subsequently, patients were either followed up at our centre or in their regional hospital. Patients with vaginal recurrences were confirmed by histology and discussed in the regional specialist gynae-oncology multidisciplinary team meetings according to network policy. Pelvic magnetic resonance imaging (MRI) and computed tomography of the chest and abdomen were carried out for re-staging.

Outcomes

The pattern of relapse at the time of first recurrence was analysed. Treatment failures were classified as vaginal, locoregional (vaginal, pelvic nodal or both) or distant (systemic and/or para-aortic nodes). Grade 3 bowel or urinary toxicity was defined retrospectively according to Common Terminology Criteria for Adverse Events (CTCAE) v3.0.

Statistical Analysis

The primary end point was isolated vaginal recurrence, defined as recurrence involving the vaginal vault ('in-field' recurrence) and/or the lower vagina ('out-of-field' recurrence) without pelvic node or distant metastases. The time to this event was computed using the Kaplan–Meier method. Time intervals were calculated from the date of diagnosis and were censored at the date of first recurrence or the date of death (for patients without recurrence). The statistical analysis was carried out using MedCalc Statistical Software version 17.0.4 (MedCalc Software, Ostend, Belgium).

Results

During the study period, 417 patients met the inclusion criteria. One patient died the day after VBT of an unknown cause and three patients moved out of the area and were lost to follow-up. The final analysis was therefore based on 414 patients.

Patient and treatment characteristics are shown in Table 1. In total, 307 patients received adjuvant VBT alone and 107 patients received pelvic EBRT followed by VBT. Fifty-eight (14%) patients received adjuvant chemotherapy with either carboplatin–paclitaxel (7%) or single-agent carboplatin (6.5%).

Eighty-five per cent of patients treated with VBT alone had stage I disease (22% IA, 63% IB), whereas 14% had stage II disease. More than two-thirds of patients receiving EBRT followed by VBT had stage II (26%) or stage III (44%) disease.

Most of our patients had endometrioid carcinomas (VBT alone 79%, EBRT + VBT 64%). Of the patients treated with VBT alone, 11% had serous histology, 3% had clear cell and 7% had mixed histology. Of the patients treated with pelvic EBRT and VBT, 17% had serous histology, 3% clear cell and 16% mixed histology.

Patients were retrospectively categorised into four risk groups (low, intermediate, high–intermediate, high) according to ESMO-ESGO-ESTRO consensus guidelines [6]. Thirty-seven per cent of the patients receiving VBT alone were high risk, whereas 62% were high–intermediate or intermediate risk. By contrast, 94% of patients receiving EBRT + VBT were high risk.

After a median follow-up of 59 months (range 2–118 months), isolated vaginal recurrences were seen in 9/414 (2.2%) patients – 6/307 (2.0%) patients receiving VBT alone and 3/107 (2.8%) patients receiving VBT after EBRT. The 5-year actuarial isolated vaginal recurrence rate was 2.3% (VBT alone 2.1%, EBRT + VBT 3.0%).

Table 2 shows the patterns of recurrence after VBT alone and EBRT + VBT. Locoregional recurrences were seen in 11/307 (3.6%) patients after VBT and in 4/107 (3.7%) patients after EBRT + VBT. Distant metastases occurred in 36/307 (12%) patients after VBT and in 26/107 (24%) patients after EBRT + VBT.

Patient and treatment characteristics of the patients with isolated vaginal recurrence are shown in Table 3. The median time to recurrence was 14 months (range 9–27 months). Of the six patients who had a vaginal recurrence after VBT alone, two patients had successful salvage treatment – one patient was treated with radical whole vagina brachytherapy and the other was treated with progesterone therapy followed by EBRT. Of the three patients with vaginal

Table 1
Patient and treatment characteristics

		VBT *n* (%)		EBRT + VBT *n* (%)	
Patients		307		107	
Median age (range)		69	(42–94)	64	(29–79)
FIGO stage	IA	68	(22)	16	(15)
	IB	193	(63)	17	(16)
	II	43	(14)	28	(26)
	IIIA	1	(0.3)	18	(17)
	IIIB	2	(0.7)	22	(21)
	IIIC1			6	(6)
Histology	Endometrioid	241	(79)	68	(64)
	Serous	34	(11)	18	(17)
	Clear cell	10	(3)	3	(3)
	Undifferentiated	1	(0.3)	1	(1)
	Mixed	21	(7)	17	(16)
Grade	1	104	(34)	18	(17)
	2	97	(32)	25	(23)
	3	105	(34)	64	(60)
	Unknown	1	(0.3)	0	
LVSI	Absent	193	(63)	47	(44)
	Present	99	(32)	55	(51)
	Unspecified	15	(5)	5	(5)
Risk group	Low	2	(1)		
	Intermediate	110	(36)	2	(2)
	High–intermediate	81	(26)	4	(4)
	High	114	(37)	101	(94)
Chemotherapy	None	277	(90)	79	(74)
	Carboplatin	18	(6)	9	(8)
	Carboplatin–paclitaxel	12	(4)	17	(16)
	Yes (regimen unknown)			1	(1)
	Unknown			1	(1)

EBRT, external beam radiotherapy; LVSI, lymphovascular space invasion; VBT, vaginal vault brachytherapy.

Table 2
Patterns of recurrence

Recurrence		VBT ($n = 307$) *n* (%)	EBRT + VBT ($n = 107$) *n* (%)	Total ($n = 414$) *n* (%)
Vaginal	Vaginal vault ('in-field')	4 (1.3)		4 (1.0)
	Lower vagina ('out-of-field')	1 (0.3)	3 (2.8)	4 (1.0)
	Both	1 (0.3)		1 (0.2)
	Total	6 (2.0)	3 (2.8)	9 (2.2)
Locoregional	Vaginal	6 (2.0)	3 (2.8)	9 (2.2)
	Pelvic nodal	4 (1.3)	1 (0.9)	5 (1.2)
	Pelvic nodal and vaginal	1 (0.3)		1 (0.2)
	Total	11 (3.6)	4 (3.7)	15 (3.6)
Distant	Distant	15 (4.9)	21 (19.6)	36 (8.7)
	Distant and vaginal	5 (1.6)	1 (0.9)	6 (1.4)
	Distant and pelvic nodal	3 (1.0)		3 (0.7)
	Distant, pelvic nodal and vaginal	2 (0.7)		2 (0.5)
	Total	36 (12)	26 (24)	62 (15)

EBRT, external beam radiotherapy; VBT, vaginal vault brachytherapy.

Table 3
Patient and treatment characteristics of patients with isolated vaginal recurrence

Age	Histology	FIGO stage	Grade	LVSI	Risk group	Treatment	Chemotherapy	Vaginal recurrence	Time to recurrence (months)
71	Endometrioid	IB	2	Negative	Intermediate	VBT alone	No	Out-of-field	13
78	Endometrioid	IB	1	Unknown	Intermediate	VBT alone	No	In-field	13
79	Endometrioid	IB	2	Unknown	Intermediate	VBT alone	No	In-field	21
62	Endometrioid	IA	3	Negative	High–intermediate	VBT alone	No	In-field	22
82	Endometrioid	IB	2	Positive	High–intermediate	VBT alone	No	Both	14
82	Serous	II	3	Negative	High	VBT alone	Carboplatin	In-field	27
65	Endometrioid	II	3	Positive	High	EBRT + VBT	No	Out-of-field	9
59	Endometrioid	IIIB	1	Negative	High	EBRT + VBT	No	Out-of-field	23
68	Endometrioid	IIIB	3	Positive	High	EBRT + VBT	No	Out-of-field	12

EBRT, external beam radiotherapy; LVSI, lymphovascular space invasion; VBT, vaginal vault brachytherapy.

recurrence after EBRT + VBT, two patients were successfully salvaged with progesterone therapy followed by radical whole vagina brachytherapy. The remaining five patients were either not fit for radical salvage treatment at the time of recurrence or eventually succumbed to metastatic disease.

After EBRT + VBT, one patient developed grade 3 urinary toxicity and another developed grade 3 bowel toxicity (the latter had previously had multiple surgeries, including surgery for obstruction secondary to adhesions). No grade 3 bowel or urinary toxicity was observed in patients treated with VBT alone.

Discussion

Our study has shown that adjuvant VBT for endometrial cancer delivered within an exclusively radiographer-led service is safe and effective. At a median follow-up of 59 months, the 5-year isolated vaginal recurrence rate was 2.3% in patients receiving VBT ± EBRT (VBT alone 2.1%, EBRT + VBT 3.0%).

The PORTEC-2 trial [4,7] randomised patients with high–intermediate risk endometrial cancer to receive either VBT or EBRT. High–intermediate risk was defined as age >60 years with disease equivalent to FIGO 2009 stage IB grade 1 or 2 or stage IA grade 3. At a median follow-up of 116 months, the 5- and 10-year isolated vaginal recurrence rate was 2.4% and 3.4% for VBT versus 1.9% and 2.4% for EBRT ± VBT [7]. This is comparable with the isolated vaginal recurrence rate in our series despite the inclusion of higher risk patients than PORTEC-2 (grade 3 with deep myometrial invasion, cervical stromal involvement, stage III disease, non-endometrioid histology).

Thirty-seven per cent of our patients receiving VBT alone would have been classified as high risk according to the ESMO-ESGO-ESTRO guidelines [6]. According to the consensus recommendations, these patients should have received pelvic EBRT as they did not undergo staging lymphadenectomy, but the final choice of treatment was made by the patient. Of interest, only one of the six patients with isolated vaginal relapse after VBT was in the high risk category. Other groups [8,9] have also reported low vaginal recurrence rates (1.9–3%) after VBT alone for high risk stage I patients, suggesting that this may be a reasonable option to discuss as part of the shared decision-making process.

Only two patients in our series had late grade 3 bowel or urinary toxicity, both of whom had received pelvic EBRT.

Although severe toxicity after VBT alone in published series is low (0–5%) [10], data from the PORTEC-2 quality of life analysis [11] has nevertheless shown a long-term adverse effect on sexual functioning compared with the normal population. We did not collect data on late vaginal toxicity in this analysis, as a significant proportion of the patients were followed up elsewhere in the network.

The treated length in our centre is 2 cm, which is shorter than in PORTEC-2 (proximal half of the vagina) [4]. A comprehensive review of adjuvant VBT for early stage endometrial cancer by the American Brachytherapy Society (ABS) [10] reported that most commonly, dose is prescribed to the proximal 3–5 cm or the proximal one-third to half of the vagina, but there is considerable variation from the proximal 1–10 cm (the ABS recommends treating the proximal 3–5 cm of the vagina [12]). Despite this, only 4/414 (0.9%) patients in our series developed out-of-field recurrences in the lower vagina, suggesting that treating the proximal 2 cm alone is probably sufficient and may result in less vaginal morbidity.

Our current practice is for trained radiographers to size and place vaginal applicators and to deliver treatment using a standard plan without image guidance. Over the last decade, a number of dosimetric studies have led to increasing use of image guidance for postoperative VBT. An ABS survey in 2014 [13] revealed that 83% of clinicians in the USA used image guidance for VBT treatments.

One of the main arguments for image guidance is the detection of air gaps between the vaginal cylinder and the vaginal mucosa, which may lower the dose delivered to the vaginal mucosa, leading to an increased risk of recurrence. A study of 25 patients that used computed tomography imaging before each brachytherapy insertion [14] found air gaps in 80% of patients, resulting in an average dose reduction to the vaginal mucosa of 27% (range 9–58%), although less than a quarter of the air gaps occurred in the vaginal apex/treated volume. In 40% of patients there were no air gaps at the first fraction, but air gaps developed in subsequent fractions. The authors therefore recommended pelvic computed tomography before each fraction.

Another study using computed tomography imaging [15] reported that although air gaps were found in 32% of patients, they were more frequently seen in the distal vagina rather than in the treated volume. In this study, the median dose received by the vaginal mucosa at 5 mm was still 99.6% (range 96–100%). Nevertheless, the authors advocated imaging before the first fraction.

More recently, MRI-guided VBT has been adopted by some centres in view of the superior soft tissue contrast compared with computed tomography. One study of MRI-guided VBT reported air gaps in 48% of patients, resulting in 75% of patients in this study receiving $<$50% dose to the vaginal cuff [16].

The solution for air gaps identified on imaging remains uncertain. Although applicator repositioning and replacement has been suggested [15], with careful assessment of vaginal size and applicator selection, the largest applicator that can be tolerated by the patient should have been chosen from the outset. Customised applicators [14], customised plans [17] and longer dwell times [16] have also been suggested as potential solutions to air gaps. However, there is uncertainty about the clinical significance of air gaps present at the time of VBT as none of the studies reporting dosimetric variation have correlated this with clinical outcome.

Image guidance increases the treatment process time, the need for clinician and physicist input for individual treatments and, in the case of computed tomography guidance, exposure to ionising radiation. In this age of value-based healthcare, the low vaginal recurrence rate and minimal toxicity after VBT at our centre and in the published literature should call into question the benefit of image guidance.

The limitations of this study include the fact that it was a single-centre experience and was retrospective in nature. Patients are referred from across the cancer network for treatment at our tertiary centre and are then discharged back to their local centre for follow-up. An assumption has been made that all recurrences occurring in patients receiving follow-up within our cancer network have been discussed at the specialist multidisciplinary team meeting according to network protocol. There are also limitations to the quality of toxicity data collected retrospectively and we were not able to evaluate the incidence of vaginal toxicity. Similarly, we have not collected patient-reported outcomes, which may not reflect clinician-assessed toxicity or quality of life data.

Conclusions

Radiographer-led delivery of VBT without the use of image guidance results in excellent local control rates as adjuvant therapy for endometrial cancer. Late bowel and urinary toxicity is minimal and, in this series, was only seen after EBRT + VBT. With radiotherapy services facing a significant challenge in workforce shortages, the implementation of a radiographer-led VBT service has maximised the use of skills mix within our department and provided opportunities for radiographers to develop new, extended and advanced practice roles.

Conflict of Interest

The authors report no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clon.2019.06.018.

References

[1] Creutzberg CL, van Putten WL, Koper PC, Lybeert ML, Jobsen JJ, Warlam-Rodenhuis CC, *et al*. Surgery and postoperative radiotherapy versus surgery alone for patients with stage-1 endometrial carcinoma: multicentre randomised trial.

PORTEC Study Group. Post Operative Radiation Therapy in Endometrial Carcinoma. *Lancet* 2000;355(9213):1404–1411.
[2] Keys HM, Roberts JA, Brunetto VL, Zaino RJ, Spirtos NM, Bloss JD, *et al*. A phase III trial of surgery with or without adjunctive external pelvic radiation therapy in intermediate risk endometrial adenocarcinoma: a Gynecologic Oncology Group study. *Gynecol Oncol* 2004;92(3):744–751.
[3] Creutzberg CL, Nout RA, Lybeert ML, Warlam-Rodenhuis CC, Jobsen JJ, Mens JW, *et al*. Fifteen-year radiotherapy outcomes of the randomized PORTEC-1 trial for endometrial carcinoma. *Int J Radiat Oncol Biol Phys* 2011;81(4):e631–e638.
[4] Nout RA, Smit VT, Putter H, Jurgenliemk-Schulz IM, Jobsen JJ, Lutgens LC, *et al*. Vaginal brachytherapy versus pelvic external beam radiotherapy for patients with endometrial cancer of high-intermediate risk (PORTEC-2): an open-label, non-inferiority, randomised trial. *Lancet* 2010;375(9717):816–823.
[5] *The NHS Cancer Plan: a plan for investment, a plan for reform*. Department of Health; 2000.
[6] Colombo N, Creutzberg C, Amant F, Bosse T, Gonzalez-Martin A, Ledermann J, *et al*. ESMO-ESGO-ESTRO consensus conference on endometrial cancer: diagnosis, treatment and follow-up. *Radiother Oncol* 2015;117(3):559–581.
[7] Wortman BG, Creutzberg CL, Putter H, Jurgenliemk-Schulz IM, Jobsen JJ, Lutgens L, *et al*. Ten-year results of the PORTEC-2 trial for high-intermediate risk endometrial carcinoma: improving patient selection for adjuvant therapy. *Br J Cancer* 2018;119(9):1067–1074.
[8] Barney BM, Petersen IA, Mariani A, Dowdy SC, Bakkum-Gamez JN, Haddock MG. The role of vaginal brachytherapy in the treatment of surgical stage I papillary serous or clear cell endometrial cancer. *Int J Radiat Oncol Biol Phys* 2013;85(1):109–115.
[9] Eldredge-Hindy HB, Eastwick G, Anne PR, Rosenblum NG, Schilder RJ, Chalian R, *et al*. Adjuvant vaginal cuff brachytherapy for high-risk, early stage endometrial cancer. *J Contemp Brachyther* 2014;6(3):262–270.
[10] Harkenrider MM, Block AM, Alektiar KM, Gaffney DK, Jones E, Klopp A, *et al*. American Brachytherapy Task Group Report: Adjuvant vaginal brachytherapy for early-stage endometrial cancer: a comprehensive review. *Brachytherapy* 2017;16(1):95–108.
[11] Nout RA, Putter H, Jurgenliemk-Schulz IM, Jobsen JJ, Lutgens LC, van der Steen-Banasik EM, *et al*. Five-year quality of life of endometrial cancer patients treated in the randomised Post Operative Radiation Therapy in Endometrial Cancer (PORTEC-2) trial and comparison with norm data. *Eur J Cancer* 2012;48(11):1638–1648.
[12] Small Jr W, Beriwal S, Demanes DJ, Dusenbery KE, Eifel P, Erickson B, *et al*. American Brachytherapy Society consensus guidelines for adjuvant vaginal cuff brachytherapy after hysterectomy. *Brachytherapy* 2012;11(1):58–67.
[13] Harkenrider MM, Grover S, Erickson BA, Viswanathan AN, Small C, Kliethermes S, *et al*. Vaginal brachytherapy for postoperative endometrial cancer: 2014 survey of the American Brachytherapy Society. *Brachytherapy* 2016;15(1):23–29.
[14] Richardson S, Palaniswaamy G, Grigsby PW. Dosimetric effects of air pockets around high-dose rate brachytherapy vaginal cylinders. *Int J Radiat Oncol Biol Phys* 2010;78(1):276–279.
[15] Cameron AL, Cornes P, Al-Booz H. Brachytherapy in endometrial cancer: quantification of air gaps around a vaginal cylinder. *Brachytherapy* 2008;7(4):355–358.
[16] Chapman CH, Prisciandaro JI, Maturen KE, Cao Y, Balter JM, McLean K, *et al*. MRI-based evaluation of the vaginal cuff in brachytherapy planning: are we missing the target? *Int J Radiat Oncol Biol Phys* 2016;95(2):743–750.
[17] Humphrey P, Cornes P, Al-Booz H. Vaginal vault brachytherapy in endometrial cancer: verifying target coverage with image-guided applicator placement. *Br J Radiol* 2013;86(1023):20120428.