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Vaginal vault brachytherapy in endometrial cancer: verifying target coverage with image-guided applicator placement

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Objective: This quality assurance study assesses whether CT image-guided verification has led to improvements in the technique when compared with previous studies.

Methods: The CT images were studied from a cohort of 105 consecutive patients with endometrial cancer having adjuvant brachytherapy to the vaginal vault in 2010. Images were taken at first insertion, checked for air gaps and treatment delivered. Images were later transferred to the planning system and air gaps between vaginal mucosa and vaginal cylinder were measured. Comparisons were made with the 2008 results from this centre and the literature series.

Results: Images from two patients were not assessable owing to artefacts from hip replacements. Air gaps >2 mm were seen in 11/103 patients. Repositioning or use of

a larger cylinder reduced air gaps to 7/103 patients. In total, 96/103 patients (over 93%) were able to achieve good vaginal contact throughout the treatment volume. This shows a significant improvement in applicator positioning in our centre since 2008 and also a significant improvement over the total data published in 2010 (Pearson χ^2 test=46.19; $p<0.0001$).

Conclusion: The vaginal cylinder technique with CT imaging was proven to be effective for 96/103 patients. It is necessary to consider whether there is a better technique for the few patients with air gaps >2 mm.

Advances in knowledge: For the vast majority of patients, this technique is well tolerated, without the need for analgesia, and will continue to be the first choice technique in this centre.

In current practice, there are variations in applicators used in vaginal vault brachytherapy, such as vaginal ovoids or colpostats, custom-made vaginal moulds, but most commonly used is a single line source in a rigid vaginal cylinder. In 2008, in this radiotherapy centre, Cameron et al [1] carried out a retrospective study of 25 patients receiving vaginal vault brachytherapy. It was found that 8 out of 25 patients had air gaps >2 mm in the superior 2 cm of vagina [1]. An observational study by Richardson et al [2] found 90 air pockets in 150 procedures for a cohort of 25 patients, 80% having one or more air pockets. Air gaps between the applicator and the vaginal wall can potentially reduce the dose to the clinical target volume (CTV), which in this case is the mucosal lymphatics of the upper vagina. These lie at 2–3 mm from the stretched mucosal surface according to a study by Choo et al [3]. The Groupe Européen de Curiethérapie and the European Society for Radiotherapy & Oncology (GEC-ESTRO) guidance is to prescribe vaginal brachytherapy to 5 mm from the applicator surface [4], giving a 2-mm tolerance.

A new CT scanner was introduced in this centre in 2010 and new clinicians were trained to carry out vault brachytherapy insertions. This quality assurance study considers whether high-resolution CT image-guided verification, as well as the learning curve of image-guided brachytherapy, has led to improvements in the quality of the technique over time.

METHODS AND MATERIALS

The brachytherapy CT images were studied from a cohort of 105 consecutive patients with endometrial cancer having adjuvant brachytherapy to the vaginal vault in 2010. This included all patients receiving either adjuvant vaginal vault brachytherapy alone or in combination with pelvic external beam radiotherapy (EBRT) after hysterectomy for intermediate- and high-risk endometrial cancer.

At the first brachytherapy appointment, each patient underwent vaginal examination and insertion of a urinary catheter with radio-opaque contrast in the bladder balloon. The catheter is only inserted at the first fraction of brachytherapy for imaging purposes. In this centre, it has been thought that this may assist delineation of bladder volume if required, although organs at risk contouring is not routinely carried out. An assessment for applicator sizing was carried out, considering both

the capacity of the vagina and what diameter cylinder the patient was likely to tolerate. The largest tolerable cylinder size was selected for insertion. The range of cylinder sizes available was 2.0, 2.3, 2.6, 3.0, 3.5 cm diameter. The cylinder was inserted to the top of the vagina and then clamped using an external board and clamp system (Figure 1) to ensure no movement of the cylinder, especially during transfer of the patient to and from the CT couch. The length of the vaginal cylinder protruding (if any) was noted to ensure accurate repositioning for subsequent insertions. It is known that the metal ring clamp around the distal end of the cylinder reduces the usable length of the cylinder by 7 mm. On insertion of the vaginal cylinder, if it was thought that this clamp was impeding the cylinder from reaching the top of the vagina, then the ring clamp around the cylinder was removed and a metal probe used instead of the plastic probe. The external clamping system was then attached to the metal probe to ensure no movement of the cylinder. This is not used for every patient as it has been thought in this centre that clamping the metal probe may cause wear and tear, and over time could reduce the inner bore and risk obstructing the radiation source.

A CT scan was carried out at the first brachytherapy insertion in line with standard departmental policy. All patients were imaged with a spiral pattern on a high-resolution CT scanner with voxels of 1 mm^3 (Philips Brilliance CT Scanner, Philips Medical Systems, Eindhoven, Netherlands). The images were viewed on the CT scanner screen, without three-dimensional reconstruction, to check for any air gaps between vaginal

Figure 1. Image of clamping board, vaginal cylinder and ring clamp.

Figure 2. Transverse CT image showing air gaps.

mucosa and cylinder that were >2 mm in the superior 3.5 cm of the cylinder and 0.5 cm above it (Figure 2). Air gaps >2 mm from the edge of the cylinder mandated applicator repositioning; sometimes a larger size cylinder was inserted, or the cylinder was pushed in slightly more and imaging was repeated.

A standard plan treatment was delivered using the Varian GammaMedplusTM afterloader unit (Varian Medical Systems, Inc., Palo Alto, CA). The dose was prescribed to 0.5 cm from the surface of the cylinder, using a loaded length of 3 cm to treat the upper 4 cm of the vaginal vault. The dose delivered depended on whether the brachytherapy was being given alone or after pelvic EBRT. Doses prescribed for adjuvant treatment of endometrial cancer were 21.6 Gy in four treatments with brachytherapy alone, or 8.0 Gy in two treatments after 45 Gy EBRT or a single fraction of 5.4 Gy brachytherapy after 50.4 Gy.

For the purpose of this study, the CT images were later transferred to the planning system (BrachyvisionTM; Varian Medical Systems, Inc.) and examined for the presence of air gaps between the vaginal mucosal surface and the vaginal cylinder. Any air gaps observed in the target volume (upper 4 cm of vagina) were measured and recorded. This was carried out for all 105 cases by a single investigator to minimise the risk of interobserver variation. Comparisons were made with results from this centre and those of previously

published cohort series [1, 2] using two-tailed probability tests (Fisher and Pearson).

RESULTS

Images were reviewed for 105 consecutive patients having adjuvant brachytherapy for endometrial cancer. Brachytherapy alone (21.6 Gy in four fractions prescribed at 0.5 cm from the cylinder surface) was given in 56 patients. EBRT was given before brachytherapy in 49 patients. Of these 49 patients, 31 had 45-Gy EBRT followed by 8 Gy in two fractions of brachytherapy and 18 had 50.4-Gy EBRT followed by 5.4 Gy in a single fraction of brachytherapy. Images were obtained only on the first fraction of brachytherapy. Images from two patients were not assessable as the vaginal vault and cylinder were obscured by artefacts from unilateral or bilateral hip replacements. A further six patients had unilateral hip replacements and two had bilateral replacements; however, their images were still assessable for air gaps.

Of the 103 patients with assessable images, 38 were found to have 1 or more air gaps within the target volume, with a total of 67 air gaps measured. However, air gaps >2 mm were seen in only 11 out of 103 patients. These air gaps had all been noted at the time of CT, and corrective action had been considered or attempted and documented in treatment records. Of these 11 patients, 2 had a larger diameter cylinder inserted, which removed the air gaps completely. Two of the patients had the cylinder pushed in a further 1 cm, reducing air gaps to within the 2-mm tolerance. Therefore, repositioning or the use of a larger cylinder reduced air gaps >2 mm to 7/103 patients. For the remaining seven patients, it was not possible to reduce the gaps to within tolerance. One patient was found to have a number of vaginal adhesions, which had to be broken down digitally before insertion of the cylinder and a larger cylinder was not possible. One patient had a bulky vertical scar with air pockets either side. Two patients already had the largest cylinder inserted and repositioning did not reduce air gaps to within the 2-mm tolerance. Three patients were assessed as not being able to tolerate a larger cylinder owing to anxiety or discomfort. In total, 96 out of 103 patients (over 93%) were able to achieve good vaginal contact throughout the treatment volume.

A significant improvement in standard size applicator positioning over time is suggested in our centre between

2008 and now (Fisher exact probability test 0.01). Cameron et al [1] reported 8 out of 25 cases having an air gap. Richardson et al [2] reported that over 80% of patients had air gaps using this technique. This suggests a significant improvement over the total data published in 2012 (Pearson χ^2 test=46.19; $p<0.0001$). This suggests that only 7% of patients might benefit from a custom applicator to improve dosimetry (Table 1).

DISCUSSION

The Dutch randomised trial, PORTEC 2, reported that vaginal vault brachytherapy was an effective treatment to reduce vaginal relapse and recommended that it should be the treatment of choice for high- or intermediate-risk endometrial cancer [5].

The clinical benefit in reducing relapse is believed to derive from sterilising subclinical microscopic metastatic disease in the upper vaginal submucosal lymphatics. Choo et al [3] found that the vaginal lymphatics lie within 3 mm in the stretched vaginal mucosa. This has been recognised in the GEC-ESTRO guidance, which recommends the dose prescription point for adjuvant therapy is 0.5 cm from the surface of the applicator [4]. As the CTV is the vaginal mucosal lymphatics, it is important that this depth is covered by the prescribed brachytherapy dose. Hence, an air gap of >2 mm will prevent a portion of the lymphatic channels from receiving the prescribed dose and risk relapse. It is recognised that different centres prescribe to different vaginal lengths. In this centre, the upper 4 cm of the vagina is considered to be the target volume so air gaps were measured only within this volume to verify the existing technique. However, the same principles would apply for a longer vaginal treatment length, so other centres could repeat this study with their own specific treatment parameters to verify their technique.

Using a standard-size vaginal cylinder has been found to generally be a well-tolerated and simple technique. However, criticism of the vaginal cylinder technique is that the vagina may not conform well to the shape of the cylinder, as this is not the natural shape of the vaginal vault, neither before nor after hysterectomy. It is possible that air gaps may be present and close contact of the vaginal mucosa to the cylinder may not be achieved. To overcome this, some centres advocate individualised vaginal moulds (Institut Gustave-Roussy, Paris, France) or expanding vaginal applicators (Capri™ applicator;

Varian Medical Systems, Inc.). This may improve dosimetry but will use additional resources. This study was done in response to the earlier studies suggesting suboptimal dosimetry from the rigid cylinder technique [1, 2] to see whether the image-guided applicator placement could improve over time with training and recognition of its potential importance.

The use of imaging has long been recommended for all types of brachytherapy but may be underused in clinical practice. Informal surveys at the UK Brachytherapy Radiographers' Forum show that universal image-guided vaginal vault applicator placement was routine in only a minority of UK radiotherapy centres in 2011. It is advocated in the NHS Executive Manual of Cancer Services Standards [6] that "Catheters used in after-loading equipment should be imaged within patients, where possible, prior to commencement of treatment" and then again in the Manual of Cancer Services [7] stating that "The position of applications used in after-loading equipment should be imaged within patients prior to commencement of treatment". This is further clarified with a specific note in measure 11-3T-405 in the 2011 National Cancer Peer Review Programme Manual for Cancer Services: Radiotherapy Measures [8] that "Imaging of vaginal vault applicators should be carried out before the first treatment". It is a controversial issue when considering what the purpose of vault brachytherapy applicator imaging is if a standard plan is always selected. However, the image taken at brachytherapy may assist in planning how to treat future disease recurrence or for technique quality assurance, as in this study. If imaging is a requirement, then it is important to consider which imaging modality is suitable for the technique. Having compared orthogonal X-ray imaging with CT imaging in this department it was thought that the additional soft-tissue information was beneficial in ensuring good cylinder size selection and optimal positioning.

It is important to note that Richardson et al [2] reported using a smaller vaginal cylinder for the vast majority of cases. This study has shown that, in this centre, the vaginal examination and the assessment of vaginal size and patient tolerance of the applicator have improved since the study by Cameron et al [1] in 2008. There were fewer air gaps, which may be explained by an overall increase in diameter size. Also by formalising of the 2-mm air gap tolerance, there is now a clear

Table 1. Applicator diameter comparison with previous studies

Study	Applicator diameters (cm)					% air gaps >2 mm
	2	2.3	2.6	3.0	3.5	
Bristol 2008	4%	0%	40%	36%	20%	32%
Cameron et al [1]						
Washington 2010	0%	0%	96%	4%	0%	72%
Richardson et al [2]						
Bristol, present study	0%	1%	16%	54%	30%	11%
						7% after repositioning

action level requiring repositioning or a larger applicator. Using a standard protocol for vaginal examination, applicator size assessment and image assessment in our centre benefits most patients. As a result, it has been possible for oncologists to both delegate this task to a specially trained radiographer and improve the quality of treatment over the same era. This has led to an opportunity for role extension for therapy radiographers who specialise in brachytherapy.

In this series, no attempt at customised dosimetry was made. The seven patients with remaining air gaps had all previously received EBRT and customised dosimetry was not considered to be worthwhile when weighing up the extra time required.

However, for the 7% of patients not optimally treated by a rigid cylinder technique, there could have been several options for customised dosimetry. This may be particularly important if the planned treatment was to be brachytherapy alone. The use of individualised vaginal moulds (Institut Gustave-Roussy) or expanding multichannel vaginal applicators (Capri applicator; Varian Medical Systems, Inc.) would require individualised planning to be carried out to improve target volume coverage in the area of any air gaps. Another option that is currently being explored in this centre would be to

use vaginal ovoids or colpostats if air gaps are found with the cylinder technique. However, this potentially could be more uncomfortable for the patient and may be less well tolerated than insertion of a vaginal cylinder. It is hoped in this centre that the development of standard plans for ovoids will keep the time required for dosimetry to a minimum and allow a switch to this applicator in the same outpatient appointment if air gaps are noted with the cylinder technique. A further paper will be written to report progress with this technique.

CONCLUSION

There is a learning curve to optimal vaginal brachytherapy. With the recognition of potentially poor placement, a programme of image-guided insertion and quality control, we have been able to improve practice. We have identified a minority of patients who could still benefit from the extra time and expense of customised vaginal applicators. For the vast majority of patients, the standard vaginal cylinder technique is well tolerated without the need for any analgesia and so will continue to be the first choice technique in this centre.

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