Original paper

Three-dimensional dosimetric considerations from different point A definitions in cervical cancer low-dose-rate brachytherapy

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Abstract

Purpose: To investigate the dosimetric difference due to the different point A definitions in cervical cancer low-dose-rate (LDR) intracavitary brachytherapy.

Material and methods: Twenty CT-based LDR brachytherapy plans of 11 cervical patients were retrospectively reviewed. Two plans with point As following the modified Manchester system which defines point A being 2 cm superior to the cervical os along the tandem and 2 cm lateral (A_{os}), and the American Brachytherapy Society (ABS) guideline definition in which the point A is 2 cm superior to the vaginal fornices instead of os (A_{ovoid}) were generated. Using the same source strength, two plans prescribed the same dose to A_{os} and A_{ovoid}. Dosimetric differences between plans including point A dose rate, treatment volume encompassed by the prescription isodose line (TV), and dose rate of 2 cc of the rectum and bladder to the prescription dose were measured.

Results: On average A_{ovoid} was 8.9 mm superior to A_{os} along the tandem direction with a standard deviation of 5.4 mm. With the same source strength and arrangement, A_{os} dose rate was 19% higher than A_{ovoid} dose rate. The average TV(A_{ovoid}) was 118.0 cc, which was 30% more than the average TV(A_{os}) of 93.0 cc. D_{2cc}/D($A_{prescribe}$) increased from 51% to 60% for rectum, and increased from 89% and 106% for bladder, if the prescription point changed from A_{os} to A_{ovoid}.

Conclusions: Different point A definitions lead to significant dose differences. Careful consideration should be given when changing practice from one point A definition to another, to ensure dosimetric and clinical equivalency from the previous clinical experiences.

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Key words: cervical cancer, LDR brachytherapy, point A.

Purpose

Intracavitary brachytherapy is an integral component of definitive treatment for locally advanced cervical cancer. Traditionally, two dimensional (2D) film-based planning with point dose-based prescription was used [1], in which dose is prescribed to the point A, and the isodose line traveling through point A forms the classic pear shape encompassing the intended boost treatment volume. With increasing availability of 3-dimensional (3D) imaging compatible applicators, 3D volumetric planning has been recommended by the American Brachytherapy Society (ABS) 2012 guidelines [2-4]. By contouring the high risk clinical target volume (HR-CTV), the bladder and the rectum dose volume information, e.g., $D_{90\%}$ of the HR-CTV, and the D_{2cc} of the rectum and the bladder, would be used to design the plan. In clinical practice, due to the limited access of good soft tissue contrast image modality, e.g., MRI, a hybrid planning approach combining point A-based prescription and dose volume-based plan evaluation is often adopted, in which CT images are used to localize sources and evaluate critical structure dose volume information, but point A-based prescription rather than target-based dose prescription is used. The abundant clinical experience accumulated by the radiation oncologists throughout decades of practice, makes point A-based prescription still an important component in cervical cancer brachytherapy with active researches underway [5-7].

The definition of point A has had several variations in terms of its location along the tandem direction. In the original Manchester system [1], point A was defined as "2 cm lateral to the central canal of the uterus, and 2 cm up from the mucous membrane of the lateral fornix in the

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axis of the uterus" (A_{ovoid}). In 1953, the definition was modified to be "2 cm up from the lower end of the last intrauterine tube, and then 2 cm laterally in the plane of uterus" (A_{os}) based on the observation that a high proportion of the patients had "the cervix eroded away and the lateral vaginal fornices covered by fungating tumor or, in the indurated type of cancer, so narrowed that they scarcely exist" [8]. Since the last intrauterine tube is usually placed against the cervical os, following this definition A_{os} would be easier to define in 2D film-based planning due to the superior radiographic visibility of the flange of the tandem, which is supposedly adjacent to the cervical os. These two definitions of point A are both used clinically and described in textbooks. For example, the definition of point A from the vaginal fornices (A_{ovoid}) has been adopted by the ABS guidelines [2-4], whereas the definition of point A from the cervical os (A_{os}) is described and referenced to in a standard medical physics textbook [9].

Switching between two point A definitions in clinical practice may be problematic. Several studies [5,10-15] showed that a slight variation in point A location can result in significant dose variation. In a very recent study, Anderson *et al*. [5] evaluated the impact of selection of different point As on the dose to HR-CTV contoured from MR images in high-dose-rate (HDR) cervical cancer brachytherapy patients. They found on average there were small difference between two different point A definitions. However, in certain cases the point A dose difference could be as high as 12%. In this study, we retrospectively evaluated the dosimetric impacts due to different point A definitions based on a series of 3D CT planning images for low-dose-rate (LDR) cervical cancer brachytherapy from our institution. In addition to the geometric shift of point A location from one definition to another, the changes of the treatment volume (i.e., the volume encompassed by the prescription isodose line) and the changes of various volumetric, and dosimetric parameters of critical organs were also analyzed. Results derived from this study may provide useful information on relationships between point A definitions and 3D volumetric, and dosimetric parameters and may help in the transfer of clinical experiences of point A-based prescription to 3D target volume-based prescription.

Material and methods

Twenty CT-based LDR brachytherapy plans of 11 cervical patients treated from December 2009 through August 2011 were retrospectively reviewed in the Eclipse® treatment planning system (Varian Medical Systems, Palo Alto, CA). The hybrid approach was used in all treatment plans. Critical organs including the rectum and the bladder were contoured and confirmed by two radiation oncologists independently. In the original plan used for treatment, point As were defined following the modified Manchester definition (A_{os}): 2 cm superior to the cervical os along the tandem and 2 cm lateral. The location has been double checked by two physicists independently. In practice, the top of the flange on the tandem was used as a surrogate for the cervical os since the anatomical os was difficult to identify and the flange was right next to the os. In all cases, Henschke applicators [16] were used with different cap sizes, and 3-4 ^{137}Cs sources were used in the tandem and 1 ^{137}Cs source in each ovoid. The source arrangement was optimized to deliver prescription dose to point A while minimizing the values of $\dot{D}_{2cc}$ (the dose rate value corresponding to 2 cc on the cumulative dose volume histogram) of the rectum and the bladder. The prescription dose to point A was 22.5 Gy for each fraction following our institution guideline for cervical cancer LDR.

A_{ovoid} was inserted into the same CT image following the 2012 ABS recommendation [2] for each of the clinical plans. A new plan was generated based on the same source arrangement, but with the prescription point changed from A_{os} to A_{ovoid}. It should be noted that since two point As are most likely at different locations with different dose rates, the change of the prescription point would change the treatment time, and the absolute dose to the target volumes and normal structures. The amount of geometric shift between two definitions of point As was measured. Dosimetric parameters including dose rates to both point As, the treatment volumes (TV) and dose rates to 2 cc of the rectum and the bladder respect to the prescription dose ($\dot{D}_{2cc}/\dot{D}(A)$) were recorded. TV was defined as the volume encompassed by the isodose rate line traveling through the prescription point, e.g., in the original plan it was the volume encompassed by isodose rate line traveling through A_{os}, and in the new plan it was the volume encompassed by isodose rate line traveling through A_{ovoid}.

Results

A histogram of the shifts between A_{ovoid} and A_{os} is shown in Figure 1. A positive value on the X-axis indicates that A_{ovoid} was superior to A_{os} along the tandem direction. The average shift between A_{ovoid} and A_{os} was 8.9 mm with a standard deviation of 5.4 mm. Only 2 out of 20 cases had A_{ovoid} inferior to A_{os}.

Based on the original planned source arrangement which was kept to be the same between the original clinical plan and the new plan, the average dose rate at A_{ovoid} was 43.7 cGy/hr, and the average dose rate at A_{os} was 51.3 cGy/hr. The standard deviation of the dose rate at A_{ovoid} was 6.38 cGy/hr (14.6% of the mean) and 6.77 cGy/hr (13.2% of the mean) for A_{os}. If we calculate ($\dot{D}(A_{os}/\dot{D}(A_{ovoid})$ for an individual case, the dose rate ratio was 119% on average. The average treatment volume (TV) defined by A_{ovoid} ($TV(A_{ovoid})$) was 118.0 cc, which was 30% more than the average $TV(A_{os})$ of 93.0 cc. Table 1 listed the treatment volume (TV) between the original clinical plan and the new plan among all the cases.

Figure 2 shows the relationships between the geometric shift of point A ($A_{ovoid} - A_{os}$), the ratio of $\dot{D}(A_{ovoid}/\dot{D}(A_{os})$ and $TV(A_{ovoid})/TV(A_{os})$. With point A shifting away from the ovoids, $\dot{D}(A)$ decreased and TV(A) increased. From the graph, the geometric shift of point A was poorly correlated with the dose rate change to point A and TV change. Therefore, there was no reliable mathematical formula to calculate the dosimetric consequences, e.g., point A dose rate change, and the TV change, from the geometric changes.

Table 1. Dosimetric parameters between the original plan and the new plan

Case #	Original plan (A_{os})			New plan (A_{ovoid})		
	TV [cc]	D_{rectum} [%]	$D_{bladder}$ [%]	TV [cc]	D_{rectum} [%]	$D_{bladder}$ [%]
1	91.3	26	86	101.4	28	92
2	122.9	36	120	120.0	35	118
3	85.6	46	51	127.5	60	67
4	78.5	60	82	85.1	64	86
5	82.6	44	78	111.7	54	96
6	85.3	44	83	83.3	44	81
7	108.8	59	85	131.4	67	97
8	106.9	50	92	115.6	52	97
9	88.3	55	96	105.2	62	108
10	68.2	84	112	87.8	100	133
11	102.7	71	81	103.8	72	82
12	114.5	57	96	135.4	64	107
13	70.7	38	88	126.6	57	130
14	97.2	40	111	140.0	51	142
15	71.1	37	76	104.5	48	98
16	97.8	60	72	117.5	68	82
17	93.1	62	120	138.3	81	156
18	121.2	61	73	114.3	58	70
19	65.2	38	88	154.6	69	159
20	107.6	45	99	155.1	57	127
Average	93.0	51	89	118.0	60	106

**TV is the treatment volume. Rectum and bladder dose is specified as D_{2cc}/D_A.*

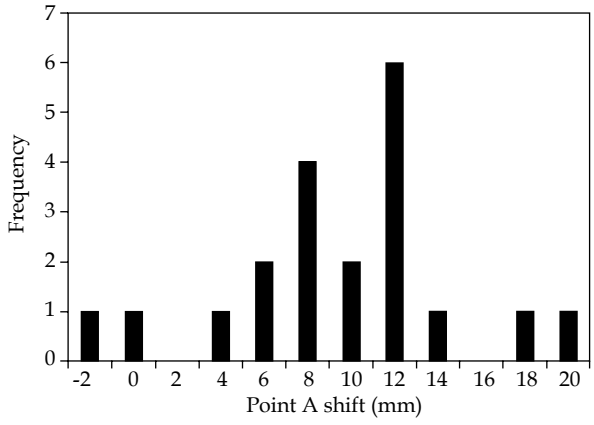

Fig. 1. A histogram of the shifts between A_{ovoid} and A_{os} along the direction parallel to the tandem. The positive number indicates A_{ovoid} was superior to A_{os}

The doses to 2 cc of the rectum and the bladder were measured relative to the prescription dose and listed in Table 1. With the same source arrangement between the original clinical plan and the new plan, the isodose-rate lines were fixed. Therefore, $\dot{D}_{2cc}$ for bladder and rectum would stay the same regardless of the prescription method. However, by prescribing to point A, the bladder and rectum D_{2cc} would be different between two plans and determined by the $\dot{D}_{2cc}$ to $\dot{D}(A)$ ratio. In the original plan which had A_{os} as the prescription point, the average rectum and the bladder $\dot{D}_{2cc}$ were 51% and 89% of $\dot{D}(A_{os})$, respectively, compared to 60% and 106% of $\dot{D}(A_{ovoid})$, when A_{ovoid} was used as the prescription point.

Discussion

In this study we were able to utilize 3D CT image-guided treatment planning to extract information about not only the shift of point A and dose rate change, but also the changes of prescribed treatment volume and critical organ volumetric dose in LDR cervical cancer brachytherapy. This study revealed that there was a clear difference in dose delivered when using the two different point A definitions. For the investigated patient population, this difference led to an almost 9 mm shift in point A location along the tandem on average, which is similar to Anderson *et al.*'s finding [5]. This observation is different from the finding by Tod and Meredith [8], in which they suggested the change from the original point A definition in the Manchester system (A_{ovoid}) to the modified Manchester system (A_{os}) due to minimum difference between those two points, but better visualization of A_{os} on radio-

graph. They wrote: "in the average case the lower end of the cervical canal is level with the lateral fornices, as indicated by ovoid position". The difference in the current study could be due to the difference in patients' bulk of disease at the time of treatment. In their paper, the authors mentioned that a high proportion of patient under treatment had their cervix "eroded away". Patients with such an advanced stage of disease may not be as common in today due to comprehensive screening and early diagnoses. Although the original rationale for changing the original point A definition in the Manchester system (A_{ovoid}) to the modified Manchester system (A_{os}) may not apply today, we are not recommending one definition over another, which is a question that should only be answered by clinical trials.

This study is intended to provide volumetric and dosimetric information on what a clinician may encounter if he/she utilizes the different definition of point A in clinical practice. Currently, with the recently published ABS guidelines [2-4], it is likely that more and more practices which have been prescribing to A_{os} will tend to start to prescribe to A_{ovoid}. If the source arrangement and source strength remains the same, the dose rate at A_{ovoid} is 14% lower than that of A_{os}. Therefore, without correspondingly adjusting the prescription dose, the total reference air kerma would be 14% higher and the treatment volume would be 30% larger. This finding is larger than Anderson *et al.*'s finding, in which the change of total reference air kerma and treatment volume were merely 2% and 3%, respectively. The difference may due to the difference treatment modalities, e.g., LDR vs. HDR.

As shown in the current study, with a same source arrangement and strength, the dose rate at A_{ovoid} is likely to be lower than that at A_{os}. In clinical practice, it is often the case where the source strength and arrangement is chosen, so that the dose rate at the prescription point is close to a certain value. Thus, if a decision is made to shift the prescription point from A_{os} to A_{ovoid} and the dose rate at A_{ovoid} is made to be similar to the value previously used for the cases with A_{os} as the prescription point, the resultant dose rate at A_{os} is most likely going to be higher, indicating a higher dose rate delivery compared to the prior clinical treatments. To demonstrate this effect, we carried out a simple experiment: a new plan prescribing to A_{ovoid} was generated assuming its prescription point A_{ovoid} received the same dose rate as the prescription point A_{os} had in the original plan. Figure 3 compares the dose rate to A_{os} in the original plan and the dose rate to A_{os} in the new plan. In the original plan, the dose rate to A_{os} was 51.3 cGy/hr on average, whereas in the new plan the dose rate to A_{os} had an average of 61.7 cGy/hr with certain cases well beyond 80 cGy/hr. As pointed out in the ABS guideline for LDR cervical cancer brachytherapy [4], when point A dose rate increased from a typical 40-60 cGy/hr LDR range to 80-120 cGy/hr of medium-dose-rate range, late complications, including small bowel obstruction, vesico-vaginal fistula, and ureterohydronephrosis could increase from 30% to 45%, even the prescription dose remains the same [17]. Thus, when the prescription point is changed, both total prescription dose and dose rate to the previously would be defined

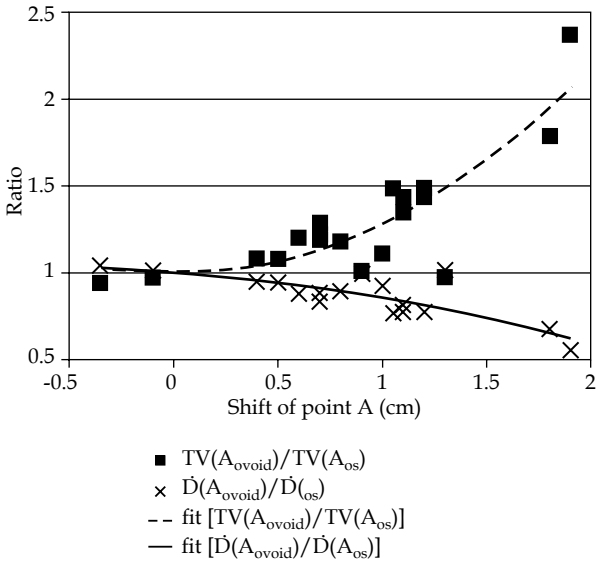

Fig. 2. Shift between A_{os} and A_{ovoid} vs. $\dot{D}(A_{ovoid})/\dot{D}(A_{os})$ and $TV(A_{ovoid})/TV(A_{os})$. The 2nd order polynomial fitting lines are also plotted

treatment volume have to be taken into consideration to replicate accumulated clinical experiences.

Point A based cervical cancer brachytherapy prescription and reporting has been introduced along with the film based planning in order to provide consistency in dose delivery and reporting, allowing for easier comparison of clinical outcomes. With the increasing availability of the 3D CT images, utilization of film based planning may diminish. However, point A based prescription and reporting is still encouraged as the most current clinical experience is based on this practice and the prescription can be easily integrated in the 3D image based planning. This study further demonstrated that the point A re-defi-

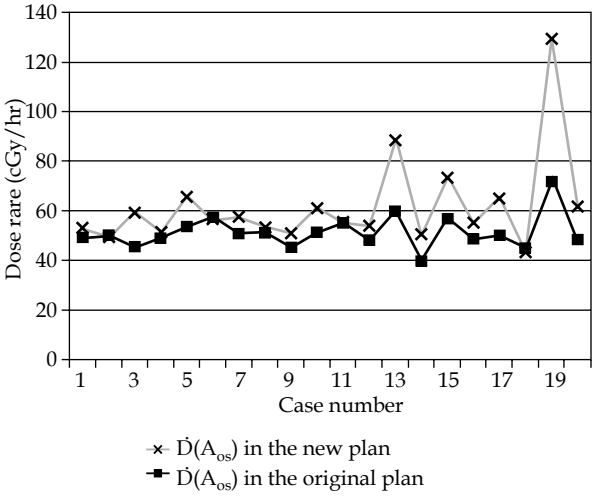

Fig. 3. Dose rate to A_{os} in the original plan (prescribed to A_{os}) and the new plan (prescribed to A_{ovoid}), which delivers the same dose rate to the prescription point of all 20 cases

nition can lead to significant dosimetric differences. Careful consideration should be given when changing practice from one point A definition to another to ensure dosimetric, and clinical equivalency from the previous clinical experiences.

Disclosure

Authors report no conflict of interest.

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