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 (Aos), and the American Brachytherapy Society (ABS) guideline definition in which the point A is 2 cm superior to the vaginal fornices instead of os (Aovoid) were generated. Using the same source strength, two plans prescribed the same dose to Aos and Aovoid. 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 Aovoid was 8.9 mm superior to Aos along the tandem direction with a standard deviation of 5.4 mm. With the same source strength and arrangement, Aos dose rate was 19% higher than Aovoid dose rate. The average TV(Aovoid) was 118.0 cc, which was 30% more than the average TV(Aos) of 93.0 cc. D2cc/D(Pre) increased from 51% to 60% for rectum, and increased from 89% and 106% for bladder, if the prescription point changed from Aos to Aovoid.

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.

Key words: cervical cancer, LDR brachytherapy, point A.
axis of the uterus” (Ao void). 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” (Ao 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 Ao 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 (Ao void) has been adopted by the ABS guidelines [2-4], whereas the definition of point A from the cervical os (Ao 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 (Ao 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 137Cs sources were used in the tandem and 1 137Cs source in each ovoid. The source arrangement was optimized to deliver prescription dose to point A while minimizing the values of D2cc (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. Ao void 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 Ao os to Ao void. 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 (D2cc/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 Ao os, and in the new plan it was the volume encompassed by isodose rate line traveling through Ao void.

Results

A histogram of the shifts between Ao void and Ao os is shown in Figure 1. A positive value on the X-axis indicates that Ao void was superior to Ao os along the tandem direction. The average shift between Ao void and Ao os was 8.9 mm with a standard deviation of 5.4 mm. Only 2 out of 20 cases had Ao void inferior to Ao 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 Ao void was 43.7 cGy/hr, and the average dose rate at Ao os was 51.3 cGy/hr. The standard deviation of the dose rate at Ao void was 6.38 cGy/hr (14.6% of the mean) and 6.77 cGy/ hr (13.2% of the mean) for Ao os. If we calculate (D(Ao os) / D(Ao void)) for an individual case, the dose rate ratio was 119% on average. The average treatment volume (TV) defined by Ao void (TV(Ao void)) was 118.0 cc, which was 30% more than the average TV(Ao 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 (Ao void – Ao os), the ratio of D(Ao void)/ D(Ao os) and TV(Ao void)/TV(Ao os). With point A shifting away from the ovoids, 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.
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, $D_{2cc}$ 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 $D(A)$ ratio. In the original plan which had $A_{os}$ as the prescription point, the average rectum and the bladder $D_{2cc}$ were 51% and 89% of $D(A_{os})$, respectively, compared to 60% and 106% of $D(A_{ovoid})$, 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-

### 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        | 62             | 118             |
| 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 $D_{2cc}/D_A$. 

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![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 $A_{os}$](image-url)
Dosimetric considerations from different point A definitions

which have been prescribing to A
ovoid guidelines [2-4], it is likely that more and more practices
ical practice. Currently, with the recently published ABS
he/she utilizes the different definition of point A in clin-
simetric information on what a clinician may encounter if
swered by clinical trials.

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
ovoid. 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
ovoid 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
ovoid as the prescrip-
tion point, the resultant dose rate at A
ovoid is most likely going
to be higher, indicating a higher dose rate delivery com-
pared 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
ovoid had in the original plan. Figure 3
compares the dose rate to A
ovoid in the original plan and the
dose rate to A
ovoid in the new plan. In the original plan, the
dose rate to A
ovoid was 51.3 cGy/hr on average, whereas in
the new plan the dose rate to A
ovoid 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
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 compar-
ison 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-
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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