

Dose evaluation of organs at risk (OAR) cervical cancer using dose volume histogram (DVH) on brachytherapy

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Abstract. Brachytherapy is one way to cure cervical cancer. It works by placing a radioactive source near the tumor. However, there are some healthy tissues or organs at risk (OAR) such as bladder and rectum which received radiation also. This study aims to evaluate the radiation dose of the bladder and rectum. There were 12 total radiation dose data of the bladder and rectum obtained from patients' brachytherapy. The dose of cervix for all patients was 6 Gy. Two-dimensional calculation of the radiation dose was based on the International Commission on Radiation Units and Measurements (ICRU) points or called D_{ICRU} while the 3-dimensional calculation derived from Dose Volume Histogram (DVH) on a volume of 2 cc (D_{2cc}). The radiation dose of bladder and rectum from both methods were analysed using independent t test. The mean D_{ICRU} of bladder was 4.33730 Gy and its D_{2cc} was 4.78090 Gy. D_{ICRU} and D_{2cc} bladder did not differ significantly ($p = 0.144$). The mean D_{ICRU} of rectum was 3.57980 Gy and 4.58670 Gy for D_{2cc}. The mean D_{ICRU} of rectum differed significantly from D_{2cc} of rectum ($p = 0.000$). The three-dimensional method radiation dose of the bladder and rectum was higher than the two-dimensional method with ratios 1.10227 for bladder and 1.28127 for rectum. The radiation dose of the bladder and rectum was still below the tolerance dose. Two-dimensional calculation of the bladder and rectum dose was lower than three-dimension which was more accurate due to its calculation at the whole volume of the organs.

1. Introduction

Cervical cancer is a deadly disease for women. This type of cancer is the most prevalent in the world. One way to cure cervical cancer is radiotherapy, either external radiotherapy irradiating the cancer tissue whose radiation source is outside the body or brachytherapy inserting the source into or around the cancerous tissue.

High dose rate (HDR) intracavitary brachytherapy is the most common method used to treat cervical cancer [1]. This therapy is able to give a radiation dose of more than 12 Gy/h^s [2]. The process begins with the installation of brachytherapy applicator in the cavity of the cervix. This applicator serves as a radioactive source when irradiating the cervix. After the applicator is attached, the images of patient's organ are taken by radiograph devices. The next process called treatment planning system (TPS) can be carried out using the two and three-dimensional methods. Using two-dimensional radiograph of the patient, two-dimensional dose calculations are based on points of organ by the International Commission Radiation Units (ICRU) 38 in 1985. As the development of three-dimensional radiography technology, Groupe Européen de Churietherapie / European Society for Therapeutic Radiology and Oncology (GEC Estro) in 2006 gave the recommended dose calculations



based on three-dimensional image of the patient obtained from dose volume histogram (DVH) and the volume histogram connecting organ with the radiation dose received [3]. TPS is a very important process in brachytherapy in order to produce the optimum radiation dose to the tumor and minimum dose to surrounding healthy tissue. The radioactive sources are then inserted into the applicator and irradiate cancerous tissue within a specific period before eventually taken back then stored in a well-protected place.

In practice, the radiation is received by not only cervix but also the healthy organs near the cervix such as bladder and rectum called organ at risk (OAR) which extremely sensitive to radiation when receiving doses above the tolerance, which consequently need a change of direction file or change in dose [2]. Hence, a dose evaluation of the bladder and rectum in cervical cancer brachytherapy is required. This study aims to evaluate the radiation dose of the bladder and rectum using both 2-dimensional and 3-dimensional methods.

2. Materials and methods

2.1. Installation applicator

This study used 12 cervical cancer brachytherapy patient data. The method used in accordance with cervical cancer brachytherapy procedures. The process began with the installation of applicator. The applicator used was Fletcher Suitdelclos consisting the tandem and ovoid. Installation of the applicator was conducted in patients who had been given an anaesthetic.

2.2. CT scan

The radiographic images of patient's organs were produced by CT scan. Patients did the CT scan after install edapplicator. CT scan produced images that can be reconstructed to form a three dimension (3D) through digital reconstruction radiography (DRR). Furthermore, CT scan image was transferred to the HDR brachytherapy for the treatment planning system via DICOM (Digital Imaging and Communications in Medicine) for defined tumours and coloured it by different colours for different organs.

2.3. Treatment Planning System (TPS)

TPS uses Brachyvision software both two-dimensional method and three-dimensional. Two-dimensional method based on points on two-dimensional radiographic image of the patient. The points are A, B, rectum and bladder as ICRU 38 recommendations. ICRU recommendations are made based on Three-dimensional image. Three-dimensional method uses dose volume histogram (DVH) to calculate radiation dose of organs. DVH summarize information in three-dimensional dose distribution. This histogram usually displayed as percent by volume of the total volume on the ordinate axis and the dose on the abscissa. The prescribed dose is 6 Gy for all patients. In accordance with the recommendations American brachytherapy society (ABS), the dose of the rectum and bladder must be below 80% of the prescribed dose to the cervix.

2.4. Evaluation of dose

Dose evaluation using two-dimensional method performed at the ICRU 38 points of the bladder and rectum while three-dimensional ones obtained from 2 cc volume of organ of DVH (D_{2cc}). The radiation dose obtained from both methods are analysed using SPSS independent t test ($\alpha = 0.05$).

3. Results and discussion

Figure 1 is the result of two-dimensional method (D_{icru}) which shows point A, point B, bladder and rectum point. D_{icru} was obtained by drawing a line from the applicator to the ICRU points while three-dimensional method was obtained from volume 2cc of DVH as shown in Figure 2.

The mean D_{icru} for bladder is 4.33730 Gy and the mean D_{2cc} for bladder is 4.78090 Gy. As shown in Table 1, for bladder, the mean of D_{2cc} is greater than the mean of D_{icru} with ratio 1.10227. Based on

independent test t test, two and three-dimensional methods dose of bladder did not differ significantly ($p = 0.144$). The mean D_{icru} of rectum was 3.57980 Gy while the mean D_{2cc} of rectum was 4.58670 Gy. Based on table 1, the mean D_{2cc} is greater than D_{icru} with ratio 1.28127. The differences between the mean D_{2cc} and D_{icru} of rectum are significant based on the statistical test results ($p = 0.000$).

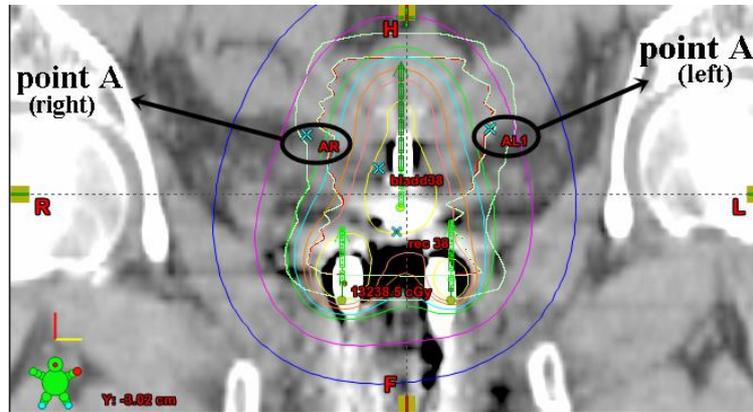


Figure 1. Supine position of the patient

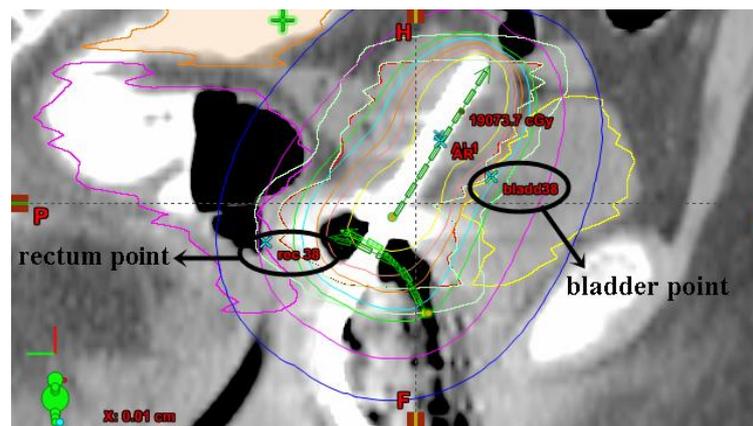


Figure 2. Oblique position of the patient

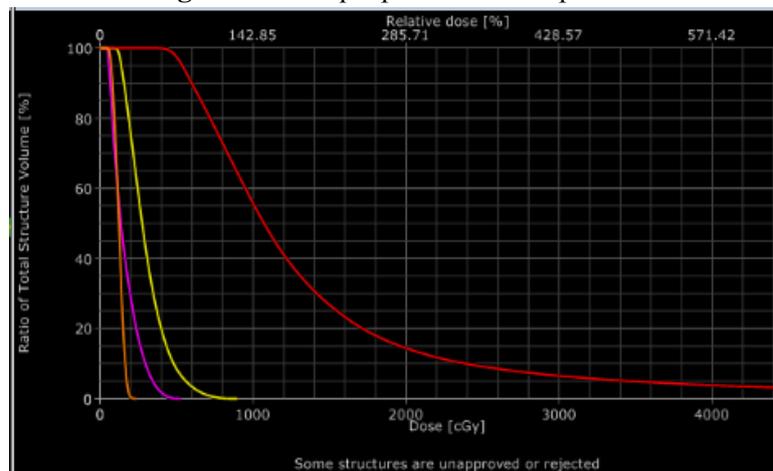


Figure 3. Dose Volume Histogram

Table 1. The mean D_{icru} and D_{2cc}

Organ	D_{icru} (Gy)	D_{2cc} (Gy)
Bladder	4.33730	4.78090
Rectum	3.57980	4.58670

As it is shown in Table 1, the average radiation dose bladder methods of 2-dimensional and 3-dimensional still below 4.8 Gy. At the same table, it also indicates the average radiation dose rectal method of 2-dimensional and 3-dimensional does not exceed 4.8 Gy. Both doses of radiation are in accordance with the recommendations of ABS. It means that the radiation dose is not harmful to the patients' bladder and rectum. But, there were some patients received radiation doses exceeding 4.8 Gy. The result was also performed by Sharma et al. This was caused by the distance of the bladder or rectum distance that was too close to the applicator so that received large doses. In accordance with the study of Zhang et al., the closer organs with the radioactive source in the applicator, the greater the dose of radiation received by these organs. Conversely, the distant organ of the applicator, the smaller the dose of radiation received.

It also found several differences in radiation dose between the bladder and rectum from one patient to another caused by patient anatomy. Based on the two-dimensional method, anatomy bladder and rectum belonging to different patients cause the difference in distance between the organs of the applicator and the radiation dose among patients' OAR. In addition, based on 3-dimensional method, the patients' anatomy lead to differences in organ volume and DVH generated as well.

The bladder filled with urine was able to influence the radiation dose to expand and push the applicator away from the surrounding organs. Thus, the radiation dose of bladder urine charged varies with the radiation dose when the bladder is empty. The rectum, with the same treatment filled with faeces slightly expands, leading to the differences in radiation dose between the empty and filled rectum.

Table 1 shows the average dose of radiation three-dimensional method is higher than two-dimensional one. The average ratio D_{2cc} bladder against D_{icru} is 1.10227 with insignificant differences in bladder radiation dose between 3- and 2-dimensional method ($p = 0.144$). This is consistent with the research conducted by Kirisits et al. and Hashim et al. However, some researchers, Jamema et al., Onal et al., And Tan et al. showed the opposite result, a significant difference between the dose of 3-dimensional and 2-dimensional bladder dose. Rectal radiation dose ratio using both methods was 1.28127 with differences radiation dose of those methods differing significantly ($p = 0.000$). Meanwhile, according to research Jamema et al., Tan., Et al., Onal et al., And Vinod et al., both doses were not different significantly.

As it is described above, the comparison results of the two methods are varied. But, with the similar indication that three-dimensional dose greater than the dose two dimensions which according to the research by Jamema et al., it can be caused by differences in radiographic and applicators. Besides, the latter method calculates the dose based on the distance of the applicator organ point compared to 3-dimensional method calculating the dose based on the volume of the organ. However, 3-dimensional method displays the more clear size of the tumor and OAR and the more accurate dose calculation. The size of the organ is obviously known that too large or small radiation doses can be avoided.

The different radiographic tools produced different images of the bladder and rectum. Based on the two-dimensional method, the OAR image differences lead to differences in ICRU point and dose. Meanwhile, according to three-dimensional method, the difference images of OAR produced different volume and DVH. Different applicator types produced different brachytherapy dose distribution related to the shape of the applicators. Various types of the applicator adapted to the location of the cervical tumour and the selection of the proper applicator can reduce the radiation dose of the bladder and rectum.

4. Conclusion

This study concluded the mean radiation dose of bladder from two-dimensional method (Dicru) was 4.33730 Gy while three-dimensional methods (D_{2cc}) was 4.78090 Gy. The mean Dicru of rectum was 3.57980 Gy while its mean D_{2cc} was 4.58670 Gy. The mean radiation dose of the bladder and rectum were below the tolerance dose. Besides, the ratio of the mean bladder D_{2cc} to D_{icru} was 1.10227. Differences bladder radiation dose of both methods was not significance ($p = 0.144$). The ratio of the D_{2cc} rectum to its D_{icru} was 1.28127. Rectal radiation dose of these two methods were different significantly ($p = 0.000$).

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