Pelvic MRI Application to the Dosimetric Analysis in Brachytherapy of Uterine Cervix Carcinoma

Sung Ja Ahn, M.D., Woong Ki Chung, M.D.
and Byung Sik Nah, M.D.

Department of Therapeutic Radiology, Chonnam University Medical School, Kwang-ju, Korea

= Abstract =

Purpose : Before we report the results of curative radiotherapy in cervix cancer patients, we review the significance and safety of our dose specification methods in the brachytherapy system to have the insight of the potential predictive value of doses at specified points.

Materials and Methods : We analyze the 45 cases of cervix cancer patients treated with intracavitary brachytherapy. In the lateral simulation film we draw the isodose curve and observe the absorbed dose rate of point A, the reference point of bladder(SBD) and rectum(SRD). In the sagittal view of pelvic MRI film we demarcate the tumor volume(TV) and determine whether the prescription dose curve of point A covers the tumor volume adequately by drawing the isodose curve as correctly as possible. Also we estimate the maximum point dose of bladder(MBD) and rectum(MRD) and calculate the inclusion area where the absorbed dose rate is higher than that of point A in the bladder(HBV) and rectum(HRV), respectively.

Results : Of forty-five cases, the isodose curve of point A seems to cover tumor volume optimally in only 24(53%). The optimal tumor coverage seems to be associated not with the stage of the disease but with the tumor volume. There is no statistically significant association between SBD/SRD and MBD/MRD, respectively. SRD has statistically marginally significant association with HRV, while TV has statistically significant association with HBV and HRV.

Conclusion : Our current treatment calculation methods seem to have the defect in the aspects of the nonoptimal coverage of the bulky tumor and the inappropriate estimation of bladder dose. We therefore need to modify the applicator geometry to optimize the dose distribution at the position of lower tandem source. Also it appears that the position of the bladder in relation to the applicators needs to be defined individually to define "hot spots".

Key Words : Cervix cancer, Brachytherapy, Pelvic MRI, Dosimetry

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통신저자 : 안성자 광주시 동구 학동 8 전남의대 치료방사선과학교실

INTRODUCTION

Brachytherapy plays an essential role in the definitive radiation treatment of cervical carcinoma. Although there are many literatures on the subject of the interrelationship between the tumor control or complication rate and the radiation dose[1-5], the conclusions are contradictory. Also the interpretations of the results are complicated further by the difficulty encountered in dosimetric measurements of parameters with high variability from one patient to another[6]. The dosimetry of intracavitary irradiation is complex in that the optimum dose that can be delivered is dictated not only by the volume and extent of tumor but also by the adjacent dose-limiting structures, such as small bowel, large intestine, rectum, and bladder. The steep gradient of dose rate in the vicinity of the intracavitary arrangement makes it difficult to determine the exact doses received by critical structures even with in vivo dosimetry[6]. Although some guidelines have evolved to assist in optimization of dose in carcinoma of the cervix[6-8] and the commonly used prescription points are point A, point B, rectal dose, and bladder dose. These points are said to be only representative values and not to be absolute values indicating individual variability.

In our hospital, the pelvic MRI(magnetic resonance imaging) has been available since 1991 and is more commonly used than the pelvic CT for the work-up study of cervix cancer. By combining the coronal and sagittal view of pelvic MRI with the simulation AP and lateral radiographs, we can figure out the more delicate reference points representing tumor volume and the adjacent normal structures. To have insight of the potential predictive value of doses at specified points in the simulation radiograph and of a generalized overview of the complex dosimetry involved, a retrospective analysis of intracavitary insertions using the Buchler applicator system is performed for the cervix cancer patients treated at the Department of Therapeutic Radiology, Chonnam University Hospital.

MATERIALS AND METHODS

In our hospital the intracavitary radiotherapy has been started in May, 1987. It is the remote afterloading system(Buchler, Germany) of which devices are composed of three channels(one intrauterine tandem applicator and two ovoids applicators). All parts are interconnected outside the patient with one fixation screw(Fig. 1)[1]. The radioactive isotope loaded in the tandem is cobalt-60 and oscillates at a constant rate in a tube during the treatment time, while those for ovoids are cesium-137 fixed in a tube. The initial source activity of cobalt-60 and cesium-137 was 1.1 Ci and 1.25 Ci, respectively.

Some ready-made isodose charts are supplied with the Buchler system according to the applicator geometry. Of available isodose charts, we

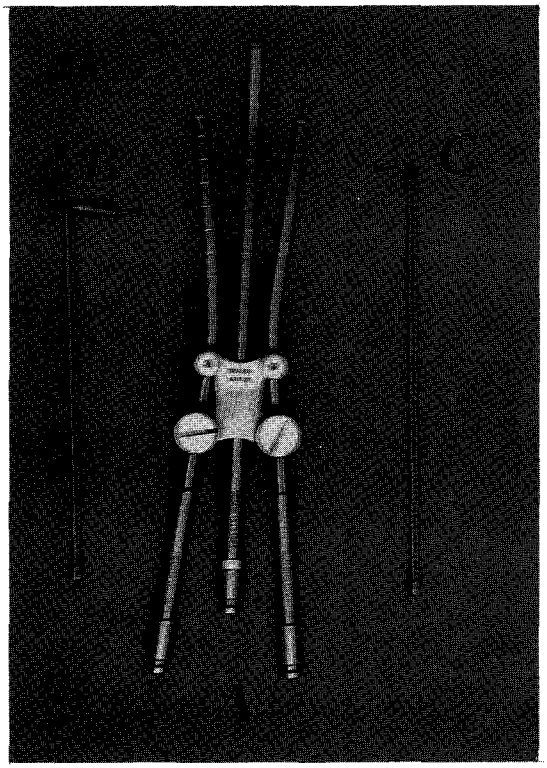

Fig. 1. Buchler applicator sets, (A) three channels(one intrauterine tandem and two ovoids applicators), dummy sources of cesium(B) and cobalt(C).

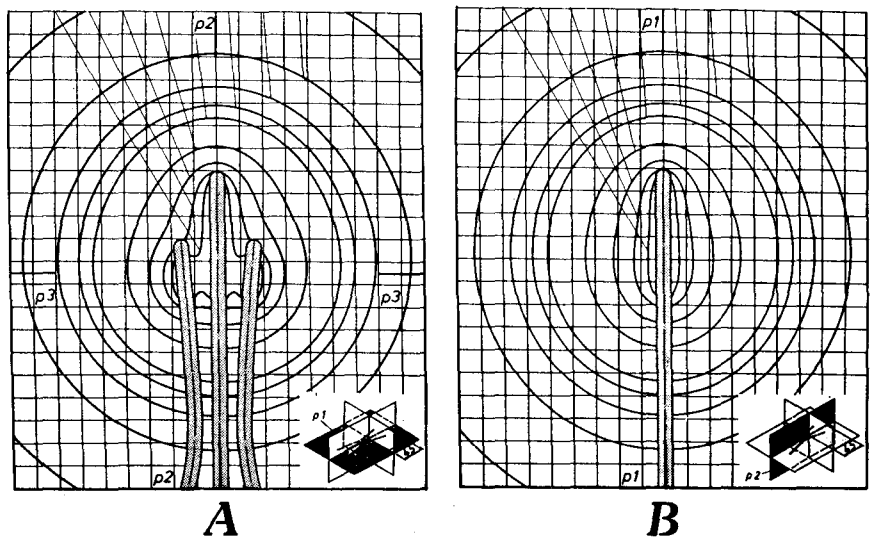

Fig. 2. (A) Transverse view and (B) sagittal view of the isodose chart of the most commonly used applicator geometry in the brachytherapy of the uterine cervix cancer patients at Department of Therapeutic Radiology, Chonnam University Hospital.

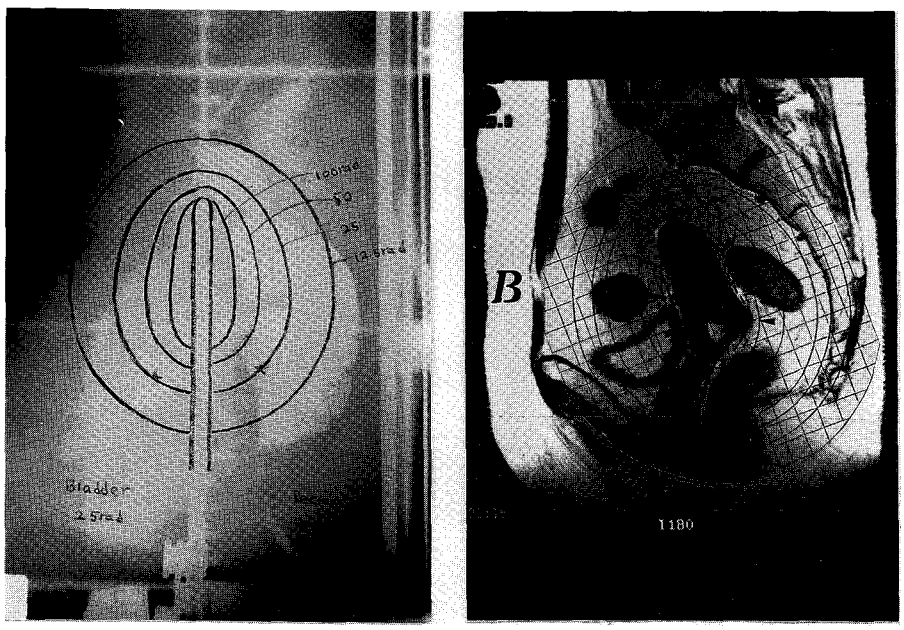

Fig. 3. Lateral simulation radiograph(A) and the sagittal image of pelvic MRI(B) with isodose chart on it.

choose one isodose chart which is considered to be the most optimal and adapts the applicator geometry for this configuration by simulation rather than to the each patient's pelvic anatomy(Fig. 2). For each application, the isodose distribution is viewed in the frontal and sagittal planes. We

prescribe the treatment dose to the point A, which is defined as the point 2cm lateral and above the external Os of uterine cervix. The calculated dose rate at the point A is 77cGy per minute. The localization of bladder and rectum is performed using radiographs taken with contrast media in the bladder and rectum. The bladder reference point is localized by using a Foley catheter with the balloon filled with a contrast material. On the lateral radiograph, the bladder reference point is defined at the center of a balloon. The rectal reference point is identified on the lateral radiograph and is located on the anterior rectal wall at the level of cervix visualized by the barium on the rectum.

Pelvic MRI has been used as the work-up study for the cervix cancer since 1992 and is lately more commonly recommended than the pelvic CT. Four hundred and thirteen cervix cancer patients received three channel intracavitary radiotherapy from 1992 to 1996. We randomly selected the 45 cases who had initial pelvic MRI film and simulation film; 6 patients of stage IB1, 5 of IB2, 9 of IIA, 21 0f IIB and 4 of III.

We review the lateral simulation radiograph and compare it to the sagittal image of MRI film. The target(cervix region and corpus) is configured out and the lateral isodose surface line of the point A is also drawn on MRI film(Fig. 3). In the lateral simulation film we draw the isodose curve and find the reference point of bladder(SBD) and rectum(SRD). In the sagittal image of pelvic MRI film we demarcate the tumor volume(TV) and evaluate whether the prescription point A isodose curve covers the tumor volume adequately by drawing the isodose curve as correctly as possible. Also we estimate the maximum point dose of bladder(MBD) and rectum(MRD) and calculate the inclusion area where the absorbed dose rate is more than that of point A in the bladder(HBV) and rectum(HRV), respectively.

The statistical significance of the interrelationship between the two parameters is tested by the Pearson chi-square test using the BMDP software[9].

RESULTS

Of total forty-five patients, the isodose curve of the point A covers tumor volume optimally in 24(53%). The optimal tumor coverage is dependent on the tumor volume(p=0.0005) rather than on the stage of the disease as shown in Table 1 and Table 2. In the cases of bulky tumor, there is high risk of geographical missing of the optimal tumor coverage by the point A isodose line(Fig. 4). Although the tumor is not bulky, if the tumor is located at the periphery of the cervix eccentrically, the risk is similar to the bulky tumor(Fig. 5).

In the comparison between the reference point dose of bladder(SBD) and rectum(SRD) in the lateral simulation film and the estimated value of maximum point dose of bladder(MBD) and

Table 1. Interrelationship between the Stage of Uterine Cervix Cancer and Tumor Coverage by Isodose Line of Point A in the Sagittal Image of Pelvic MRI

Stage	No. of Pts	Tumor Coverage(%)	
		Optimal	Non-optimal
IB1	6	5(83%)	1(17%)
IB2	5	1(20%)	4(80%)
IIA	9	7(78%)	2(22%)
IIB	21	11(52%)	10(48%)
III	4	0(0%)	4(100%)
Total	45	24(53%)	21(47%)

p = 0.1606(χ^2-test)

Table 2. Interrelationship between the Tumor Volumetry by Pelvic MRI and Tumor Coverage by Isodose Line of Point A in the Sagittal Image of Pelvic MRI

Tumor Volume(cm2)	No. of Pts	Tumor Coverage(%)	
		Optimal	Non-optimal
3 or below it	21	17(81%)	4(19%)
above 3	24	7(29%)	17(71%)
Total	45	24(53%)	21(47%)

p = 0.0005(χ^2-test)

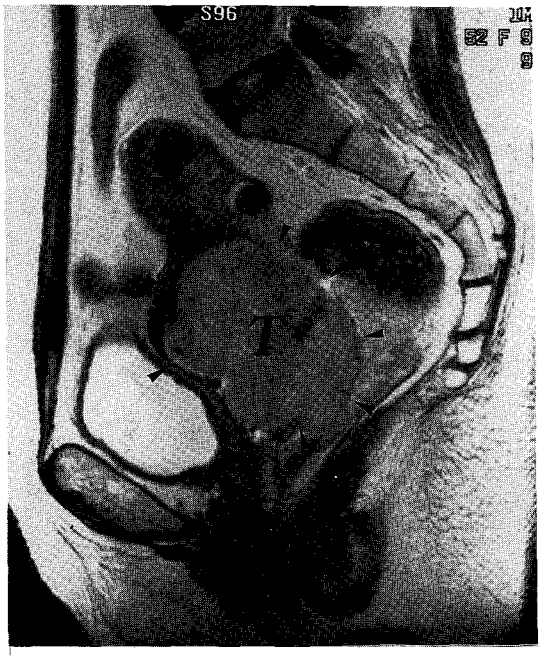

Fig. 4. Example of geographical missing of the optimal tumor coverage by the point A isodose line in the bulky uterine cervical tumor.

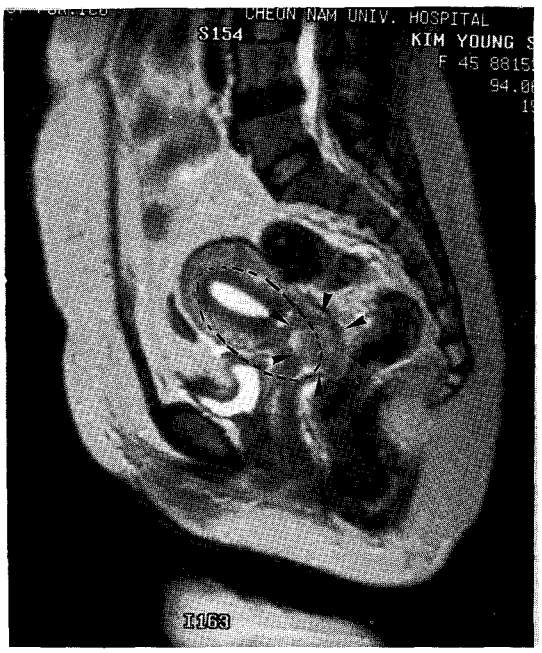

Fig. 5. Example of geographical missing of the optimal tumor coverage by the point A isodose line in the eccentrically located uterine cervical tumor. Arrow defines the tumor located on the posterior cervical lip.

Table 3. Association between the Tumor Volumetry by Pelvic MRI and Inclusion Area within the Isodose Line of Point A in the Bladder(HBV)

HBV(cm^2)	Tumor Volume(No. of Pts)	
	≤ $3cm^2$	>$3cm^2$
0	12	23
1	2	0
2	5	0
3	1	0
4	1	1
Total	21	24

p = 0.0004(χ^2-test)

Table 4. Association between the Tumor Volumetry by Pelvic MRI and Inclusion Area within the Isodose Line of Point A in the Rectum(HRV)

HBV(cm^2)	Tumor Volume(No. of Pts)	
	≤ $3cm^2$	> $3cm^2$
0	12	23
1	2	0
2	5	0
3	1	0
4	1	1
Total	21	24

p = 0.0233(χ^2-test)

rectum(MRD) in the sagittal view of pelvic MRI film, we find no statistically significant association between two parameters in the bladder and rectum.

In the comparison of SBD vs. SRD and the inclusion area within the isodose curve of the point A in the bladder(HBV) and rectum(HRV), SRD has statistically significant association with HRV (p=0.0012), while SBD does not have with HBV.

In the comparison of tumor volume(TV) and HBV or HRV, tumor volume is statistically significant association with both HBV(p=0.0004) and HRV(p=0.02)(Table 3 and 4). The inclusion area of bladder and rectum is larger in the small tumor than that of the bulky tumor(Fig. 6).

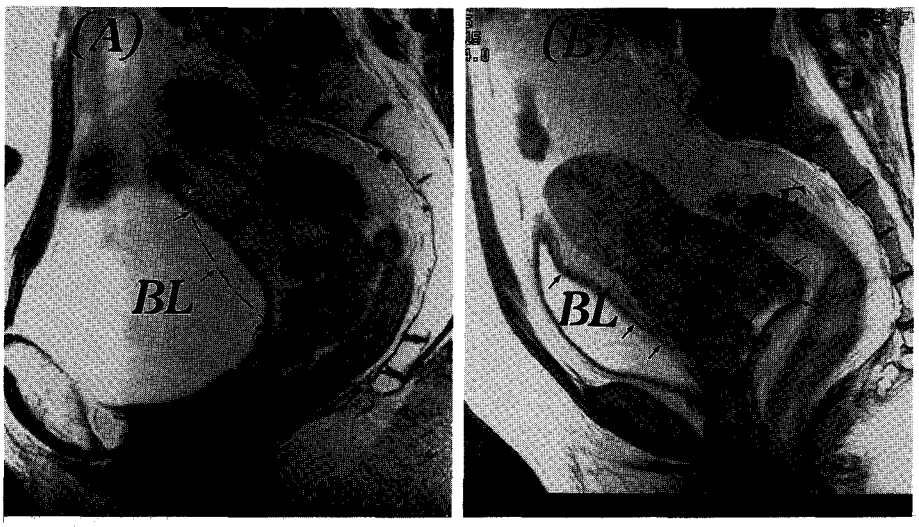

Fig. 6. Examples of inclusion area of bladder and rectum according to the small tumor(A) and bulky tumor volume(B).

DISCUSSION

Although there are many reports on the dose relationship which consider the local tumor control rate or the normal tissue complication rate of the cervix cancer[1-5], it is widely recognized that the direct comparison of the results or the introduction of the treatment methods of other's to their own is a difficult matter because the brachytherapy devices and condition are variable among units. Brachytherapy has been used in combination with external beam irradiation to take advantage of high doses in close proximity to the sources and rapid fall-off beyond. However, because of the juxtaposition of critical normal tissues to the uterine cervix and vagina, and because of individual anatomical variations in the location of these tissues, complications can not be entirely avoided. Optimum radiotherapy in cervical carcinoma entails not only attempting curative tumor doses to the target tissues but also minimizing the doses to adjacent normal, uninvolved structures.

In the dose specification in brachytherapy of cervical carcinoma, the point A is specified, which is currently considered to be the "treatment dose"[10], and points are specified defining rectum, bladder, and other tissues to represent normal tissue tolerance points. Anatomically, the point A represents the location where the uterine vessels cross their ureter. It is believed that the tolerance of these structures is the main limiting factor in the irradiation of the uterine cervix, but this anatomic relationship is quite variable[11]. Potish et al.[12] demonstrates that there is no systematic association fixed among the dose specification systems and dose is markedly affected by the position of the colpostats and tandem. To devise a uniform reporting system, ICRU report no. 38 is compiled, which recommends reporting the dose to a reference isodose(60Gy), its height, width, and thickness, as well as doses at specified points to denote doses to rectum and bladder[13]. However, the reference isodose suggested by this report appears to be complex and its applicability to the clinical setting in predicting or preventing complications is uncertain. So most of the users of the brachytherapy systems in the cervix cancer management depend on their own clinical experiences about the treatment techniques such as the fractionation size and interval.

Throughout this analysis, we find that the tumor

volumetry by pelvic MRI is an important factor determining the optimal tumor coverage within point A isodose curve or is an the indicator representing the probable absorbed dose of bladder and rectum indirectly. In our brachytherapy systems, the tumor diameter larger than 3cm seems to have the high risk of underdosage of optimal tumor coverage. While the risk of hot spot of bladder or rectum is lower than that of small tumor less than 3cm.

Cunningham et al.[14] noted in-vivo rectal and in-vitro thermoluminescent dosimeter(TLD) measurements are of little use in documenting doses as there are uncertainties because of positioning. These authors feel that doses at reference points selected on the basis of contrast radiography in rectum and bladder and calculated with the aid of computer-derived dose distributions give a more accurate estimation of doses at the preselected reference points.

Lukka et al.[15] examining CT scans of patients undergoing intracavitary treatment note that there is a marked variation in bladder position relative to the cervix, the upper limit of the undistended bladder extending from 5.5cm cephalic to the cervical os to 4.0cm below, and the posterior wall of the bladder extends from 1.5cm to 4.2cm from the cervix. Between the reference point dose of bladder and rectum checked in the lateral simulation film and the estimated maximum absorbed dose in the sagittal image of pelvic MRI film, there is no statistically significant relationship. In the comparison between the reference point dose of bladder and rectum checked in the lateral simulation film and the area which absorbed dose is higher than that of point A isodose curve, the rectal dose only has statistically marginally significant association. The dose to a small portion of the bladder is equal to the dose to the point A and there is a rapid decrease in dose at 1 and 2 cm antrior to bladder as expected.

In conclusion, our current treatment calculation methods seem to have the defect in the aspect of the inevitable underdosage of the bulky tumor volume and inappropriate estimation of bladder dose. We therefore need to modify the applicator geometry to optimize the dose distribution at the position of the lower tandem source and also it appears that the position of the bladder in relation to the applicators needs to be defined individually to define "hot spots".

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= 국문초록 =

자궁경부암의 강내조사치료에 있어서 흡수선량평가시 골반강 자기공명사진의 응용

전남대학교 의과대학 치료방사선과학교실

안성자 · 정웅기 · 나병식

목 적 : 자궁경부암환자의 근치목적의 방사선치료 성적을 보고하기에 앞서 본원에서 사용하고 있는 자궁강내치료기기의 선량투여 방법의 정확성을 평가해보고 각 장기의 흡수선량을 대변할수 있는 예측력이 어느정도인지 알아보고자 연구를 시행하였다.

대상 및 방법 : 조준필름의 측면사진에서는 본원에서 현재 사용중인 방광(SBD)과 직장(SRD)의 기준흡수점의 흡수선량을 확인 하였다. 골반강 자기공명상의 측면사진에서 종양의 두 횡축과 종축의 직경을 곱하여 종양부피(TV)를 측정하였고, 기본으로 사용되고 있는 등선량곡선을 그린후 선량기준점 A 의 등선량 곡선내에 자궁경부 종양이 포함되는지 대상 환자별로 확인하였으며, 방광(MBD)과 직장(MRD)에서 보여주는 최대흡수선량점의 값을 측정하였고, 또한 선량기준점 A 의 등선량 곡선내에 포함되는 방광(HBV)과 직장(HRV)의 면적을 계산해 보았다.

결 과 : 45례를 대상으로 분석하였다. 이중 53%(24/45) 에서만이 선량기준점 A의 등선량곡선내에 종양이 잘 포함되었다. 적절한 포함정도는 병기보다는 원발종양의 크기와 통계학적으로 유의한 관련성을 보여주었으며 종양의 측면지름의 크기가 3cm 이상인 종양은 불충분한 포함을 보여주었다. 조준필름의 측면상의 방광과 직장의 기준흡수선량값은 자기공명사진상의 방광과 직장의 최대흡수값과 각각 유의한 관계를 보여주지 못했으나, 조준필름의 직장의 흡수선량값(SRD)은 HRV 와 유의한 관련성을 보여주었다. HBV 이나 HRV 은 오히려 자기공명사진상에서 측정한 종양의 크기(TV) 와 유의한 연관성을 보여 주었다.

결 론 : 본원에서 사용하고 있는 선량계산 방법은 개별적인 종양의 크기를 고려해주지 못하였으며, 특히 방광의 흡수선량계산에 있어서 실제 흡수선량을 대변할수 있는 예측도가 낮아서 이에 대한 환자 개개인의 종양의 특성을 고려한 선량계산이 필요하리라 사료되는 바이다.