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Dosimetric Comparison Between High Dose Rate Brachytherapy Boost and Volumetric Arc Therapy Boost in Locally Advanced Cancer cervix

Hanady Hegazy[a*], Neamat Hegazy[b], Maher Soliman[c], Amr Elsaid[d]

[a,b,c,d]*ACOD,Alexandria,Egypt, 21131*

[a]*Email: hanajodyan@yahoo.com*

[b]*Email: neamatkholosy@hotmail.com*

[c]*Email: maher_oncology@yahoo.com*

[d]*Email: amrelsaid@yahoo.com*

Abstract

Concurrent chemoradiotherapy is considered the standard treatment for the locally advanced cancer cervix (LACC).Radiotherapy is usually administered by a three-dimensional conformal external beam(3DCRT EBRT) approach to whole pelvis to a minimum dose of 45Gy, followed by a brachytherapy (BT)boost to give additional dose to the gross tumor within the cervix and parametria. High dose rate (HDR) brachytherapy is commonly administered with intracavitory applicator. HDR BT allows delivery of a high radiation dose to the tumor site with rapid fall off so protect normal tissue. Besides, less target motion compared to EBRT. However, several drawbacks exist including invasive technique, pain, requiring spinal or general anesthesia and operative risks such as uterine perforation, infection, and bleeding. Due to the above risks, we tried to assess the possibility of using high technique EBRT to replace the BT boost in patients who are either medically unfit for or refuse a brachytherapy boost. we tried to achieve a similar dose distribution with comparable or improved normal tissue sparing to that seen in previously treated HDR BT plans at our institution. Dosimetric comparison between high technique of external beam radiotherapy volumetric arc therapy (VMAT) and high technique Computer topography (CT) guided HDR BT.Ten patients were selected with LACC, representing typical clinical situations according to initial tumor extension and response after EBRT. A boost was given by intracavitary CT guided HDR BT. High risk clinical target volume (HR CTV), bladder, rectum, sigmoid and small bowel were delineated.

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* Corresponding author.

Planning was done using Sagi planning system and was manually optimized with respect to organ dose limits. A VMAT planning was created using the variance planning system and a margin of 5mm were added to the CTV to create the target planning target volume (PTV).The inversely planned VMAT was challenged to deliver the highest possible doses to PTVs while respecting D2cc limits from BT, assuming the same fractionation (7 Gy in 3 fractions). When VMAT was limited to D2cc from BT, the D90 for the PTV in VMAT boost was lower than received by the HR CTV in the BT boost (6.3Gy vs. 6.9Gy, p value 0.037). Mean volume of the PTV in VMAT was higher than that of HR CTV in the BT (89 cm^3vs 41.7cm^3).The dose to the organ at risks (OARs) was comparable.D2cc was higher in VMAT for bladder, sigmoid and rectum (5.6Gy, 0.51, 5.5Gy vs. 4.3Gy, 0.33, 3.9Gy) while D2cc for the small bowel in BT was higher compared to the VMAT (4.1Gy vs. 1.94Gy).The VMAT had comparable target coverage and potential for improved sparing of most normal tissues compared to brachytherapy boost. It is an option that exists for patients who refuse BT or can't tolerate it or in case of non availability of BT or non working machine. However, this is a dosimetric comparison that needs larger number of patients and further application to study the drawbacks that might exist for the VMAT use.

Keywords: LACC; HDR BT; VMAT; HRCTV.

1. Introduction

CCR is considered the standard treatment of LACC.The radiotherapy treatment consist of EBRT and BT boost. Although using HDR brachytherapy provide a unique pear shaped dose distribution with steep dose gradients, they also contain certain limitations concerning patient specific source configurations, cause more patient discomfort, and are subject to errors due to applicator movement or alignment between fractions, insertion of the device, and image acquisition [1]. VMAT was first introduced in 2007 and described as a novel radiation technique that allowed the simultaneous variation of three parameters during treatment delivery, i.e. gantry rotation speed, treatment aperture shape via movement of multileaf collimator (MLC) leaves and dose rate [2]. VMAT showed a great potential for producing highly conformal doses to treatment volumes while sparing OARs [3].On the other hand; it was unable to deliver an increased homogenous dose to the PTV while appropriately sparing the OARs. VMAT could potentially be an alternative option for duplicating traditional brachytherapy dose distributions for patients in need of brachytherapy who are unable to undergo this treatment modality [3]. Toxicity to OARs should always be considered when using any EBRT technique to treat those who are unable to receive BT treatment with the gastrointestinal tracks toxicity being the main recorded toxicity [1]. Also the considerations for target motion and delineation made the VMAT technique limited compared to the traditional BT technique [4].

2. Methods and Materials

Ten patients were selected with locally advanced cervix cancer, representing typical clinical situations according to initial tumor extension and response after EBRT. A boost was given by intracavitary CT guided HDR brachytherapy. High risk clinical target volume (HR-CTV), bladder, rectum, and small bowel were delineated. Planning was done using Sagi planning system and was manually optimized with respect to organ dose limits. A VMAT planning was created using the variance planning system and a margin of 5mm were added to the CTV

to create the target planning target volume (PTV).The inversely planned VMAT was challenged to deliver the highest possible doses to PTVs while respecting D2cc limits from BT, assuming the same fractionation (7 Gy in 3 fractions).

-The patients received whole pelvis 3D conformal EBRT (45Gy in 25 fractions) with assumption that OARs received 100% of the dose.

-The patients underwent CT guided HDR brachytherapy boost as a part of their treatment protocol.

2.1. The brachytherapy boost

-High dose rate brachytherapy (cobalt 60) was used with intracavitary applicator.

-It was done under spinal or epidural anesthesia.

-Applicators: Tandem 40/60, Ring (30-35-25).

-Examination under anesthesia and dilatation of the cervix then insertion of the applicators.

-A CT scan was done to ensure good application then images were transferred to the CT planning (Sagi planning system) where reconstruction was done.

-Contouring of the:

- HR CTV (high risk clinical target volume) which is defined by GEC-ESTRO [5] as the area of gross residual disease at the time of brachytherapy. It includes the gross disease at the time of implant, the entire cervix and any areas clinically suspicious for residual disease.
- Organ at risk including rectum, urinary bladder and small bowel.

-Then plan was generated to achieve our goal:

-A dose to the 90% of the target of 7Gy/f in 3 fractions, (D90=7Gy).

-A dose to D2cc rectum < 4Gy/f, sigmoid <4Gy/f and urinary bladder <5 Gy/f in each fraction.

2.2. The VMAT boost was created in the following steps

- The 10 patients underwent CT imaging before the insertion of the intracavitary brachytherapy applicator to avoid any errors in VMATS planning and calculations.
- The CDs of the 10 patients were received by the planning system (Variance planning system) where VMATS planning and dosimtery done.
- Target volume delineation and organs at risk delineation were done taking in consideration the following:

-Two different planning system in two separate places

-The attempts to unify the volumes between the VMATS plans and the brachytherapy plans.

-HR-CTV in the BT boost was delineated in the VMAT boost as CTV with 5 mm around as a PTV.

- Two full arcs were used with collimator angel (90-0).
- Energy used 6 MV.

- The use of the dose volume histogram to assess the points of comparisons between the two plans.
- The use of HDR radiobiological dose equivalent worksheets available on the American brachytherapy society (ABS) online for dosimetric calculations.

For the VMAT boost, the same fractionation was assumed as for the BT: 7Gy x 3 fractions to cover the PTV after 45 Gy of the EBRT. Inversely planned VMAT was challenged to deliver the highest possible doses to the PTV while maintaining the same D2cc limits for bladder, rectum, and sigmoid. Available DVH information from brachytherapy was used as input parameters during inverse planning. The primary target parameter of interest was the D90. For VMAT the dose was to be delivered to the PTV structures and not to the CTV as in BT.If D90 values of BT could not be reproduced with VMAT, it was aimed to achieve a D90 of 7 Gy for the PTV.For treatment plan evaluation, D90 for PTV achieved with VMAT were compared with the HRCTV values from advanced BT. Besides, D2cc which was used for treatment planning for the OAR bladder, rectum and sigmoid were evaluated. All dosimetric data of different plans were compared with a paired two-tailed Student's t test, and statistical significance was assumed at $p < 0.05$.

3. Results

When VMAT was limited to D2cc from BT, the D90 for the PTV was lower than that received by the HR CTV in the BT boost (6.3Gy vs.6.9Gy,p value 0.037). Mean volume of the PTV in VMAT is higher than that of HR CTV in the BT ($89cm^3$ vs.41.7cm3). The dose to the organ at risks (OARs) was comparable.D2cc was higher in VMAT for bladder and rectum while D2cc for sigmoid and small bowel in BT was higher compared to the VMAT.

Table 1: Comparison between Brachytherapy and VMAT according to the HR CTV/PTV integral dose and parameters

Parameters	Brachytherapy	VMAT	Z	p
integral dose to HRCTV/PTV (mean dose x volume)				
Min. – Max.	50.3-588.0	468.6-1027.5	2.803*	0.005*
Mean ± SD.	191.6±161.6	671.0±185.6		
Median (IQR)	119.8 (101.8-255.6)	653.2 (502.3-752.0)		
Mean dose				
Min. – Max.	3.4-6.8	7.1-7.9	2.810*	0.005*
Mean ± SD.	5.1±1.2	7.5±0.3		
Median (IQR)	5.4 (3.9-6.0)	7.6 (7.4-7.7)		
CTV HR/PTV volume cm3				
Min. – Max.	7.4-149.6	65.0-137.0	2.497*	0.013*
Mean ± SD.	41.7±41.8	89.0±23.6		
Median (IQR)	23.3 (19.8-53.9)	85.8 (66.7-99.1)		
CTVHR/PTV D90				
Min. – Max.	5.7-8.1	6.2-6.4	2.090*	0.037*
Mean ± SD.	6.9±0.80	6.3±0.1		
Median (IQR)	7.0 (6.6-7.2)	6.3 (6.3-6.3)		

Table 2: Comparison between Brachytherapy and VMAT according to the OARs parameters

Rectum	Brachytherapy	PTV HRCTV	Z	p
Volume				
Min. – Max.	29.9-54.1	29.9-54.1	-	-
Mean ± SD.	39.0±8.4	39.0±8.4		
Median (IQR)	36.9 (32.8-43.3)	36.9 (32.8-43.3)		
Mean dose				
Min. – Max.	3.8-7.9	2.0-15.4	1.784	0.074
Mean ± SD.	5.2±1.2	4.0±4.0		
Median (IQR)	5.3 (4.2-5.6)	2.8 (2.7–3.2)		
D2cc				
Min. – Max.	3.1-4.7	3.8-7.0	2.599*	0.009*
Mean ± SD.	3.9±0.5	5.5±1.0		
Median (IQR)	4.1 (3.3-4.3)	5.3 (4.9-6.3)		
Bladder	**Brachytherapy**	**PTV HRCTV**	**Z**	**P**
Volume				
Min. – Max.	9.7-137.3	9.7-137.3		
Mean ± SD.	48.2±35.4	48.2±35.4		
Median (IQR)	42.3 (22.5-55.4)	42.3 (22.5-55.4)		
Mean dose				
Min. – Max.	3.7-7.1	1.7- 4.8	2.599*	0.009*
Mean ± SD.	4.9±1.0	3.2 ± 0.9		
Median (IQR)	4.6 (4.3-5.3)	3.2 (2.8-3.9)		
D2cc				
Min. – Max.	3.2-5.9	4.3 - 6.7	2.803	0.005*
Mean ± SD.	4.3± 0.9	5.6 ± 0.9		
Median (IQR)	4.0 (3.5-5.3)	5.7 (4.8-6.5)		

Z: Wilcoxon signed ranks test p: p value for comparing between Brachytherapy and VMAT

***: Statistically significant at p ≤ 0.05**

4. Discussion

Considering that all patients received 3 D CRT whole pelvis radiotherapy in a dose of 45Gy in 25 fractions and taking in consideration that the OARs received the full dose. The brachytherapy boost received was 7 Gy in 3 fractions and the same dose with its calculated biological equivalent dose was used for the VMAT boost under study. When VMAT was limited to D2cc from BT, the D90 for the PTV was lower significantly than that in the BT boost to the HR CTV(6.3Gy vs 6.8Gy with p value 0.037)and variation of the dose with hot areas in BT compared to more homogenous dose in the VMAT (5.7Gy-8.1Gy in BT vs 6.2Gy-6.4Gy in the VMAT).This coincide with the findings of the study done by Evgeniia Sergeevna and his colleagues [6] where the BT boost resulted in irradiation of significant target volumes by doses significantly higher than the prescribed dose while the VMAT boost significantly improved this situation. Mean volume of the PTV in VMAT is higher than that of HR CTV in the BT. The dose to OARs was comparable where the D2cc was higher in VMAT for bladder and rectum (5.6Gy& 5.5Gy vs.4.3Gy &3.9Gy for bladder and rectum respectively) while D2cc for the Sigmoid and Small bowel in BT were higher compared to the VMAT (3.19Gy and 4.1Gy vs 0.51Gy and 1.94Gy for sigmoid and bowel respectively). This coincides with what was found in the trial published by Rajni A.Sethi and his colleagues [4] where VMAT had a potential for improved sparing of most normal tissues compared to brachytherapy boost. The mean dose to the bladder, rectum and small bowel were lower in the VMAT plan compared to the brachytherapy boost with excellent PTV coverage.Also in comparison with the findings of the study done by Lila Wali and his colleagues [7] the VMAT achieved significant dose reduction of rectum, bladder and sigmoid, as well as superior homogeneous target coverage compared to BT plan. On the other hand, VMAT deliverd more radiation exposures to small bowel. It is important to illustrate that the radiation dose and coverage depend on target and OAR contouring and motion and this definitely affected by the placement of the applicator and Foley catheter.In our study the brachytherapy boost parameters were calculated while the intracavitory applicator and packing are in place while the VMAT boost calculation were done before the applicator or packing in place and this caused different position and volumes to be irradiated although all attempts to unify the volumes irradiated between the two boosts. Also the addition of internal target volume (ITV) for the VMAT boost to count for the possible mobility and varying position of the OARs and this will possibly affect the dose to the OARs. Besides, the small number of the patients involved in the study and the non availability of one working software that can compare the targets and OARs between the BT and VMAT on spot. The aim of the VMAT boost application is not to replace the brachytherapy boost but to find an alternative accessible option with comparable results.The main advantages of the VMAT boost is to facilitate the treatment procedure, reduce patient discomfort results from the BT applicator, reduce the time of irradiation session and avoid the anesthesia with all its possible complication.

5. Conclusion

The VMAT had comparable target coverage with more homogenous dose and avoidance of hot areas in the

target and potential for improved sparing of most normal tissues compared to BT boost. It is an option that exists for patients who refuse BT or can't tolerate it or in case of non availability of BT or non working machine. Still further dosimetric analysis is needed on larger number of patients and ensure the availability of one software that involve both BT and VMAT on spot. Besides further application of the VMAT beyond the level of dosimetric study to compare the side effects result from the VMAT compared to the BT boost.

6. Recommendation

It is recommended to further apply the VMAT boost on larger number of patients and compare it not only to the intracavitory BT but also interstitial BT that can cover the target properly.

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References

[1]. Otto K., Volumetric modulated arc therapy: IMRT in a single gantry arc. Med Phys, 2008.

[2]. Caitlin M, Steven B, Matthew B. VMAT for the treatment of gynecologic malignancies for patients unable to receive HDR brachytherapy. J Appl Clin Med Phys,2014.

[3]. Thomadsen BR, Lin SW, Laemmrich P, et al. Analysis of treatment delivery error in brachytherapy using formal risk analysis techniques. Int J Radiat Oncol Biol Phys, 2003.

[4]. SethiR A,Jozsef G,Grew D, Marciscano A,Pennell R,Babcock M et al. Is there a role for an external beam boost in cervical cancer radiotherapy? Front.Oncol,2013.

[5]. Johannes CA, Dimopoulos PP, Kari T, Primoz P, Daniel B, Christian K, et al. Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (IV): Basic principles and parameters for MR imaging within the frame of image based adaptive cervix cancer brachytherapy. Radiother Oncol,2012.

[6]. Evgeniia Sergeevna Sukhikh and Leonid Grigorievich Sukhikh . Dosimetric and Radiobiological Evaluation of Combined Radiotherapy of Cervical Cancer Based on the VMAT Technique, Gynaecological Malignancies :Updates and Advances, Gwo Yaw Ho and Sophia Frentzas. IntechOpen2019 .

[7]. Wali L, Helal A, Darwesh R, Attar M. A dosimetric comparison of Volumetric Modulated Arc Therapy (VMAT) and High Dose Rate (HDR) brachytherapy in localized cervical cancer radiotherapy. J Xray Sci Technol. 2019.