TURKISH JOURNAL of ONCOLOGY

Turk J Oncol 2016;31(4):128-133
doi: 10.5505/tjo.2016.1524

ORIGINAL ARTICLE

Comparison of Contouring Results for Prostate Cancer Treatment Planning Obtained by Two Different Specialists

İlknur ALSAN ÇETİN,[1] Ayşe DAĞLI DEĞERLİ,[1] Rabia ERGELEN,[2] Erkan ÖZGEN,[1] Merve SEVİNDİK[1]

[1]Department of Radiation Oncology, Marmara University Faculty of Medicine Hospital, İstanbul-*Turkey*
[2]Department of Radiology, Marmara University Faculty of Medicine Hospital, İstanbul-*Turkey*

OBJECTIVE
This study is a comparison of contoured diagnostic images derived from computed tomography (CT) and magnetic resonance imaging (MRI) by both a radiation oncologist (RO) and a radiologist (R) using volumetric modulated arc therapy (VMAT) and intensity modulated radiation therapy (IMRT) techniques.

METHODS
CT and MRI sections of 16 patients were contoured by the RO and the R. Planning target volume (PTV) criteria assessed were conformity index (CI), homogeneity index (HI), volume covered by 98% isodose line (V 98%) and maximum dose (D_{max}). In critical organs, 40 Gy organ area volume (V_{40}), 65 Gy organ area volume (V_{65}), and D_{mean} criteria were evaluated. Paired samples t-test was used for statistical analysis.

RESULTS
PTV and critical organs were compared. MRI PTV and bladder volume drawn by R were lower. Comparison of CT images revealed IMRT plans were superior in terms of D_{max} and CI, while V_{40} and D_{mean} values for rectum and bladder were lower in MRI-based VMAT plans. In MRI plans, IMRT was superior in terms of PTV, D_{max}, CI, V_{65}, and D_{mean} for critical organs; however, critical organs were well preserved with both planning techniques.

CONCLUSION
There was some difference between contouring of the R and the RO, which was reflected in the treatment plans.

Keywords: Planning techniques; prostate cancer; radiotherapy.

Introduction

It is well established that high-dose radical radiation therapy (RT) for localized prostate cancer improves disease control.[1–3] It is of the utmost importance that the RT planning process accurately defines gross tumor volume and organs at risk for successful patient management. Many centers register magnetic resonance imaging (MRI) to computed tomography (CT)

Online: December 29, 2016
Accessible online at:
www.onkder.org

Dr. İlknur ALSAN ÇETİN
Marmara Üniversitesi Tıp Fakültesi Hastanesi,
Radyasyon Onkolojisi Anabilim Dalı,
İstanbul-Turkey
E-mail: ilknurcet@gmail.com

data sets to take advantage of the superior soft-tissue contrast of MRI and electron density information of CT.[4] Changes in anatomical and tumor definition as a result of using MRI data compared with CT have been reported for prostate patients.[5–9] Studies comparing CT- versus MRI-derived volume found that in general, prostrate volume delineated on CT was approximately 1.3 times larger than MRI-derived volume.[10] This advantage of MRI is based on better soft-tissue visualization and availability of multiplanar image acquisition. As a consequence, MRI in addition to CT has been recommended for RT planning for the prostate.[9,11]

Successful RT depends on high geometric and dosimetric accuracy and precision. Intensity modulated radiation therapy (IMRT) has become the standard technique to deliver external beam RT treatment to the prostate due to its greater ability to deliver higher-dose treatment to the planning target volume (PTV) while reducing dose delivered to surrounding critical organs and healthy tissue.[12,13] A novel form of IMRT called volumetric modulated arc therapy (VMAT) is delivered using a cone beam that rotates around the patient.[14]

The aim of this study was to determine difference between organs and target volumes drawn using CT and MRI, and to evaluate interobserver variability between radiation oncologist (RO) and radiologist (R). A further goal of this research was to examine how differences in target volume calculated and affected RT planning.

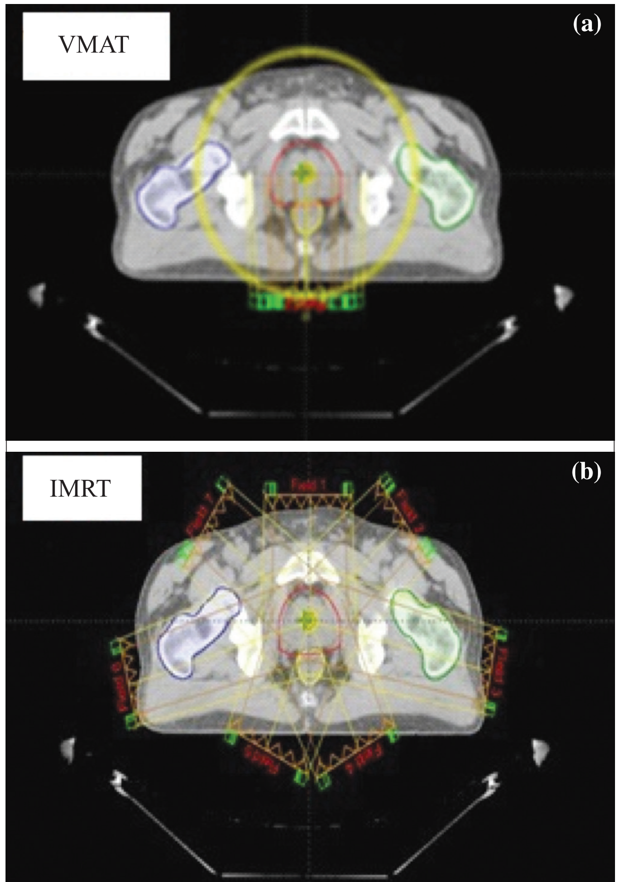

Fig. 1. **(a)** VMAT 2 full arc field display. **(b)** IMRT 7-field display.

Materials and Methods

This study was approved by the Ethical Committee of Marmara University School of Medicine with 09.2015.314 protocol number. Sixteen patients with early stage prostate cancer treated in our clinic were included.

All patients were diagnosed with low-risk prostate cancer. Patients had empty rectum, drank 1 L of water, and waited half an hour to achieve full bladder prior to acquiring images. CT and MRI scans of cross-sectional area of 3.75 cm were taken at the same position for all patients. After these images were transferred to treatment planning system (Eclipse version11; Varian Medical Systems, Palo Alto, CA, USA), they were matched 3-dimensionally. After image pairing, prostate, rectum and bladder were independently contoured by the RO and the R. PTV was created in prostate volume with 0.5 cm posterior wall and 1 cm margin in all directions.

For each patient, in addition to VMAT (2 full arc area) technique used in our clinic, 7-field (51° interval) IMRT plans were created (Figure 1a,b). Six MV photon energy was used. Calculations for both planning techniques were made using same optimization criteria and analytical anisotropic algorithm. Calculation grid of 0.25 cm was selected. Total of 78 Gy doses in 39 fractions of 2 Gy were to be delivered to PTV in all plans and all plans were normalized in such a way that at least 95% of PTV would receive entire defined dose.

Dosimetry of VMAT and IMRT plans were assessed with respect to PTV and critical organs. For PTV, volume covered by 98% isodose line (V 98%) and maximum dose (D_{max}), conformity index (CI), and homogeneity index (HI) criteria were analyzed, and for critical organs, 40 Gy organ volume (V_{40}), 65 Gy area organ volume (V_{65}), and average dose (D_{mean}) criteria were examined.

For CI, the following equation was used: $CI=TV^2_{PIV}$ / TV x PIV. TVPIV represents volume of PTV within prescription isodose line, TV denotes volume of PTV (prostate volume), and PIV denotes volume encompassed by prescription isodose line. Optimal CI value is 1. CI greater than 1 indicates that volume of 98% isodose line is greater than PTV 98%. HI value was obtained us-

Turk J Oncol 2016;31(4):128-133
doi: 10.5505/tjo.2016.1524

Table 1 Mean volume value of contours generated by radiation oncologist and radiologist on computed tomography and magnetic resonance images

	CT		MRI		p		
	R	RO	R	RO	CT_R/CT_{RO}	CT_R/MRI_R	CT_{RO}/MRI_{RO}
PTV (cc)	125±28.9	135±22	98.6±25.5	113.5±20.1	0.09	0	<0.0001
SV (cc)	12.5±4.8	15.2±5	14.7±9	15.7±6	0.01	0.2	0.6
Rectum (cc)	62.2±28.2	62.6±22.3	60±41	64.8±43.8	0.9	0.78	0.78
Bladder (cc)	283±173	286±166	459±207	425±188	0.4	<0.0001	0.002

Volumes are shown with mean±SD. CT: Computed tomography; MRI: Magnetic resonance imaging; PTV: Planning target volume; R: Radiologist; RO: Radiation oncologist; SV: Seminal vesicle.

Table 2a Summary of dosimetric comparison of volumetric modulated arc therapy and intensity modulated radiation therapy plans on computed tomography images with contours drawn by radiation oncologist and radiologist

	CT				p			
	R		RO					
	VMAT	IMRT	VMAT	IMRT	R_{IMRT}/R_{VMAT}		RO_{IMRT}/RO_{VMAT}	R_{IMRT}/RO_{IMRT}
PTV								
$V_{9\%8}$ (%)	98±0.79	97.7±2.1	96.44±1.4	97.84±1.1	0.6	<0.0001*	0.07	0.7
D_{max} (%)	104.9±0.79	104±1.1	105.6±0.79	103.3±0.6	0.02*	<0.0001*	0.06	0.01
CI	0.9±0.2	0.96±0.04	0.93±0.01	0.95±0.02	0.03*	0.04*	0.07	0.4
HI	0.06±0.02	0.06±0.02	0.07±0.02	0.07±0.03	0.8	0.82	0.26	0.11
Rectum								
V_{40} (%)	22.5±8.9	23.4±7.2	20.8±5.3	22.4±5.3	0.4	0.09	0.02*	0.03*
V_{65} (%)	11.5±5.6	11.6±5.4	9.8±3.6	10.9±4.2	0.3	0.07	0.04*	0.04*
D_{mean} (Gy)	2584±545.3	2446±524	2508±452.5	2572.8±387	0.5	0.33	0.3	0.5
Bladder								
V_{40} (%)	20.5±8.9	18.5±9.6	23.2±10.9	21.6±9.8	0.3	0.17	0.04*	0.04*
V_{65} (%)	9.2±3.9	10.7±4.7	12.1±5.3	12.3±5.9	0.07	0.6	0.01*	0.004*
D_{mean} (Gy)	1990±713.6	2074±821	2365.6±911.8	2107.8±999.4	0.49	0.17	0.8	0.06

CI: Conformity index; CT: Computed tomography, D_{max}: Maximum dose; D_{mean}: Average dose; HI: Homogeneity index; IMRT: Intensity modulated radiation therapy; PTV: Planning target volume; R: Radiologist; RO: Radiation oncologist; VMAT: Volumetric modulated arc therapy; V_{40}: Volume irradiated to 40 Gy; V_{65}: Volume irradiated to 65 Gy; $V_{98\%}$: planning target volume covered by the 98% isodose line. Mean values of the 16 patients in each group are shown ±1 SD.

ing following equality: HI = $(D_{max}-D_{min})/D_{rx}$. D_{max} is 1% of PTV dose, Dmin is 99% of PTV dose, and D_{rx} is the prescribed dose. HI value should be 0 for ideal treatment. To evaluate critical organ doses, 40 Gy organ area volume (V_{40}), 65 Gy organ area volume (V_{65}), and average organ dose (D_{mean}) values in the bladder and rectum were used.

Dosimetric differences obtained were assessed using paired samples t-test and values below p<0.05 were considered statistically significant.

Results

The target volume and volume for critical organs obtained from the contours independently drawn on CT and MRI images by 2 different radiology specialists were compared. In the comparison of CT images, seminal vesicle drawn by the RO was larger (p=0.01). In comparison of MRI images, contours of PTV and bladder volume of RO were greater. When volumes drawn were compared in terms of technique, it was determined that drawings of both specialists had larger PTV and bladder volume on CT images (p=0.004, p<0.001, respectively) (Table 1). Statistically significant difference in bladder volume was likely due to length of time elapsed before MRI was performed.

Dosimetric comparisons were first made between the 2 specialists and then between imaging techniques. Comparison of IMRT and VMAT plans, critical organs, and target tissues for each patient using contours drawn on CT images is presented in Table 2a.

Both the R and the RO had better contour results in IMRT plans than VMAT plans according to D_{max} and CI.

Table 2b Summary dosimetric comparison of volumetric modulated arc therapy and intensity modulated radiation therapy plans on magnetic resonance images with contours drawn by radiation oncologist and radiologist

	MR				p			
	R		RO					
	VMAT	IMRT	VMAT	IMRT	R_{IMRT}/R_{VMAT}		RO_{IMRT}/RO_{VMAT}	R_{IMRT}/RO_{IMRT}
PTV								
$V_{98\%}$ (%)	97.6±1.7	97.4±2.1	97.7±1.1	97.3±1.5	0.8	0.3	0.7	0.7
D_{max} (%)	104.4±1	103±1	105.4±0.9	103±0.9	0.001*	0.001*	0.75	0.05
CI	0.95±0.05	0.96±0.06	0.94±0.01	0.95±0.02	0.02*	0.03*	0.53	0.29
HI	0.07±0.03	0.05±0.02	0.07±0.02	0.07±0.03	0.2	0.67	0.09	0.98
Rectum								
V_{40} (%)	20.6±7.3	17.4±6.6	17.5±7.1	17.7±6.7	0.13	0.22	0.036*	0.04*
V_{65} (%)	8.2±3.6	8.1±3.5	7.1±4.7	7.9±4.5	0.89	0.39	0.78	0.84
D_{mean} (Gy)	2135±528	1987±420	2982±3180	2147±467	0.23	0.29	0.07*	0.02*
Bladder								
V_{40} (%)	15±17	13.8±16.6	14.6±12.9	16.4±14.4	0.29	0.79	0.02*	0.04*
V_{65} (%)	7.2±10.9	7.5±10.4	7.4±7.4	9.1±8.8	0.37	0.88	0.36	0.21
D_{mean} (Gy)	1545±1309	1418±1257	1592±1089	1676±1163	0.18	0.7	0.026*	0.04*

CI: Conformity index; CT: Computed tomography, D_{max}: Maximum dose; D_{mean}: Average dose; HI: Homogeneity index; IMRT: Intensity modulated radiation therapy; PTV: Planning target volume; R: Radiologist; RO: Radiation oncologist; VMAT: Volumetric modulated arc therapy; V_{40}: Volume irradiated to 40 Gy; V_{65}: Volume irradiated to 65 Gy; $V_{98\%}$: planning target volume covered by the 98% isodose line. Mean values of the 16 patients in each group are shown ±1 SD.

Table 3a Summary of dosimetric comparison of volumetric modulated arc therapy and intensity modulated radiation therapy plans on computed tomography and magnetic resonance images with contours drawn by radiologist

	R				p	
	VMAT		IMRT			
	CT	MRI	CT	MRI	BT_{VMAT}/MRI_{VMAT}	BT_{IMRT}/MRI_{IMRT}
PTV						
$V_{98\%}$ (%)	98±0.79	97.6±1.7	97.7±2.1	97.4±2.1	0.4	0.4
D_{max} (%)	104.9±0.79	104.4±1	104±1.1	104±1	0.1	0.2
CI	0.9±0.2	0.95±0.05	0.96±0.04	0.94±0.06	0.3	0.19
HI	0.06±0.02	0.07±0.03	0.06±0.02	0.05±0.02	0.38	0.11
Rectum						
V_{40} (%)	24.5±8.9	20.6±7.3	23.4±7.2	17.4±6.6	0.008*	0.006*
V_{65} (%)	11.5±5.6	8.2±3.6	11.6±5.4	8.1±3.5	0.02*	0.01 *
D_{mean} (Gy)	2584±545.3	2135±528	2446±524	1987±420	0.007 *	0.001 *
Bladder						
V_{40} (%)	19±8.9	15±17	20.5±9.6	13.8±16.6	0.03*	0.001*
V_{65} (%)	9.2±3.9	7.2±10.9	10.7±4.7	7.5±10.4	0.04*	0.003*
D_{mean} (Gy)	1990±713.6	1545±1309	2074±821	1418±1257	0.001*	0.006*

CT: Computed tomography; D_{max}: Maximum dose; D_{mean}: Average dose; HI: Homogeneity index; IMRT: Intensity modulated radiation therapy; PTV: Planning target volume; R: Radiologist; VMAT: Volumetric modulated arc therapy; V_{40}: Volume irradiated to 40 Gy; V_{65}: Volume irradiated to 65 Gy; $V_{98\%}$: planning target volume covered by the 98% isodose line. Mean values of the 16 patients in each group are shown ±1 SD.

When critical organs were evaluated, doses of V_{40} and V_{65} were lower when VMAT technique was used. IMRT plans were superior according to D_{max} and CI in the contours plotted on MRI images, while the VMAT plans were superior to the V_{40} and V_{65} doses for rectum and bladder (Table 2b). When comparing the plans based on volumes defined by the R, no difference was found in target volume contour plotted on MRI using either technique, but better protection of critical organs was observed in MRI volumes (Table 3a).

Similar results were obtained in the volume-based plan comparison of the RO (Table 3b).

Turk J Oncol 2016;31(4):128-133
doi: 10.5505/tjo.2016.1524

Table 3b Summary of dosimetric comparison of volumetric modulated arc therapy and intensity modulated radiation therapy plans on computed tomography and magnetic resonance images with contours drawn by radiation oncologist

	RO				p	
	VMAT		IMRT			
	CT	MRI	CT	MRI	MRI_{VMAT}/CT_{VMAT}	MRI_{IMRT}/CT_{IMRT}
PTV						
$V_{\%98}$ (%)	97.84±1.1	97.7±1.1	97.44±1.4	97.3±1.5	0.76	0.3
D_{max} (%)	105.6±0.79	105.4±0.9	103.3±0.6	103±0.9	0.4	0.36
CI	0.95±0.01	0.94±0.01	0.93±0.02	0.95±0.02	0.3	0.13
HI	0.07±0.02	0.07±0.02	0.07±0.03	0.07±0.03	0.5	0.93
Rectum						
V_{40} (%)	20.8±5.3	17.5±7.1	22.4±5.3	17.7±6.7	0.04*	0.01*
V_{65} (%)	9.8±3.6	7.1±4.7	10.9±4.2	7.9±4.5	0.009*	0.002*
D_{mean} (Gy)	2508±452.5	2982±3180	2572.8±387	2147±467	0.007*	<0.0001*
Bladder						
V_{40} (%)	23.2±10.9	14.6±12.9	21.6±9.8	16.4±14.4	0.007*	0.002*
V_{65} (%)	12.1±5.3	7.4±7.4	12.3±5.9	9.1±8.8	0.009*	0.005*
D_{mean} (Gy)	2365.6±911.8	1592±1089	2107.8±999	1676±1163	0.004*	0.0001*

CT: Computed tomography; D_{max}: Maximum dose; D_{mean}: Average dose; HI: Homogeneity index; IMRT: Intensity modulated radiation therapy; PTV: Planning target volume; R: Radiologist; VMAT: Volumetric modulated arc therapy; V_{40}: Volume irradiated to 40 Gy; V_{65}: Volume irradiated to 65 Gy; $V_{98\%}$: planning target volume covered by the 98% isodose line. Mean values of the 16 patients in each group are shown ±1 SD.

Discussion

Correct targeting of target tissue in RT is very important, both for tumor control and the protection of nearby healthy tissue. It is more likely that desired high doses can be delivered while reducing risk of complications during and after treatment with smaller, precise targets. Many studies have indicated that use of MRI in conjunction with CT to clinically identify the prostate and seminal vesicle is the gold standard. Villers et al. compared delineations of CT alone and CT with MRI in combination of 3 ROs and clinical target volume (CTV) plotted on CT were larger than CTV volumes plotted on CT with MRI.[15] In our study, when we compared volumes of the RO on CT and MRI, prostate volume was clearer and volume was smaller because MRI images provided more detail of the soft tissue.

We were careful to ensure that MRI and CT images were taken at the same position and within the same cross-sectional area in order to ensure that the images were recorded with the least possible amount of error. Hanvey et al. also emphasized the necessity of same MRI and CT position.[16] CT and MRI images taken at RT position were noted to have significantly smaller volume in the prostate seminal vesicle and bone structure recordings than MRI in diagnostic position (p=0.001).

It has been proven in many studies that advanced RT techniques in prostate radiotherapy are superior to conventional RT techniques in terms of target conformity and critical organ protection.[17,18] There have been many studies comparing advanced techniques. Fontenot et al. compared single-field VMAT technique and 7 to 9-field IMRT technique and no significant difference was found in terms of target conformity, target homogeneity, or critical organs (p>0.005).[19] In our study, it was observed that IMRT plans were superior to VMAT plans in terms of target conformation and target homogeneity. Both techniques yielded similar results for critical organs; however R had lower average contour volume, which yields better critical organ doses.

Chow et al. compared IMRT and VMAT plans in prostate patient suffering from weight loss and phantom and reported that VMAT results were superior and preferable to IMRT plans.[20] Elith et al. compared 5-field IMRT with single-field and double-field VMAT plans. It was determined that IMRT plans produced better results in terms of target homogeneity and VMAT plans were better in terms of target conformation and critical organ doses.[21]

There was a difference in the PTV volumes plotted by R and RO, and this difference was reflected in the treatment plans made; meanwhile both specialists had smaller PTV volumes based on MRI. Doses to critical organs were low. While IMRT plans are advantageous for the target dose conformation, critical organs were well preserved with both techniques. Both planning techniques were clinically relevant and results were consistent with the literature.

Disclosure Statement

The authors declare no conflicts of interest.

References

1. Zietman AL, DeSilvio ML, Slater JD, Rossi CJ Jr, Miller DW, Adams JA, et al. Comparison of conventional-dose vs high-dose conformal radiation therapy in clinically localized adenocarcinoma of the prostate: a randomized controlled trial. JAMA 2005;294(10):1233–9.
2. Dearnaley DP, Sydes MR, Graham JD, Aird EG, Bottomley D, Cowan RA, et al. Escalated-dose versus standard-dose conformal radiotherapy in prostate cancer: first results from the MRC RT01 randomised controlled trial. Lancet Oncol 2007;8(6):475–87.
3. Pollack A, Zagars GK, Starkschall G, Antolak JA, Lee JJ, Huang E, et al. Prostate cancer radiation dose response: results of the M. D. Anderson phase III randomized trial. Int J Radiat Oncol Biol Phys 2002;53(5):1097–105.
4. Khoo VS. MRI--"magic radiotherapy imaging" for treatment planning? Br J Radiol 2000;73(867):229–33.
5. Sannazzari GL, Ragona R, Ruo Redda MG, Giglioli FR, Isolato G, Guarneri A. CT-MRI image fusion for delineation of volumes in three-dimensional conformal radiation therapy in the treatment of localized prostate cancer. Br J Radiol 2002;75(895):603–7.
6. Sefrova J, Odrazka K, Paluska P, Belobradek Z, Brodak M, Dolezel M, et al. Magnetic resonance imaging in postprostatectomy radiotherapy planning. Int J Radiat Oncol Biol Phys 2012;82(2):911–8.
7. Khoo VS, Joon DL. New developments in MRI for target volume delineation in radiotherapy. Br J Radiol 2006;79:2–15.
8. Smith WL, Lewis C, Bauman G, Rodrigues G, D'Souza D, Ash R, et al. Prostate volume contouring: a 3D analysis of segmentation using 3DTRUS, CT, and MR. Int J Radiat Oncol Biol Phys 2007;67(4):1238–47.
9. Rasch C, Barillot I, Remeijer P, Touw A, van Herk M, Lebesque JV. Definition of the prostate in CT and MRI: a multi-observer study. Int J Radiat Oncol Biol Phys 1999;43(1):57–66.
10. Steenbakkers RJ, Deurloo KE, Nowak PJ, Lebesque JV, van Herk M, Rasch CR. Reduction of dose delivered to the rectum and bulb of the penis using MRI delineation for radiotherapy of the prostate. Int J Radiat Oncol Biol Phys 2003;57(5):1269–79.
11. Milosevic M, Voruganti S, Blend R, Alasti H, Warde P, McLean M, et al. Magnetic resonance imaging (MRI) for localization of the prostatic apex: comparison to computed tomography (CT) and urethrography. Radiother Oncol 1998;47(3):277–84.
12. Kopp RW, Duff M, Catalfamo F, Shah D, Rajecki M, Ahmad K. VMAT vs. 7-field-IMRT: assessing the dosimetric parameters of prostate cancer treatment with a 292-patient sample. Med Dosim 2011;36(4):365–72.
13. Sze HC, Lee MC, Hung WM, Yau TK, Lee AW. RapidArc radiotherapy planning for prostate cancer: single-arc and double-arc techniques vs. intensity-modulated radiotherapy. Med Dosim 2012;37(1):87–91.
14. Otto K. Volumetric modulated arc therapy: IMRT in a single gantry arc. Med Phys 2008;35(1):310–7.
15. Villeirs GM, Van Vaerenbergh K, Vakaet L, Bral S, Claus F, De Neve WJ, et al. Interobserver delineation variation using CT versus combined CT + MRI in intensity-modulated radiotherapy for prostate cancer. Strahlenther Onkol 2005;181(7):424–30.
16. Hanvey S, Sadozye AH, McJury M, Glegg M, Foster J. The influence of MRI scan position on image registration accuracy, target delineation and calculated dose in prostatic radiotherapy. Br J Radiol 2012;85(1020):e1256–62.
17. Wolff D, Stieler F, Welzel G, Lorenz F, Abo-Madyan Y, Mai S, et al. Volumetric modulated arc therapy (VMAT) vs. serial tomotherapy, step-and-shoot IMRT and 3D-conformal RT for treatment of prostate cancer. Radiother Oncol 200;93(2):226–33.
18. Palma D, Vollans E, James K, Nakano S, Moiseenko V, Shaffer R, et al. Volumetric modulated arc therapy for delivery of prostate radiotherapy: comparison with intensity-modulated radiotherapy and three-dimensional conformal radiotherapy. Int J Radiat Oncol Biol Phys 2008;72(4):996–1001.
19. Fontenot JD, King ML, Johnson SA, Wood CG, Price MJ, Lo KK. Single-arc volumetric-modulated arc therapy can provide dose distributions equivalent to fixed-beam intensity-modulated radiation therapy for prostatic irradiation with seminal vesicle and/or lymph node involvement. Br J Radiol 2012;85(1011):231–6.
20. Chow JC, Jiang R. Comparison of dosimetric variation between prostate IMRT and VMAT due to patient's weight loss: Patient and phantom study. Rep Pract Oncol Radiother 2013;18(5):272–8.
21. Elith CA, Dempsey SE, Warren-Forward HM. A retrospective planning analysis comparing intensity modulated radiation therapy (IMRT) to volumetric modulated arc therapy (VMAT) using two optimization algorithms for the treatment of early-stage prostate cancer. J Med Radiat Sci 2013;60(3):84–92.