Consistency Study of Multiparametric Magnetic Resonance and Computed Tomography Targeting in Targeted Radiotherapy for Prostate Cancer

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Research

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Abstract

Background: To compare the difference of location by computed tomography (CT) and multiparametric magnetic resonance imaging (mpMRI) on the target delineation and volume for organs at risk (OARs) among patients with prostate cancer.

Methods: T1-weighted imaging (T1WI), T2-weighted imaging (T2WI), and CT were performed among 11 patients who received radiotherapy for prostate cancer at our center between August 2018 and December 2019. The target areas were delineated using the Eclipse system, and the radiotherapy plans were made based on the treatment planning system (TPS) to compare target volume and dose-volume histogram (DVH) relative to rectum and bladder.

Results: The clinical target volume (CTV) of T1WI and T2WI decreased by 18.8% (P=0.001) and 22.72% (P=0.003), respectively, compared with CT. The planning target volume (PTV) on T1WI and T2WI were 20.45% (P=0.015) and 22.31% (P= 0.008) smaller than that defined by CT. There was no significant difference in either CTV or PTV between the areas outlined on T1WI and T2WI. The DVH resulting from CT and MRI comparisons showed that the rectum and bladder dose levels were lower with MRI images compared with CT. It should be noted that at the lateral directions, the range of outlining on T2WI sequence were significantly smaller than others.

Conclusion: Target planning based on mpMRI (T1WI, T2WI) is more precise than CT, which can significantly reduce the range of the target area and the volume of rectum and bladder exposed to high levels of radiation, improve the fitness and radiographic accuracy of the target area, especially on T2WI.

Background

Prostate cancer (PCa) is one of the most common cancer in men worldwide.(1, 2) Currently, radiotherapy is the standard of care for PCa patients.(3, 4) The 5-year disease-free survival rates for PCa patients receiving external beam radiation therapy (EBRT) range between 67% and 91.2%. (5) Notably, intensity-modulated radiation therapy (IMRT) has been widely used in PCa patients, providing local disease control and minimizing the occurrence of radiotherapy-related side effects. The favorable efficacy and safety profiles of IMRT is primarily attributed to its ability to adjust the radiation field and the irradiation doses so that the dose delivered to the tumor is maximized while adjacent non-malignant tissues receive little to no radiation. [(4)]

Accurate imaging and target localization are essential for maximizing radiotherapy efficacy. Currently, EBRT for PCa utilizes localized CT as the standard imaging method. (2) Although CT plays an important role in the planning and implementation of radiotherapy, [(6)]it provides limited accuracy in internal tumor structure and tumor margins,making it challenging to avoid irradiation of non-malignant tissues.(7) In contrast, by providing more accurate imaging of intraprostatic lesions and pelvic tissues, mpMRI can

increase the radiation dose to the target area.[3, 6]Clinicopathological examination indicated that MRI could achieve a CTV accuracy of close to 95%.[7]

T1WI can illustrate the external outline of the prostate gland, distinguishing the prostate from the pelvic muscles and periprostatic adipose tissue; however, imaging of the lesions within the gland is challenging, hindering the diagnosis of lymph node and bone metastases. (8–10) T2WI provide excellent soft-tissue contrast, allowing for the assessment of peritoneal involvement, and invasion in seminal vesicles and other adjacent tissues; (9–11) hence, T2WI MRI is currently the most promising method for PCa imaging. [2]

High intra-target dose delivery in multifocal, non-uniform prostate tumors can improve local tumor control and patient prognosis. [2, 11] According to the national comprehensive cancer network (NCCN) guidelines, delivery of 70-70.2 Gy in doses of 2.5–2.7 Gy is recommended for patients with PCa. (12) Since image quality affects the accuracy of target volume planning, improving image quality is critical for the success of radiotherapy. MRI has several advantages compared to CT, including low radiation, higher soft-tissue resolution, (13, 14) and better discrimination of prostate lesions from the adjacent non-malignant tissues; (15) thus, MRI has emerged as a promising imaging modality for EBRT. [3, 4, 6] In this study, we assessed the performance of MRI in target volume identification and its potential to improve PCa radiotherapy outcomes.

1. Methods

1.1 Patient Information

A total of 11 patients with pathologically confirmed prostate cancer were selected at our center from August 2018 to December 2019. All patients were diagnosed with middle-risk to high-risk prostate cancer (group). The average age of these patients was 67 years, their T stages ranged from T2 to T4, their Gleason score ranged from 8 to 10, and their prostate-specific antigen (PSA) levels were 0.039–248.6 ng/ml (Table 1). All patients received radiotherapy at Shandong Cancer Hospital following complete pelvic enhanced CT examination.

Table 1
Patient characteristics

Clinical parameter	Number(n = 11)	Percent(%)
Age (range)	67(54–84)	
T stage		
T2	2	18
T3	3	27
T4	6	55
Initial PSA value		
< 10 ng/ml	4	40
10–20 ng/ml	2	20
> 20 ng/ml	4	40
Gleason score		
8	6	55
9	3	27
10	1	18
D'Amico risk group		
High	2	18
Very high	9	82
TNM staging according to the 8th edition American Joint Committee on Cancer staging		

1.2 Image Acquisition

Patients were instructed to empty the bladder 1 hour before image acquisition and drink 1000 ml bottle of water and a 500 ml bottle of solution containing 200 ± 50 HU meglumine diatrizoate. The patients lay in a prone position with the hands raised and the elbows held to the forehead; the position was fixed with an abdominopelvic locator, and the center position was labeled with laser marking. A spiral CT scan (Philips) was used to scan the lower abdomen from the mid-lumbar spine to the lower margin of the pubic symphysis, with a layer spacing of 3 mm, a matrix of 512 × 512, a window width (WW) of 300 HU, and a window level (WL) of 45 HU. Within half an hour, MRI positioning (GE Signa Excite 3.0T) was used according to CT cross laser positioning line registration; the MRI sequences included T1WI (matrix 320 × 256, FOV 44 × 39.6 mm, layer spacing 3 mm, echo time/repetition time (TE/TR) = 1.7/4.5 ms) and T2WI

(matrix 384 × 384, FOV 44 × 39.6 mm, layer spacing 3 mm, TE/TR = 84.5/9318 ms). The scanning range was the same as that of CT.

1.3 Target Area Delineation And Dose Calculation

Following the Radiation Therapy Oncology Group (RTOG) prostate cancer target area delineation guidelines, one experienced radiotherapy experts delineated the target areas on CT and MRI, respectively. For each patient, a physicist used the Eclipse 8.6 (Varian Medical Systems Inc., Palo Alto) planning system to make a radiotherapy plan. All patients received 7-field IMRT. The CTV included the entire prostate (mass and normal tissue) and the seminal vesicles within 2 □ of the top of the prostate. All directions on CTV are expanded by 5 mm to become PTV. Organ at risk (OARs) includes bladder, rectum and bilateral femoral heads. The target area dose calculation of CT positioning and MRI positioning was performed on CT and MRI-CT fusion images, respectively, and the calculation was based on the location of bone markers. Each patient was irradiated with 6MV X-ray. The DT (Total dose) was 70-76Gy, 1.8-2Gy/fraction.

For the three groups of radiotherapy plans, the dose parameters of the OARs (bladder, rectum) were extracted from DVH. The geometric center of the prostate cancer target area was defined as point O, and the horizontal plane of that point was included in the analysis. OA was defined as the distance from point O to the front end of the target area, and OP was the distance from point O to the back end. OR and OL were the distances to the right and left ends of the target area, respectively, in the same horizontal plane as the geometric center of the target area. The apex and base of the prostate were also labeled.

1.4 Statistical Analysis

All analyses were performed using SPSS Statistics 22.0 statistical software, and the measurement data were expressed as $\bar{X}\pm SD$. All data were subjected to the Shapiro-Wilk normality test, followed by the t-test if normally distributed or Kruskal-Wallis 1-way ANOVA test if non-normally distributed. For more than two groups of data, the nonparametric Wilcoxon test was used to conduct a pairwise comparison of continuous variables between each 2 groups. $P < 0.05$ was considered statistically significant. All tests were two-sided tests, with an α value of 0.05.

2. Results

2.1 CTV volumes of the prostate cancer delineated by T1WI, T2WI and CT imaging

The CTV volumes of the 11 prostate cancer patients delineated by T1WI, T2WI and CT imaging were (41.55 ± 19.84) cm^3,(39.56 ± 19.22) cm^3 and (51.19 ± 22.33) cm^3 (Fig. 1, Table 2), respectively. Compared with CT imaging, the CTV volumes delineated by T1WI and T2WI were reduced by 18.9% (P =

0.001), 23.63% (P = 0.003), respectively. The difference was statistically significant, that is, the CTV volumes delineated by MRI were significantly smaller than those delineated by CT. However, there was no significant difference between T1WI and T2WI (P = 0.323) (Table 1, Fig. 2).

Table 2
The average CTV and PTV volumes contour difference between the CT and MRI images

Group	CTV(cm^3)	PTV(cm^3)
CT	51.19 ± 22.33	113.87 ± 42.52
T1WI	41.55 ± 19.84	90.59 ± 34.17
T2WI	39.56 ± 19.22	88.47 ± 33.95
t-value	5.806 [a]	3.626 [a]
	3.946 [b]	3.294 [b]
P-value	0.001 [a]	0.005 [a]
	0.003 [b]	0.008 [b]
a: the difference between CT and T1WI b□the difference between CT and T2WI		

2.2 PTV volumes delineated by T1WI, T2WI and CT imaging

The PTV target area volumes of the 11 patients delineated by T1WI, T2WI and CT imaging were 90.59 ± 34.17 cm^3, 88.47. ± 33.95 cm^3, and 113.87. ± 42.52 cm^3 (Table 2), respectively. Compared with CT imaging, the PTV delineated by T1WI and T2WI were reduced by 20.45% (P = 0.005), 22.86% (P = 0.008), respectively. The difference was statistically significant, that is, the PTV volumes delineated by MRI was significant less than those delineated by CT (Table 2, Fig. 2). PTV volumes delineated by T1WI and T2WI showed no significant difference (P = 0.527) (Table 2, Fig. 2). On a box-and-whisker plot, the PTV box was significantly higher for CT than for T1WI or T2WI, and the upper section of the box was relatively short, indicating that the PTVs were greater on CT than on the MRI sequences and that there were more patients with high values on CT. Therefore, the PTVs delineated by T1WI and T2WI were significantly more specific than those delineated by CT (Fig. 2).

2.3 Dose Comparison Of Oars

When we compared the 7-field IMRT planning of the T1WI, T2WI and CT groups, the bladder exposure dose volumes of V20, V25, V30, V35, V40, V45, V50, V55, V60, V65 and V70 in the first two groups were smaller than those of the CT group (Fig. 3), but the differences among the three groups were not significant (P > 0.05) (Table 3, Table 4). As for the rectal dose, the values of exposure dose/total volume × 100% were not significantly different among the three groups when the exposure dose was < 30 Gy, while

that of the CT group was slightly smaller than those of the T1WI group or the T2WI group when the exposure volume was > 30 Gy, but the difference between the two groups was not statistically significant (P > 0.05) (Table 3, Table 4, Fig. 3).

Table 3
The dose volume difference between CT and MRI images of the rectum in the seven-field IMRT plans(cm^3)

Group	CT	T1WI	T2WI	^aP	^bP	^cP
V20%	50.36 ± 21.42	47.23 ± 19.97	48.67 ± 21.61	0.343	0.599	0.357
V25%	39.60 ± 20.87	39.04 ± 21.81	40.01 ± 21.25	0.816	0.877	0.548
V30%	30.38 ± 17.75	30.34 ± 18.95	30.29 ± 18.42	0.986	0.964	0.969
V35%	22.41 ± 13.82	22.77 ± 13.90	20.20 ± 12.37	0.804	0.336	0.202
V40%	16.37 ± 11.56	16.08 ± 11.15	15.22 ± 10.46	0.839	0.390	0.427
V45%	11.96 ± 10.03	11.94 ± 10.08	11.13 ± 8.74	0.983	0.497	0.430
V50%	12.09 ± 8.33	11.79 ± 9.32	10.49 ± 7.57	0.884	0.349	0.358
V55%	9.52 ± 7.33	9.22 ± 9.10	7.95 ± 6.98	0.892	0.342	0.369
V60%	7.41 ± 6.31	7.32 ± 8.66	6.02 ± 6.34	0.798	0.574	0.878
V65%	6.11 ± 5.18	6.55 ± 8.31	4.76 ± 5.95	0.805	0.535	0.620
V70%	2.82 ± 3.52	4.78 ± 7.46	3.72 ± 5.16	0.620	0.836	1.000
a: the difference between CT and T1WI b□the difference between CT and T2WI c□ the difference between T1WI and T2WI						

Table 4
The dose volume difference between CT and MRI images of the bladder in **the seven-field IMRT plans(cm^3)**

Group	CT	T1WI	T2WI	^aP	^bP	^cP
V20%	34.80 ± 18.01	33.25 ± 18.14	32.50 ± 17.27	0.651	0.496	0.257
V25%	29.45 ± 17.19	28.28 ± 16.05	27.83 ± 15.88	0.723	0.623	0.481
V30%	24.89 ± 16.17	23.07 ± 13.92	22.67 ± 14.35	0.570	0.491	0.545
V35%	20.63 ± 14.68	18.46 ± 11.88	18.24 ± 12.28	0.479	0.431	0.678
V40%	17.26 ± 13.43	14.83 ± 10.04	14.84 ± 10.79	0.399	0.387	0.990
V45%	14.08 ± 12.06	11.65 ± 8.66	11.65 ± 9.86	0.352	0.351	0.996
V50%	14.83 ± 10.33	11.30 ± 7.37	11.95 ± 8.28	0.247	0.332	0.288
V55%	12.01 ± 8.56	8.02 ± 6.36	9.65 ± 6.99	0.241	0.340	0.300
V60%	9.70 ± 7.22	7.14 ± 4.90	7.69 ± 5.84	0.238	0.339	0.338
V65%	8.52 ± 5.67	5.30 ± 4.11	5.83 ± 4.91	0.222	0.354	0.283
V70%	4.657 ± 4.68	3.66 ± 2.73	3.96 ± 3.30	0.435	0.625	0.422

a: the difference between CT and T1WI b□the difference between CT and T2WI c□ the difference between T1WI and T2WI

2.4 Spatial distribution difference of PTV delineated by T1WI, T2WI and CT imaging

Data analysis showed that except for the OR and OL directions in the T2WI group, which had significantly smaller values than those of the CT group (P = 0.002, P = 0.037) (Table 5), the values of the remaining positions showed no significant difference between the CT and T1WI groups, between the CT and T2WI groups, or between the T1WI and T2WI groups (Fig. 4, Table 5). The average differences in apex between T2WI and CT and between T1WI and CT were 0.72 ± 1.37 cm and 0.33 ± 0.22 cm, respectively, but these differences, despite their magnitude, were not significant (P = 0.220, P = 0.840). The average differences in base of prostate between T2WI and CT and between T1WI and CT were0.64 ± 0.89 cm and 0.25 ± 0.22 cm, respectively; once again, these differences, although pronounced, were not significant (P = 0.848, P = 0.146). Overall, the PTV location of CT, T1WI, and T2WI in all positions were approximately the same. Although the PTV of CT was larger than MRI in all directions, there was no statistically significant difference.

Table 5

The average radial differences (cm) of the PTV outlining between the CT ,T1WI, T2WI images in the OA,OP,OR,OL,apex and base direction.

	CT & T1WI(□)			CT & T2WI(□)			T1WI & T2WI(□)		
	`X ± SD	T	P	`X ± SD	T	P	`X ± SD	T	P
A	0.40 ± 0.27	1.917	0.084	0.62 ± 1.00	1.055	0.319	0.54 ± 0.91	-0.942	0.371
P	0.32 ± 0.26	0.259	0.801	0.45 ± 0.65	0.265	0.797	0.49 ± 0.65	-0.104	0.920
R	0.29 ± 0.17	-1.967	0.078	0.49 ± 0.63	4.378	0.002	0.38 ± 0.74	1.189	0.265
L	0.31 ± 0.31	1.486	0.168	0.52 ± 0.89	2.446	0.037	0.48 ± 0.95	0.288	0.780
Apex	0.33 ± 0.22	1.916	0.840	0.72 ± 1.37	1.317	0.220	0.67 ± 1.18	0.154	0.881
Base	0.25 ± 0.22	1.576	0.146	0.64 ± 0.89	-0.179	0.848	0.44 ± 0.70	-1.018	0.335

CT & T1WI: comparison between the CT and T1WI groups CT & T2WI: comparison between the CT and T2WI groups T1WI & T2WI: comparison between the T1WI and T2WI group

3. Disscussion:

In this study, we compared the target volume and localization as well as the exposure dose of OAR with CT and mpMRI. The results showed that the CTV delineated by T1WI and T2WI were 81.1% and 76.37%, smaller than the same target defined by CT, respectively. There was no significant difference in target volume between T1WI and T2WI. The PTV volumes delineated by T1WI and T2WI were 79.55% and 76.14% of the volume measured through CT, respectively. Target localization showed an obvious disparity in the apex and base of the prostate. The average differences in apex contouring of PTV between T1WI and T2WI were 0.64 ± 0.89 cm and 0.25 ± 0.22 cm, compared with CT, respectively, and the average distances of these two at the base were 5.64 ± 0.89 cm and 5.25 ± 0.22 cm, respectively. Concurrently, we found that the PTVs delineated by CT and T2WI in the lateral (OR and OL) directions were significantly different (P = 0.002 and 0.037, respectively); the average differences were 0.49 ± 0.63 cm and 0.52 ± 0.89 cm, respectively. By comparing the DVHs of the IMRT planning, we found that the two mpMRI groups received slightly lower bladder and rectal doses than the CT group, but the difference was not statistically significant.

Radiotherapy is an important treatment for prostate cancer and is widely used in decision-making for prostate cancer treatment at various stages. (11, 16) Currently, EBRT is the main radiotherapy for prostate cancer .(4) CT is commonly used in image acquisition and delineation to support clinical decision

making. Although CT has the advantages of rapid operation, accurate positioning, clear imaging. This image technology can provide high tissue density resolution in the formulation and implementation, especially electronic density information provided for radiotherapy dose calculation. However, it has a notable weakness in that it does not sufficiently display the internal structure and edge of the prostate, especially at the apex of the prostate and the junction of the prostate, rectum and bladder. (14, 16, 17) The soft tissue resolution of CT is poor, and it is difficult to distinguish apex from the surrounding soft tissues considering this area is wrapped by distal urethra, upper penis bulb and the levator ani muscle. This area appears only as a homogenetic soft tissue density in the CT image. This imaging defect This often makes the delineation of the radiotherapy target area inaccurate. The European society for radiotherapy and oncology(ESTRO) guidelines indicate that the delineation range of the apex of the prostate should be an area 1□ above the penis bulb. (2) Moreover, series of studies have confirmed that the target area determined by CT is much larger than the actual tumor distribution range, which makes it difficult to avoid toxic and side effects in radiotherapy, thereby reducing the quality of life of patients. (6) The high resolution of MRI soft tissue can clearly display the internal structure of the prostate and the boundaries of pelvic organs such as the rectum and bladder. Even the complex structure of the apex of the prostate can be clearly distinguished, especially in the T2WI sequence, which significantly reduces the observer The inter-error is gradually applied to the target area of prostate cancer. (9, 16, 17)

Various literatures have confirmed that the prostate volume delineated on CT is larger than that on MRI. In 1997, Kazufumi et al. analyzed the prostate volumes of 22 patients and found that the prostate volumes displayed on CT and MRI were 63.0 cm^3 and 50.9 cm^3, respectively, with a difference of 30%. (18) This volume difference was particularly significant in the apex and seminal vesicles. (19, 20) Sannazzarl et al. compared the CT and MRI target areas of 8 patients in 2002 and found that the CTV delineated with MRI was 5 mm smaller in all directions than the volume delineated by CT, and the total target area volume was reduced by 34%. (19) This result is consistent with the research of Rasch, Kagawa, Bettina, etc. Other studies have also confirmed that the prostate and seminal vesicle volumes delineated by MRI were smaller than those delineated by CT, (6) and this change in target area may reduce radiation-related toxicity and improve patient survival. (3) Hentschel B et al. used CT and MRI to delineate the target area of the prostate CTV and found that the target area was larger on CT than on MRI, especially at the upper and lower boundaries of the prostate. (21) However, previous studies rarely involved Asian countries such as China. Our finding is similar to those reported in the literature, which showed that the average PTV measured on the two MRI sequences(T1WI and T2WI)was greatly reduced (20.45% and 24.86%) compared with the CT-based volume, while the average target volume was reduced by 23.28 cm^3 and 25.4 cm^3. This result indicate that MRI positioning allowing reducing the error of target delineation effectively, decreasing the exposure dose of normal tissue in the pelvis and facilitating radiotherapy accuracy.

Interestingly, a significantly differentness in the lateral (OR and OL) position is noticed,which is consistent with the report of Sannazzarl et al. (19). This result may be caused by the superior soft tissue contrast of MRI in prostate anatomical imaging (see Fig. 5) .Because anterior of the prostate is fixed by the anterior

fibromuscular stroma and the posterior prostate has the thickness capsule ,the border in the anterior-posterior direction is visible easily on both images (22). Considering the distinct anatomical characteristics, the PTV delineation showed no significant difference in anterior-posterior direction. In the lateral direction of prostate, however, shown a different circumstance. The levator ani muscle, which fixed prostate, is thickest in lateral direction, resulting in the significant discrepancies between CT and MRI, particularly in T2WI sequence.

In this study, the target volume reduced by MRI was smaller than previously reported, which may be due to the application of more accurate MRI equipment, with a layer spacing of 3 mm instead of the previous 8 mm, and the improvement of imaging compared with previous studies. In this study, compared with CT, the delineation range of prostate apex by MRI positioning was 0.33–0.72 cm, and that of the prostate bottom was 0.25–0.64 cm. This suggests that clinicians can appropriately reduce the target area range of upper and lower levels of the lesion when delineating the target area of prostate cancer. The anatomical relationship of tissues in the pelvic cavity is complicated, and there are OAR include bladder and rectum. We compared the effect of prostate target area of CT, T1WI and T2WI sequence on the dosimetry of bladder and rectum. Compared with CT group, the exposure doses of bladder and rectum (when exposure dose < 30Gy) of MRI group decreased, but there was no statistical difference, which consistent with the research of OT et al (16).

Previous studies have confirmed that mpMRI has a better resolution of the internal anatomical structure of the prostate. These imaging methods can accurately detect the presence of malignancy from normal tissue and the extent of tumor invasion clearly, which improves the accuracy of prostate cancer biological target area and optimizes radiotherapy planning greatly. Although mpMRI is superior to CT in determining the biological target area, considering the geometric deformation possibility during process, the MRI-only target delineation based on has a certain risk of target edge missing, which needs to be combined with pathological slices for further research.

4 Conclusions

Target area delineation is a crucial link in precision radiotherapy progress. Accurate target delineation contributes to improve the quality of planning and reduce the radiation level of healthy tissues, thereby improving patient prognosis. This study indicated that in prostate cancer radiotherapy, the target area based on mpMRI (T1WI, T2WI) is more accurate than CT, which can significantly reduce the target area and the volume of the rectum and bladder exposed to high radiation dose, and improve the positioning capability. Since T2WI is superior in target outlining, it is worth prioritizing to application.

Abbreviations

CT
computed tomography
mpMRI

multiparametric magnetic resonance imaging
OARs
organs at risk
T1WI
T1-weighted imaging
T2WI
T2-weighted imaging
TPS
treatment planning system
DVH
dose-volume histogram
CTV
clinical target volume
PTV
planning target volume
PCa
prostate cancer
EBRT
external beam radiation therapy
IMRT
intensity-modulated radiation therapy
NCCN
national comprehensive cancer network
PSA
prostate-specific antigen
WW
window width
WL
window level
TE
echo time
TR
repetition time
RTOG
radiation therapy oncology group
DT
total dose
ESTRO
European society for radiotherapy and oncology

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committee of Shandong Cancer Hospital. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from individual participants.

Consent for publication

All data published here are under the consent for publication. Written informed consent was obtained from all individual participants included in the study.

Availability of data and materials

The datasets generated and analyzed during the present study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no conflict of interest.

Funding statement

Not applicable

Authors' contributions

Yong-Hua Yu and Xiao-Dong Li conceived of the study. The study was designed by Xiao-Dong Li. Data collection was done by Zhen Xu and Lu Fu. Data analysis was done by Zhen Xu. All co-authors wrote the manuscript. All authors read and approved the final manuscript.

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Figures

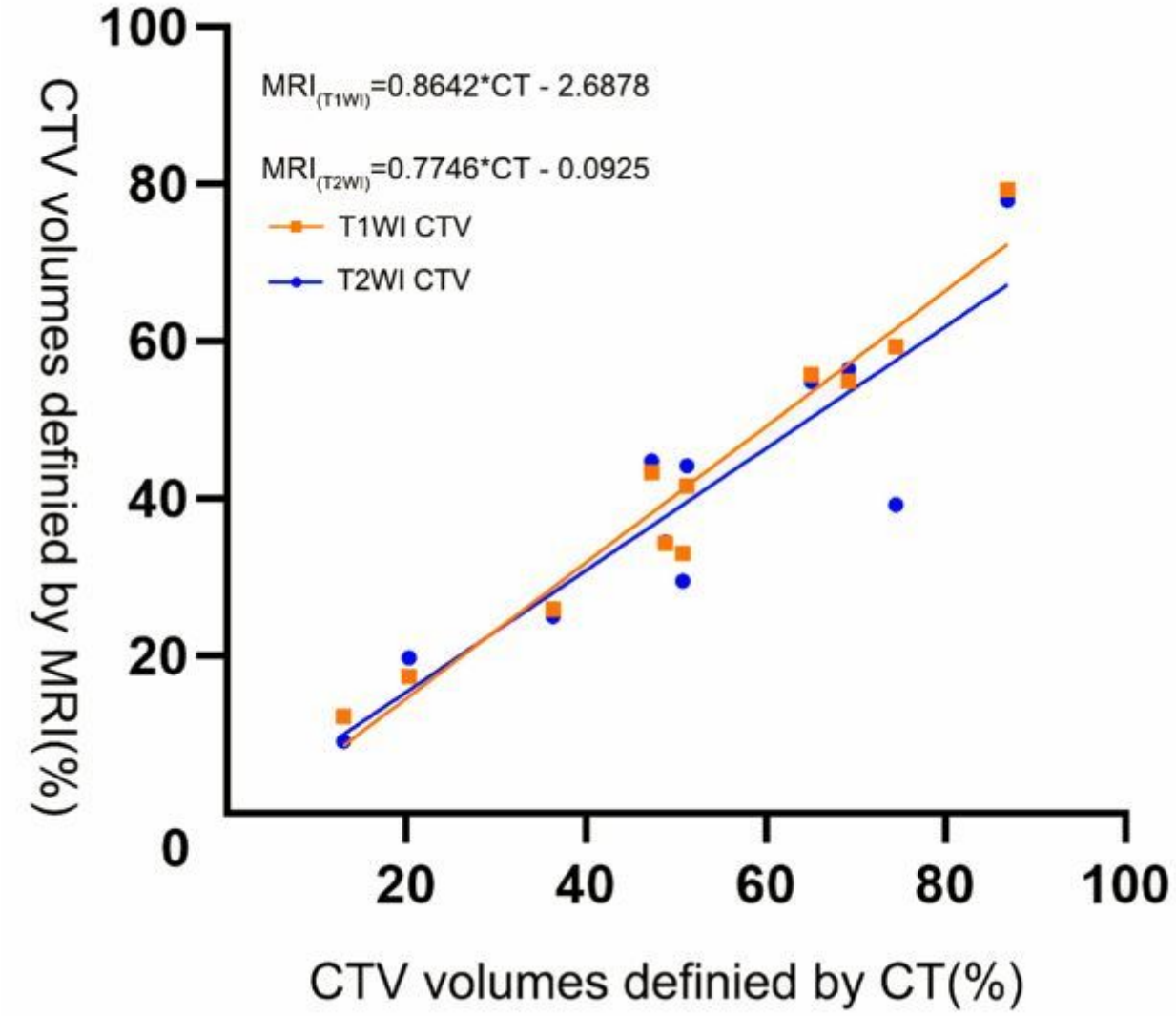

Figure 1

The relationship of CTV defined by T1WI, T2WI and CT imaging

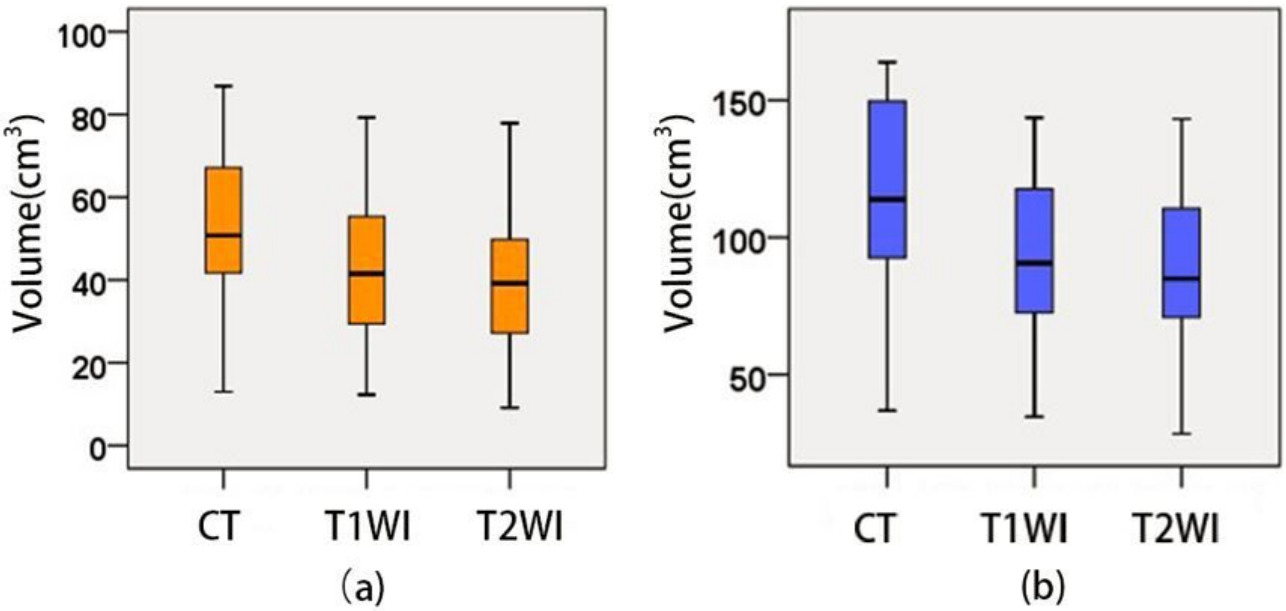

Figure 2

The CTV and PTV target volume definied by CT,T1WI and T2WI groups (a) The CTV outlined by the 3 types of imaging. (b)The PTV outlined by the 3 types of imaging.

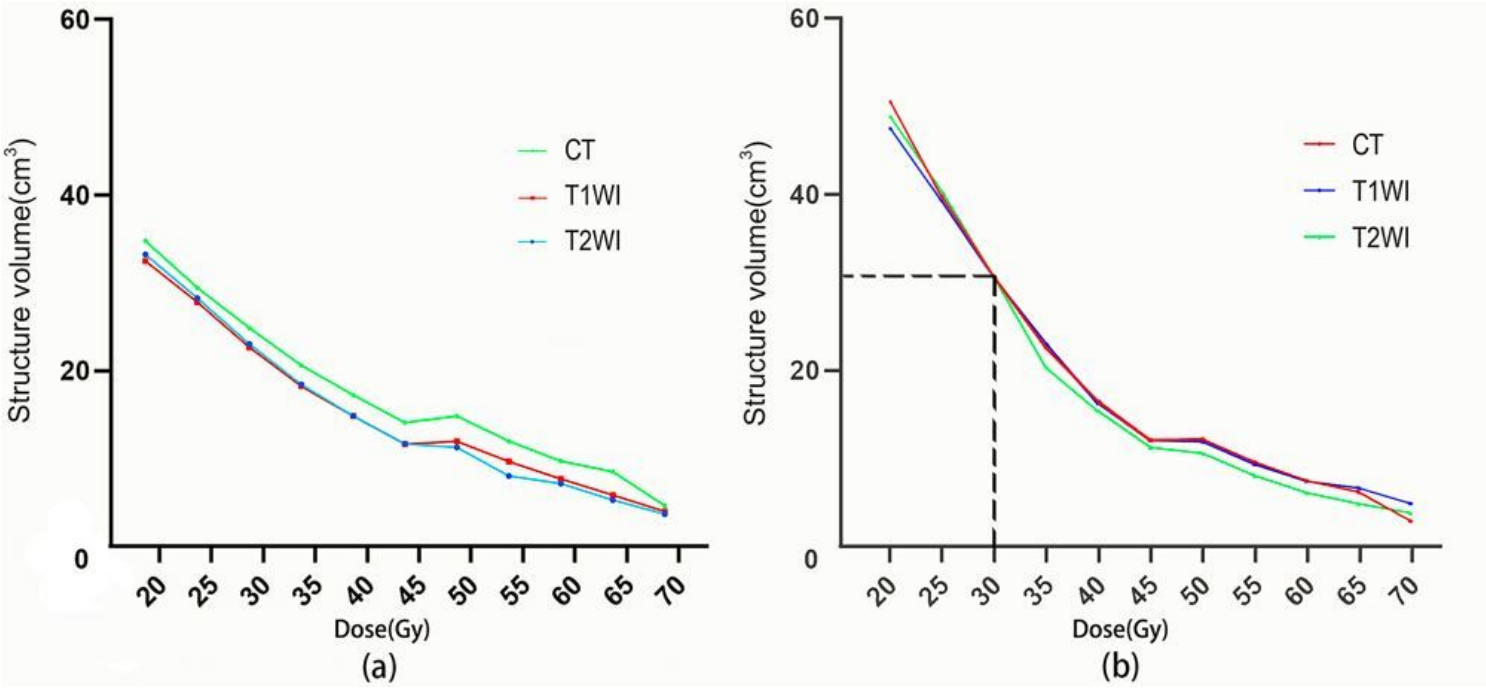

Figure 3

DVH differences of the bladder(a) and rectum(b) between the PTV defined by CT images, T1WI images and T2WI images.

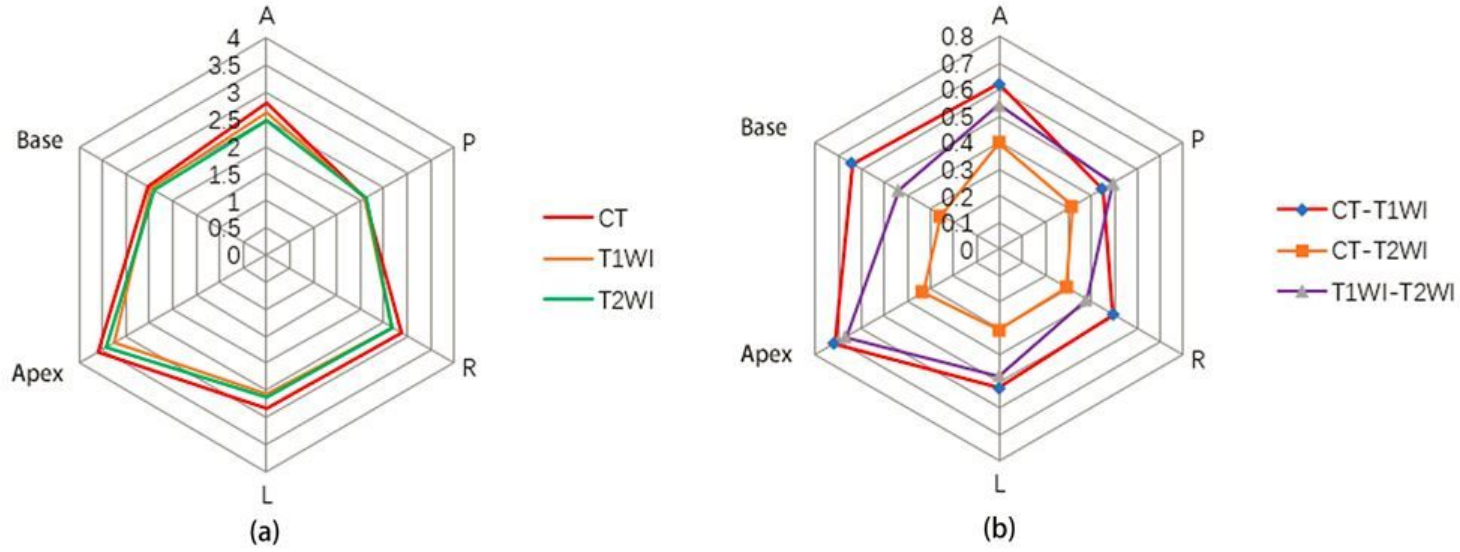

Figure 4

The spatial distributions maps of the PTV defined by CT, T1WI and T2WI images (a) The targets outlined by CT, T1WI and T2WI images are roughly the same. (b) T2WI provide significantly more specific target outlines than CT. The discrepancy in delineation between the two groups was mainly in the basal and apical areas of the prostate. There was a small discrepancy between the target regions defined by T1WI and T2WI.

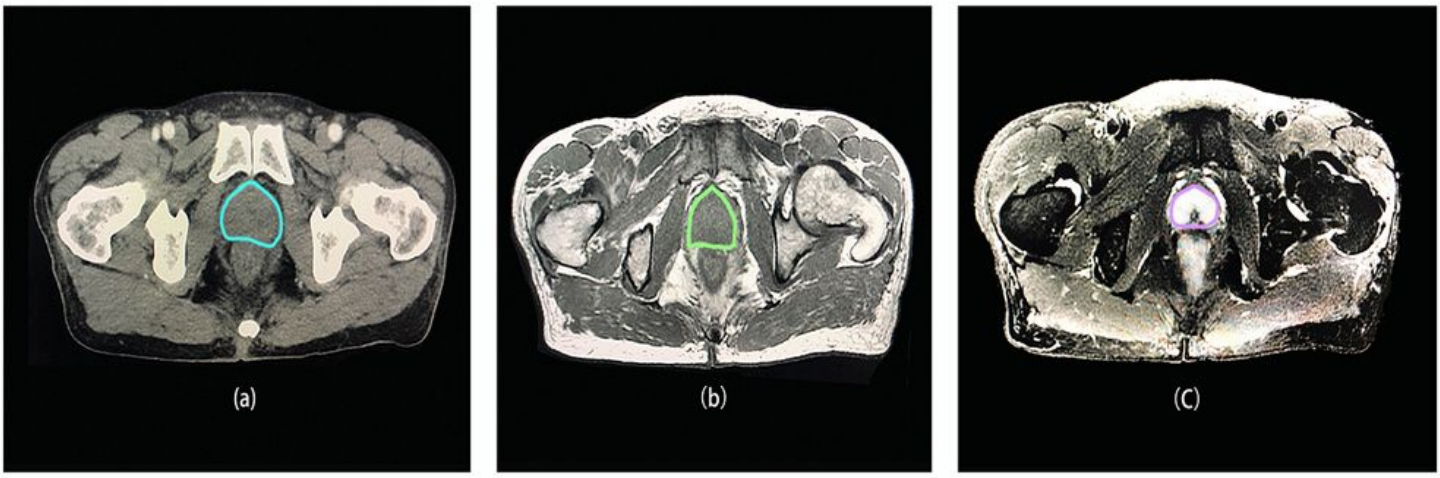

Figure 5

The sectional imaging of CT (a), T1WI (b) and T2WI (c) of the same patient along the same plane of view. (a).the boundary between prostate gland and surrounding tissue was unclear. (b).the boundary between the visible gland and peri-glandular adipose tissue, levator ani muscle and the posterior rectum could be seen on T1WI image. (c). T2WI image clearly showed the prostatic capsule, which was in strong contrast with peripheral zone of the prostate (peri-prostate tissue, mainly composed of mesentery, neurovascular bundle and levator ani muscle).

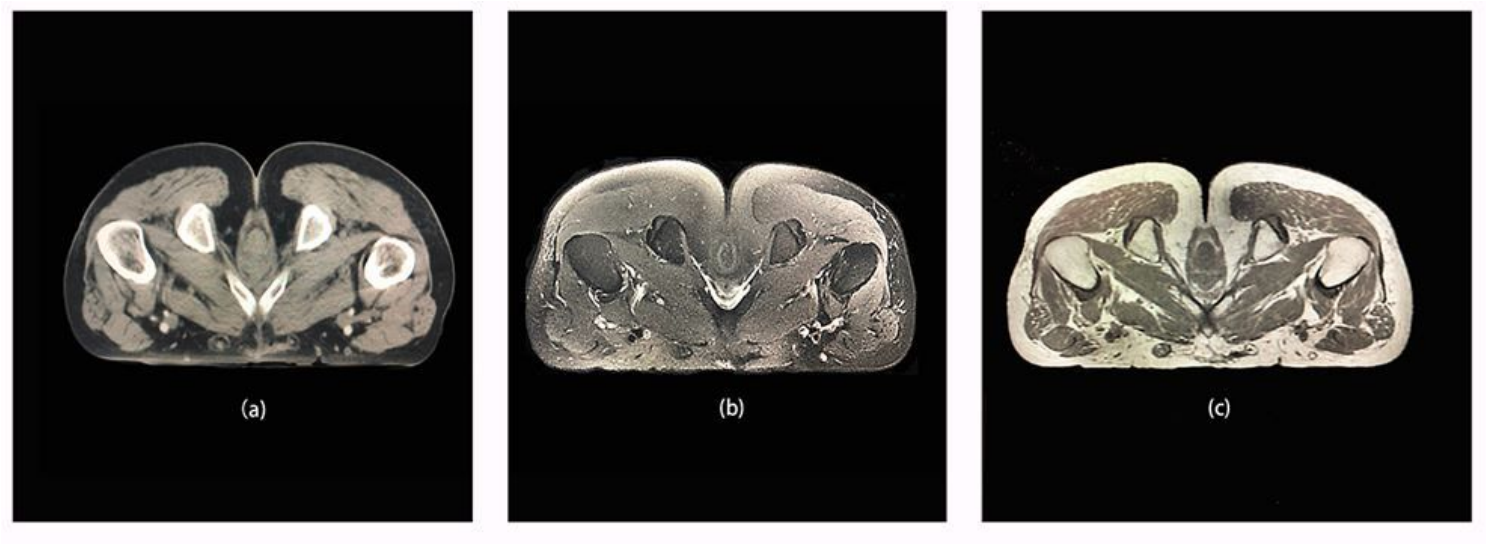

Figure 6

CT and MRI images of prostate apex at the same level of the same patient. (a) is the CT image. It can be seen that the development of the prostate apex was not obvious, which is difficult to distinguish from the surrounding muscle tissue. (b) is T2 lipidemic image. The apex and surrounding tissues of prostate can be clearly distinguished.