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Research Article

An Impact of Pelvic Magnetic Resonance Imaging to Radiotherapy Volume Definition in Patients with Intermediate- and High-Risk Prostate Cancer: A Population Based Study

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Abstract

Purpose: Pelvic MRI (PMRI) is an important pre-radiotherapy (RT) evaluation procedure in patients with intermediate- and high-risk prostate cancer. We conducted a retrospective study to evaluate an influence of PMRI to delineation of RT clinical target volume (CTV).

Methods: Medical records of prostate cancer patients treated with intensity-modulated RT (IMRT) in single institution in 2009-2015 were retrieved and examined retrospectively. Initial risk group affiliation was defined using NCCN criteria. PMRI reports of patients with intermediate and high-risk prostate cancer were reviewed and risk group affiliation was re-defined in regards of T- and N-stage. CTVs for IMRT treatment plans were contoured. Accounting to information obtained from PMRI. Extra-capsular extension (ECE) and seminal vesicles invasion (SVI) were included to high-dose CTV. Regional pelvic lymph nodes (RPLN) were planned to treat in all high-risk pts. RPLN considered pathological by PMRI were included to separate CTV to receive RT dose higher than unaffected RPLN stations.

Results: Between 2009 and 2013, 169 patients with intermediate and high-risk prostate cancer underwent PMRI at around 1 month before commencing IMRT. Initially, 89 patients were affiliated to intermediate-risk and 80 to high-risk group. In general, PTV-changes based on PMRI data required in 66 patients (39%). Thirty seven of 89 intermediate-risk patients (42%) were switched to high-risk group, necessitating irradiation of RPLN. ECE and SVI were included to high-dose CTV in 64 (38%) and 29 patients (17%) respectively. RPLN were thought pathological in 10 patients (6%), which justified contouring of a separate CTV for dose escalation.

Conclusion: In our retrospective series, PMRI-scans had a significant impact on RT target coverage decision in patients with intermediate and high-risk prostate cancer. However, a true value of this impact should be defined a large scale prospective clinical trial.

Keywords: Prostate cancer; Magnetic resonance imaging; Radiotherapy; Clinical target volume

Introduction

Diagnosis of prostate carcinoma is usually made by trans-rectal ultrasound (TRUS) guided core biopsy. The clinical T-stage (Table 1) [1] defined by TRUS and digital rectal examination (DRE) along with Gleason-score and initial value of prostate-specific antigen (PSA) are crucial parameters to affiliate prostate cancer patient to low-, intermediate-, or high risk group in order to determine clinical prognosis and properly select local and systemic therapies [2,3].

The DRE is defined by current guidelines as a standard method to determine the clinical T-stage in prostate cancer patients [4], despite of rising evidence of poor correlation of DRE findings with pathological T-stage in radical prostatectomy series [5], and lack of inter-observer consistency [6]. Incorrect clinical staging may have detrimental consequences in patients selected for definitive radiotherapy (RT). Undetected extracapsular extension (ECE) and/or seminal vesicle invasion (SVI) may result to inadequate coverage of all the disease within clinical target volume (CTV), potentially leading to RT failure.Other methods used to evaluate local extension of prostate cancer included TRUS and computerized tomography (CT). However, TRUS by its own right has been shown not any better than DRE, and its interpretation was reported as user-dependent [7,8]. Furthermore, CT has no advantage in staging because of limited ability for definition of tiny variances in soft tissue density [9].

Magnetic resonance imaging (MRI) has been proved to be of superior accuracy for staging prostate cancer due to its capacity to visualizing normal anatomy and identifying ECE, SVI and metastases

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Table 1: Clinical staging of prostate cancer (AJCC, 2002) [1].

Category	Description
Primary tumor (T)	
T1	Clinically in apparent neither palpable nor visible by imaging
T1a	Tumor Incidental histologic finding in ≤ 5% of tissue resected
T1b	Tumor Incidental histologic finding in > 5% of tissue resected
T1c	Tumor identified by FNA (e.g., because of elevated PSA)
T2	Tumor confined to prostate
T2a	Tumor involves ≤ 1/2 of one lobe
T2b	Tumor involves > 1/2 of one lobe, but not both lobes
T2c	Tumor involves both lobes
T3	Tumor extends through prostate capsule
T3a	ECE (unilateral or bilateral)
T3b	SVI
T4	Tumor is fixed or invades adjacent structures other than SVI
RLN (N)	
NX	RLN were not assessed
N0	No RLN metastasis
N1	RLN metastasis

AJCC: American Joint Committee for Cancer; FNA: Fine Needle Biopsy; PSA: Prostatic Specific Antigen; ECE: Extracapsular Eextension; SVI: Seminal Vesicle(s) Involvement; RLN: Regional Lymph Nodes.

Table 2: Risk group stratification of patients with localized prostate cancer (NCCN).

Risk group	Required characteristics			5-10-year bPFS/CSS (%)
	PSA (ng/ml)	Gleason's score	T-stage	
Low (all apply)	<10	≤6	T1 – T2a	80-90 / >95
Intermediate (any of)	10-20	7	T2b – T2c	70-85 / 75-90
High (any of)	>20	8-10	T3 – T4	30-60 / 60-80

NCCN: National Comprehensive Cancer Network; PSA: Prostatic Specific Antigen; bPFS – biochemical Progression-free Survival; CSS: Ause-specific Survival.

in regional pelvic lymph nodes (RPLN) as well [10,11]. The MRI-defined T-stage has also been revealed as having better correlation than DRE and TRUS with biochemical control in patients undergoing radical RT for prostate cancer [12]. Therefore, applying MRI-scan to decision-making on RT target coverage may be more precised as compared with conventional staging based on DRE and TRUS [13,15]. This could be particularly important for patients initially affiliated to intermediate- and high risk group because of high Gleason score and/or high PSA values, as they have greater probability of ECE, SVI and RPLN metastases [2,3].

Ourretrospective study aimed to evaluate an impact of diagnostic MRI-scan to definition of RT CTVs in patients with intermediate- and high-risk prostate cancer.

Patients and Methods

The medical records of patients with intermediate- and high-risk prostate adenocarcinoma treated by intensity modulated RT (IMRT) in single medical from 2009 to 2015 were collected and reviewed by approval of the Institutional Review Board. One hundred seventy eight patients were identified. All patients had histologically confirmed adenocarcinoma of the prostate gland, based on TRUS-guided biopsy. Initial clinical stage was established in accordance with DRE and TRUS. Patients were then risk-stratified according to National Comprehensive Cancer Network (NCCN) criteria,

Table 3: Patient characteristics.

Variable	Value
Age (years), median (range)	68.2 (48-81)
Prostatic specific antigen (ng/ml), median (range)	12.92 (1.9-84)
Gleason score, n	
6	23
7	91
8	41
9	13
10	1
NCCN risk group [4]	
Intermediate	89
High	80

NCCN: National Comprehensive Cancer Network.

Table 4: Risk group affiliation in regards to MRI-scan (169 patients).

NCCN group [4]	Relation to MRI-scan (absolute / per cent)	
	Before	After
Intermediate	89 / 53	52 / 31
High	80 / 47	117 / 69

NCCN: National Comprehensive Cancer Network; MRI: Magnetic Resonance Imaging.

accounting on stage, Gleason's score and PSA value (Table 1) [4]. All patients started neo-adjuvant androgen deprivation therapy (ADP) with bicalutamide combined with luteinizing hormone-releasing hormone agonist (LHRHA), and were referred for definitive IMRT.

All patients were considered to IMRT 78 Gy to prostate and 54 Gy to SV in 2 Gy daily fractions given 5 days a week. IMRT 44 Gy to RPLN was deemed necessary in patients with calculated risk of RPLN metastases of 15% or more [16,17]. On admission to RT-unit, 169 patients were referred to diagnostic pelvic MRI-scan for accurate definition of CTV at subsequent CT-simulation. MRI was contraindicated for various reasons in remaining 9 patients, and their records were excluded from the study. The MRI-scans were acquired at 1.5 Tesla Philips-scanner with an external phased-array body coil. T1- and T2-weighted sequences were acquired in axial, coronal and sagittal planes, covering prostate, SV and pelvic lymph nodes inclusive presacral, obturator, and common, internal and external iliac nodal stations. MRI-scans were reviewed by diagnostic radiologist and radiation oncologist. Clinical stage and risk group affiliation were redefined based on presence of ECE, SVI and RPLN suspicious for metastases.

RT-planning CT-scan using Marconi CT-simulator was performed at 1 week after diagnostic MRI-scan. All patients were immobilized using knee-fix device. CT-scan was extended from L4-L5 intervertebral space down to 2cm bellow minor trochanter with axial slice thickness 2.5mm. CTV contours were delineated by radiation oncologist. Where ECE was detected by MRI, a prostate CTV was expanded uniformly by 3mm. If SVI was identified, SV's were incorporated to joint high-dose (78Gy) CTV along with prostate. Nodal CTV was contoured in all high risk patients. In occurrence of RPLN suspicious for metastases, separate high-dose nodal CTV was delineated for escalating the total dose to 60Gy. Planning target volume (PTV) for RPLN was generated by adding 8mm uniform margin around nodal CTVs. PTVs for SV and prostate were created with 6.5mm posterior margin and 8mm margins in other directions around CTV.

Results

The characteristics of 169 patients included to this retrospective study are listed Table 3. The median age was 68.2 years, and median PSA value was 12.92ng/ml. The Gleason score varied from 6 to 10. Based on initial clinical information, the patients were nearly equally distributed to intermediate- and high-risk group (Table 4). All patients were considered for IMRT to prostate and SV, and elective irradiation of RPLN was thought necessary only for high-risk group patients.

Diagnostic MRI scan detected ECE, SVI, and RPLN suspicious for metastases in 64 (38%), 29 (17%), and 10 (6%) patients respectively. As a result, 37 of 80 (42%) patients initially belonging to intermediate risk group were shifted to high risk group (Table 4).

Overall, CTV changes were required in 66 patients (39%) based on MRI-scan results (Table 5). After incorporation of the MRI data to IMRT planning, elective irradiation of RPLN was considered necessary in 117 (67%) patients as compared to 80 (49%) patients before MRI (p=0.02). Prostate CTV was expanded by 3mm margin to include ECE in 64 (38%) patients. SV were incorporated to joint CTV with prostate to accounting for SVI in 29 (17%) patient. Separate nodal CTV was delineated for delivering radiation to RPLN suspicious for metastases in 10 (6%) of patients.

Table 5: CTV change in regards to MRI-scan (absolute n / per cent).

CTV description	Initial risk group		Total (n=169)
	Intermediate (n=89)	High (n=80)	
Elective RPLN CTV Before MRI After MRI	 0 / 0 37 / 42	 80 / 80 80 / 80	 80 / 47 117 / 69
Expanded prostate CTV for ECE Before MRI After MRI	 0 / 0 34 / 38	 0 / 0 30 / 38	 0 / 0 64 / 38
Prostate and SV joint CTV for SVI Before MRI After MRI	 0 / 0 15 / 17	 0 / 0 14 / 18	 0 / 0 29 / 17
Separate CTV for RPLN suspicious for metastases Before MRI After MRI	 0 / 0 3 / 4	 0 / 0 7 / 9	 0 / 0 10 / 6
Total CTV change after MRI	38 / 43	28 / 35	66 / 39

CTV: Clinical Target Volume; MRI: Magnetic Resonance Imaging; RPLN: Regional Pelvic Lymph nodes; ECE: Extracapsular Extension; SV: Seminal Vesicles; SVI: Seminal Vesicles Involvement.

Discussion

Our population based retrospective study demonstrated that pre-planning MRI-scan had a significant impact on decision making about RT-target coverage in patients with intermediate- and high-risk prostate cancer. Post-MRI correction of CTVs were required in 39% of patients, inclusive elective irradiation of RPLN, expansion of prostate CTV due to ECE, assembling prostate and SV into a single CTV because of SVI, and defining a separate CTV for RPLN suspicious for metastases. These findings correspond with preceding publications, which have reported on substantial influence of MRI-scans on surgical management of prostate cancer [18,19].

Previous studies have examined an impact of MRI-scans on RT-volume delineation in terms of changes of prostate contouring. MRI-based contouring not only enabled for significantly smaller CTVs as compared to CT-scans due to reduced incorporation of normal tissue, but also resulted in decreased likelihood of inter- and intra-observer variation in target demarcation, particularly at the prostate apex [20-22]. A recent publication [15] testified that in addition to better anatomical definition of prostate, MRI-scans allowed more accurate pathological-feature contouring, specifically for ECE and SVI. These revelations were further confirmed by our study. However, to contrast with *Chang et al* [15] we intentionally left patients with low risk prostate cancer out of study scope. The possibility of extra-prostatic extension is considered negligible in these patients, and to our view their inclusion to study could potentially underestimate an effect of MRI-scans on CTVs delineation.

ECE is not routinely accounted for in RT protocols, and the CTV encompasses only the prostate to the edge of the capsule. Nevertheless, pathological series have reported that where ECE is present, an average spread is 2-3mm beyond the prostatic capsule in the involved areas [11,13,14]. This microscopic extra-prostatic extension of the tumor should be included to CTV according to the ICRU-50 guidelines [23]. Recent publication showed that that this microscopic extension would have been missed in 8% of patients, unless MRI-scan was implemented to RT planning [15]. Our retrospective population based study revealed probability of even higher probability rate of such geographical missing (38%). Furthermore, SVI also may not be accounted for correctly without MRI-scan. Some investigators advocate only inclusion of the base of SVs into prostate CTV, or using predictive tools to identify patients with higher risk of SVI without performing MRI-scan [16,17,24-26]. However, a study by Chang et al [15] demonstrated that 16% of patients would not have received an adequate dose to the full extent of SVs based on clinical staging alone. Our series showed that SVI would not be sufficiently covered in 29 patients (17%) unless MRI data were incorporated to IMRT planning.

In addition to accurate detection of ECE and SVI, MRI-scan can also effectively recognize metastases to RPLN in patients with prostate cancer [27,28]. A number of retrospective and randomized controlled trials justified using definitive RT in combination with androgen deprivation therapy (ADT) as improving local control, biochemical relapse-free survival (bRFS), and overall survival (OS) rates in node positive patients with prostate cancer [29-33]. These trials used conventional RT techniques, applying the total doses to whole pelvisno more than 45-50 Gy delivered by standard fractions in order to respect the limits of the bowel tolerance to radiation [34]. However, it is unclear if such doses are sufficient to treat positive RPLN for curative intent. Dose escalation to positive RPLN using modern techniques in attempt to improve outcomes of RT of prostate cancer is a rapidly evolving treatment paradigm yet not approved by randomised controlled trials. Increasing the total dose to positive RPLN to 60-70 Gy with acceptable toxicity using IMRT was feasible in few phase I-II studies [35-39]. A promising trend to high bRFS and OS rates was also reported [37,39]. In our series of intermediate- and high- risk prostate cancer, RPLN suspicious for metastases were identified in 10 (6%) patients. We delineated separate CTV for positive RPLN aiming dose escalation to 60Gy.

The upgrading effect of MRI reported here is consistent with previous reports. *Jackson et al* [12] found that 52% of patients were upgraded to higher risk group after MRI-scan. A study by *Chang et al*

[15] showed that lack MRI could result in underdosage or geographical missing in 20% of patients. In our hands, CTVs correction was required in 39% of patients after MRI. Another advantage of accurate risk group definition with MRI is more appropriate selection of ADT schedule. There is a solid evidence for better survival with longer course of ADT in patients with high-risk prostate cancer [4,29,40]. To our data, 42% of patients initially belonging to intermediate risk group were shifted to high risk group after MRI, and therefore longer courses of ADT were justified for them.

This study does have a number of pitfalls. A retrospective character of the trial was an obvious limitation. Pre-MRI evaluation including DRE and TRUS could be performed by different urologists without clear guidance for attempting detection of the disease extension beyond the prostate. As a result, ECE and SVI could be underreported at primary assessment, and therefore the study may overestimate the benefits of MRI. Additionally, this was not a surgical study, and false positive findings by MRI could not be accounted for. However, given the high specificity of MRI reported in radical prostatectomy series [11,41], it would be sensible to include visualized ECE, SVI and positive RPLN into the high-dose CTVs. Furthermore, for availability difficulties MRI-scans were performed 2-3 months after starting neoadjuvant ADT and were therefore not true initial staging scans. Other investigators revealed significant drop of an original volumes of the prostate and primary tumor after few month of ADT [42]. Accordingly, a substantial fraction of patients in our study may have been downstaged on the MRI owing tumour shrinkage attributable to ADT. Moreover, the MRI protocols underwent profound changes since the study period because of a constant technological development. Diffusion-weighted MRI is now part of routine evaluation of prostate cancer patients in our center. With improved sensitivity and specificity of newer technologies, the pelvic MRI would likely have even higher impact on RT target coverage decision than what was reported here.

To conclude, MRI can have a potential impact on the target coverage decision in the RT-management of intermediate- and high-risk prostate cancer patients. However, a true value of this impact should be defined in a large scale prospective clinical trial.

References

1. AJCC Cancer Staging Manual, 6th edition. Springer, 2002.
2. D'Amico AV, Cote K, Loffredo M, et al. Determinants of prostate cancer-specific survival after radiation therapy for patients with clinically localized prostate cancer. J Clin Oncol. 2002; 20: 4567-4573.
3. D'Amico AV, Moul JW, Carrol PR, et al. Surrogate end-point for prostate cancer-specific mortality after radical prostatectomy or radiation therapy. J Natl Cancer Inst. 2003; 95: 1376-1383.
4. Mohler J, Bahnson RR, Boston B, et al. NCCN clinical practice guidelines in oncology: prostate cancer. J Natl Compr Canc Netw. 2010; 8: 162–200.
5. Philip J, Dutta Roy S, Ballal M, Foster CS, Javle P. Is a digital rectal examination necessary in the diagnosis and clinical staging of early prostate cancer?. BJU Int. 2005; 95: 969–971.
6. Smith DS, Catalona WJ. Interexaminer variability of digital rectal examination in detecting prostate cancer. Urology. 1995; 45: 70-74.
7. Smith JA, Scardino PT, ResnickMI, et al. Transrectal ultrasound versus digital rectal examination for the staging of carcinoma of the prostate: results of a prospective multi-institutional trial. J Urol. 1997; 157: 902-906.
8. Narayan P, GajendranV, Taylor SP, et al. The role of transrectal ultrasound-guided biopsy-based staging preoperative serum prostate-specific antigen, and biopsy Gleason score in prediction of final pathologic diagnosis in prostate cancer. Urology. 1995; 46: 205-212.
9. Hricack H, Choike PL, Eberhardt SC, et al. Imaging prostate cancer: a multidisciplinary perspective. Radiology. 2007; 243; 28-53.
10. Mullerad M, Hricak H, Kuroiwa K et al. Comparison of endorectal magnetic resonance imaging, guided prostate biopsy and digital rectal examination in thepreoperative anatomical localization of prostate cancer. J Urol. 2005; 174: 2158–2163.
11. Nakashima J, Tanimoto A, Imai Y et al. Endorectal MRI for prediction of tumor site, tumor size, and local extension of prostate cancer. Urology. 2004; 64: 101–105.
12. Jackson AS, Parker CC, Norman AR et al. Tumour staging using magnetic resonance imaging in clinically localised prostate cancer: relationship to biochemical outcome after neo-adjuvant androgen deprivation and radical radiotherapy. Clin Oncol. 2005; 17: 167–171.
13. Teh BS, Bastasch MD, Wheeler TM et al. IMRT for prostate cancer: defining target volume based on correlated pathologic volume of disease. Int J Radiat Oncol Biol Phys. 2003; 56: 184-191.
14. Chao KK, Goldstein NS, Yan D et al. Clinicopathologic analysis of extracapsular extension in prostate cancer: should the clinical target volume be expanded posterolaterally to account for microscopic extension?. Int J Radiat Oncol Biol Phys. 2006; 65: 999–1007.
15. Chang JH, Joon DL, Nguyen BT et al. MRI scans significantly change target coverage decisions in radical radiotherapy for prostate cancer. J Med Imaging Radiat Oncol. 2014; 58: 237–243.
16. Partin AW, Kattan MW, Subong EM, et al. Combination of prostate-specific antigen, clinical stage, and Gleason score to predict pathologic stage of localized prostate cancer. A multi-institutional update. JAMA. 1997; 277; 1445-1451.
17. Woo S, Kaplan I, Roach M, Bagshaw M. Formula to estimate risk of pelvic lymph node metastasis from the total Gleason score for prostate cancer. J Urol. 1988; 140: 387.
18. Hricack H, Wang L, Wei DC, et al. The role of preoperative endorectal magnetic resonance imaging in the decision regarding whether to preserve or resect neurovascular bundles during radical retropubic prostatectomy. Cancer. 2004; 100: 2655-2663.
19. Labanaris AP, Zugor V, Takriti S et al. The role of conventional and functional endorectal magnetic resonance imaging in the decision of whether to preserve or resect the neurovascular bundles during radical retropubic prostatectomy. Scand J Urol Nephrol. 2009; 43: 25-31.
20. Hentschel B, Oehler W, Strauss D, et al. Definition of the CTV prostate in CT and MRI by using CT-MRI image fusion in IMRT planning for prostate cancer. Strahlenther Onkol. 2011; 187: 183-190.
21. Villeirs GM, Van Vaerenbergh K, Vakaet L, et al. Interobserver delineation variation using CT versus combined CT+ MRI in intensity-modulated radiotherapy for prostate cancer. Strahlenther Onkol. 2005; 181: 424-430.
22. Khoo EL, Schick K, Plank AW, et al. Prostate contouring variation: can it be fixed?. Int J Radiat Oncol Biol Phys. 2012; 82: 1923-1929.
23. International Commission on Radiation Units and Measurements. Prescribing, recording, and reporting photon beam radiotherapy. Bethesda, MD: International Commission on Radiation Units and Measurement; 1993. ICRU Report 50.
24. Kestin L, Goldstein N,Vicini F, et al. Treatment of prostate cancer with radiotherapy: should the entire seminal vesicles be included in the clinical target volume?. Int J Radiat Oncol Biol Phys. 2002; 54: 686-697.
25. Hayden AJ, Martin JM, Kneebone AB, et al. Australian & New Zealand Faculty of Radiation Oncology Genito-Urinary Group: 2010 consensus guidelines for definitive external beam radiotherapy for prostate carcinoma. J Med Imaging Radiat Oncol. 2010; 54: 513-525.
26. Michalski JM, Lawton C, El Naqa I, et al. Development of RTOG consensus

guidelines for the definition of the clinical target volume for postoperative conformal radiation therapy for prostate cancer. Int J Radiat Oncol Biol Phys. 2010; 76: 361-368.

27. Hedgire SS, Pargaonkar VK, Elmi A, et al. Pelvic nodal imaging. Radiol Clin North Am. 2012; 50: 1111-1125.

28. Pasoglou V, Larbi A, Collette L, et al. One-step TNM staging of high-risk prostate cancer using magnetic resonance imaging (MRI): toward an upfront simplified “all-in-one” imaging approach?. Prostate. 2014; 74: 469-477.

29. Bolla M, Van Tienhoven G, Warde P, et al. External irradiation with or without long-term androgen suppression for prostate cancer with high metastatic risk: 10-year results of an EORTC randomised study. Lancet Oncol. 2010; 11: 1066-1073.

30. Robnett TJ, Whittington R, Malkowicz SB, et al. Long-term use of combined radiation therapy and hormonal therapy in the management of stage D1 prostate cancer. Int J Radiat Oncol Biol Phys. 2002; 53: 1146-1151.

31. Rusthoven CG, Carlson JA, Waxweiler TV, et al. The impact of definitive local therapy for lymph node-positive prostate cancer: a population-based study. Int J Radiat Oncol Biol Phys. 2014; 88: 1064-1073.

32. Verhagen PC, Schröder FH, Collette L, Bangma CH. Does local treatment of the prostate in advanced and/or lymph node metastatic disease improve efficacy of androgen-deprivation therapy?. A systematic review. Eur Urol. 2010; 58: 261-269.

33. Zagars GK, Pollack A, von Eschenbach AC. Addition of radiation therapy to androgen ablation improves outcome for subclinically node-positive prostate cancer. Urology. 2001; 58: 233-239.

34. Letschert JG, Lebesque JV, de Boer RW, et al. Dose-volume correlation in radiation-related late small-bowel complications: a clinical study. Radiother Oncol. 1990; 18: 307-320.

35. Créhange G, Chen CP, Hsu CC, et al. Management of prostate cancer patients with lymph node involvement: a rapidly evolving paradigm. Cancer Treat Rev. 2012; 38: 956-967.

36. Engels B, Soete G, Tournel K, et al. Helical tomotherapy with simultaneous integrated boost for high-risk and lymph node-positive prostate cancer: early report on acute and late toxicity. Technol Cancer Res Treat. 2009; 8: 353-359.

37. Fonteyne V, Lumen N, Ost P, et al. Hypofractionated intensity-modulated arc therapy for lymph node metastasized prostate cancer: early late toxicity and 3-year clinical outcome. Radiother Oncol. 2013; 109: 229-234.

38. Guerrero Urbano T, Khoo V, Staffurth J, et al. Intensity-modulated radiotherapy allows escalation of the radiation dose to the pelvic lymph nodes in patients with locally advanced prostate cancer: preliminary results of a phase I dose escalation study. Clin Oncol. 2010; 22: 236-244.

39. Müller AC, Lütjens J, Alber M, et al. Toxicity and outcome of pelvic IMRT for node-positive prostate cancer. Strahlenther Onkol. 2012; 188: 982-989.

40. Zapatero A, Guerrero A, Maldonado X, et al. High-dose radiotherapy with short-term or long-term androgen deprivation in localised prostate cancer (DART01/05 GICOR): a randomised, controlled, phase 3 trial. Lancet Oncol. 2015; 16: 320-327.

41. Heijmink SW, Fütterer JJ, Hambrock T, et al. Prostate cancer: body-array versus endorectal coil MR imaging at 3 T-comparison of image quality, localization, and staging performance. Radiology. 2007; 244: 184-195.

42. Sanghani MV, Schultz D, Tempany CM, et al. Quantifying the change in endorectal magnetic resonance imaging-defined tumor volume during neoadjuvant androgen suppression therapy in patients with prostate cancer. Urology. 2003; 62: 487-491.

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