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Endorectal MRI for predicting pathologic T3 disease in Gleason score 7 prostate cancer: Implications for prostate brachytherapy

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Introduction

Permanent prostate brachytherapy is a safe and highly effective treatment for men with organ-confined prostate cancer (1, 2). This treatment allows for high-dose radiation treatment to the prostate while minimizing radiation exposure to the surrounding organs at risk.

Standard indications for prostate brachytherapy as a single-modality treatment have historically been limited to patients at low risk of extraprostatic extension (EPE) as defined by the Partin tables (3) and the D'Amico classification system (prostate-specific antigen [PSA] < 10 ng/mL, Gleason score [GS] ≤ 6, and clinical stage T1c–T2a). The rationale for this convention was based on early brachytherapy results suggesting that prostate-only treatments were suboptimal in men at higher risk of EPE (4–6). Contemporary brachytherapy series, however, have suggested that prostate brachytherapy monotherapy may be an option for appropriately selected men with GS 7 disease because they have a similarly low risk of EPE and because modern brachytherapy techniques can deliver an adequate dose to a 3–5 mm margin around the prostatic capsule (7–9).

Accurate estimation of both the likelihood and the extent of EPE is critical to prostate cancer management. Although the combination of PSA, GS, and clinical T-stage by digital rectal

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Conflicts of interest: none

exam (DRE) has enhanced the clinician's ability to predict EPE, there are limitations to the predictive value of these variables (10).

Magnetic resonance imaging using an endorectal coil combined with a phased-array coil (erMRI) has emerged as a promising technique for local staging of prostate cancer (11–16). The purpose of this study was to determine the ability of erMRI and other pretreatment factors to predict the presence and extent of pathologic EPE in patients with GS 7 prostate cancer.

Methods and materials

Patient selection

The MD Anderson Institutional Review Board approved the patient data collection and analysis in this study. All patients provided written informed consent for prospective data collection. The study population included 853 consecutively treated patients managed with robotic prostatectomy by a single urologic oncologist (JWD) from July 2006 to June 2010. Inclusion criteria for analysis were the following: clinical stage T1c–T2c, pretreatment PSA < 10 ng/mL, GS = 7 (3+4 or 4+3), and erMRI before prostate surgery.

erMRI

Images were acquired using a 1.5 Tesla MRI unit. Patients were imaged in the supine position with the use of a body coil for excitation and a phased-array pelvic coil combined with a commercially available balloon-covered, expandable endorectal coil for signal reception (MR Innerva; Medrad, Pittsburgh, PA). T1-weighted images were obtained through the prostate and pelvis in the transverse plane. T2-weighted images of the prostate and seminal vesicle were obtained in the transverse, sagittal, and coronal planes. Images were reviewed by an experienced radiologist specializing in the interpretation of prostate MRI. Multi-planar T2 weighted images were used to assess for EPE. Reported findings were dichotomized such that any patient with suspected EPE or for whom EPE could not be excluded was considered to be positive for EPE (EPE+ erMRI). Findings reported as organ confined disease were considered negative for EPE (EPE– MRI).

Pathologic analysis

The diagnosis of prostate cancer was histologically confirmed pre-operatively via transrectal ultrasound-guided needle biopsy of the prostate. All diagnostic prostate core biopsies underwent internal review at MD Anderson before surgery. Prostatectomy specimens were processed and analyzed according to institutional protocol (17, 18). Pathologic EPE was defined as seminal vesicle involvement or the presence of any malignant cell outside the prostatic capsule, but excluded assessment of lymph nodes removed at the time of surgery. All radical prostatectomy specimens were reviewed by an experienced genitourinary pathologist. When EPE was present, the radial distance of EPE beyond the prostatic capsule was measured and the greatest radial extent of EPE was recorded.

Statistical analysis

Contingency tables were constructed to assess erMRI test performance by comparison with pathologic findings. Fisher's exact test (categorical variables) and the Mann–Whitney *U* test (continuous variables) were used to test for association between clinical variables and pathologic EPE. Independent predictors of pathologic EPE were identified using logistic regression analysis. Associations were considered statistically significant at $p < 0.05$.

Results

Pathologic findings

We identified 171 men who met the inclusion criteria. Clinical and pathologic characteristics of the study sample are summarized in Table 1. Fifty-seven patients (33%) had pathologic EPE. The median radial distance of EPE was 1.75 mm (range, <1–15 mm). Of the 171 patients, 26 (15%) had EPE > 3 mm, and 18 (11%) had EPE > 5 mm.

erMRI prediction of pathologic EPE

Forty-eight patients (28%) were positive for EPE on erMRI. The sensitivity, specificity, and accuracy of erMRI for pathologic EPE were 50.9%, 83.3%, and 72.1%, respectively. The positive predictive value (PPV) and negative predictive value (NPV) of erMRI for pathologic EPE were 60.4% and 77.2%, respectively. An EPE– erMRI was highly predictive of EPE limited to a radial distance of 5 mm from the prostatic capsule (NPV = 95.6%).

Variables associated with pathologic EPE

Clinical T stage and erMRI findings were significant predictors of pathologic EPE (Table 2). Patients with a primary Gleason grade of 4 on initial biopsy were more likely to have EPE after prostatectomy than those with a primary Gleason grade of 3, and patients with 50% positive core biopsies were more likely to have EPE after prostatectomy than those with <50% positive core biopsies; however, these differences were not significant. Pretreatment PSA was not a significant predictor of EPE.

On multivariate analysis, clinical T stage and erMRI findings remained independent predictors of EPE, whereas GS, percentage of positive core biopsies, and pretreatment PSA were not significant predictors of EPE after prostatectomy (Table 3). Clinical T stage and erMRI findings were also predictive of EPE > 5 mm outside the prostatic capsule (Table 4).

The combination of clinical T stage and erMRI findings appeared to predict the likelihood of organ-confined prostate cancer and the radial distance of pathologic EPE when pathologic EPE was present (Table 5). Of 71 patients with clinical stage T1c disease and an EPE– erMRI, 69 (97%) had organ-confined disease and none had EPE > 2 mm outside the prostatic capsule. All 17 patients with clinical stage T2b–T2c disease and a positive erMRI finding had EPE and most (53%) of those patients had EPE > 3 mm outside the prostatic capsule.

Discussion

In this study to evaluate the ability of erMRI and other pretreatment factors to predict the presence and extent of EPE in patients with clinical stage T1c–T2c, GS 7 prostate cancer, we found that the risk of EPE was significantly and independently associated with clinical T stage and erMRI findings. An EPE– erMRI was highly predictive of pathologic EPE limited to 5 mm from the prostatic capsule. The combination of clinical T stage and erMRI findings provided the most accurate assessment of the presence and extent of EPE. Men with clinical stage T1c disease and an EPE– erMRI were highly likely to have cancer confined to the prostate, and no patient with these factors had EPE > 2 mm. In contrast, all men with clinical stage T2b–T2c disease and an EPE+ erMRI had pathologic EPE, and most had EPE > 5 mm outside the prostatic capsule. These results are particularly relevant to prostate brachytherapy, considering that the use of this therapy as a single-modality treatment is controversial in the group of patients represented here (19, 20). Our results suggest that the use of erMRI findings to predict EPE within 3–5 mm of the prostatic capsule may improve patient selection for prostate brachytherapy monotherapy in men with GS 7 prostate cancer.

In the current study, the sensitivity, specificity, and accuracy of erMRI for EPE were 50.9%, 83.3%, and 72.1%, respectively. The PPV and NPV of erMRI for EPE were 60.4% and 77.2%, respectively. These results are consistent with previously reported correlations between MRI and pathologic stage in more heterogeneous patient groups (12–16, 21–28). It has been suggested that MRI should not be routinely used for clinical staging due to suboptimal test performance (29). Recent work by Wang et al. found that erMRI findings improved prediction of pathologic EPE compared with using PSA, GS, and DRE findings alone as defined by the Partin tables or the widely used Kattan nomograms and those patients with intermediate- or high-risk disease derived the largest incremental benefit (15, 30–31). Our results support those of Wang et al. and provide a specific context supporting the use of erMRI for determining the appropriateness of prostate brachytherapy monotherapy in men with GS 7 prostate cancer.

In the current series, 33% of patients had pathologic EPE, with a median radial EPE distance of 1.75 mm. These results are comparable to those of other quantitative series investigating the extent of EPE (32–35).

Investigators at the Mayo Clinic have reported correlations of pre-treatment factors with quantitative assessment of pathologic EPE. In the first study, Davis et al. examined 376 prostatectomy specimens; 28% of the patients had EPE, the median radial distance of EPE was only 0.5 mm, and only 4% of the patients had EPE > 2.5 mm (33). A second cohort of men treated at the Mayo Clinic, inclusive of 404 prostatectomy specimens, was published in 2007 (36); 30% of the patients had EPE, the median radial distance of EPE was 0.6 mm; and <1% of patients had EPE beyond 5 mm. Adverse risk factors, including GS 7, have been shown to correlate not only with the presence of EPE but also with greater EPE distance (32). Therefore, the discrepancy in EPE distance between the Mayo Clinic series and our study is almost certainly due to differences between the two patient groups, considering that 42% and 54% of the patients in two Mayo Clinic studies respectively had GS 3–6.

Chao et al. examined 371 prostatectomy specimens from William Beaumont Hospital; 33% of the patients had EPE, and the median radial distance of EPE was 2.4 mm (32). Pretreatment PSA, GS, clinical T stage, primary Gleason grade, and percentage of positive core biopsies were all associated with risk of pathologic EPE (32). In our series, only clinical T stage and erMRI findings were significant predictors of pathologic EPE. The restricted eligibility criteria in the current analysis combined with a smaller sample size probably account for the lack of significant association between PSA, GS, percentage of positive core biopsies and pathologic EPE. In the William Beaumont Hospital series, 5% of patients had EPE > 4 mm (32), whereas in the current study, 15% of patients had EPE > 3 mm and 11% had EPE > 5 mm. This difference can also be explained by the inclusion of patients with generally more favorable risk factors in the William Beaumont Hospital series than in the current cohort of all patients with intermediate-risk disease.

We found that the odds ratios for erMRI detection of any EPE and of EPE > 5 mm were 3.06 and 3.75, respectively. Of all variables analyzed, only erMRI findings showed an increased ability to differentiate EPE with increasing EPE distance. Jager et al. first reported this finding in a study of 34 patients (28). In their study, erMRI findings were correlated with post-prostatectomy histopathology; the accuracy of erMRI for detecting EPE < 1 mm was poor, although accuracy improved with greater distance of capsular penetration. This finding may be particularly relevant for prostate brachytherapy, where the extent of EPE (rather than the simple presence or absence of EPE) is the primary question, as prostate brachytherapy can deliver a curative radiation dose to a margin 3–5 mm beyond the prostatic capsule (7, 37).

Our results also suggest that the presence and extent of EPE may be better predicted by using a combination of pretreatment factors plus erMRI findings rather than pretreatment factors alone. This concept is consistent with current standards of practice in which factors such as PSA, GS, and clinical T stage provide a more accurate prediction of pathologic EPE than any single risk factor alone (38). For example, in the current series, a man with clinical stage T1c, GS 7, PSA < 10 ng/mL, and an EPE– erMRI had a 0% risk of pathologic EPE > 3 mm outside the prostatic capsule. A patient with these factors is likely to be an excellent candidate for brachytherapy monotherapy because of the high probability that all cancer is confined to the treatment area. In contrast, all patients with clinical stage T2b–T2c, GS 7, PSA < 10 ng/mL, and an EPE+ erMRI had pathologic EPE, and most had pathologic EPE beyond 3 mm. Although the number of patients with clinical stage T2b–T2c disease was relatively small (n = 41), these findings suggest that in this group of patients inclusion of supplemental external beam radiation or external beam radiation therapy alone may be preferable radiation treatment strategies to brachytherapy monotherapy. Validation of these findings in a larger cohort is warranted.

Our study has several limitations. First, our result that erMRI findings and clinical T stage predict EPE may not be generalizable. Radiologists with more experience reviewing prostate MRI can more accurately correlate pretreatment imaging with histopathologic findings (21). Each erMRI scan in the current study was reviewed by an experienced radiologist with a focus on prostate MRI. Furthermore, although having all clinical staging performed by the same practitioner could be considered a strength of our analysis; the applicability to other

practitioners could be questioned because of the notorious subjectivity of the DRE. Second, the definition we used for EPE+ erMRI included any borderline cases. The most specific findings for EPE are asymmetry of the neurovascular bundle, blunting of the rectoprostatic angle, and direct tumor extension outside the prostatic capsule (39). Focal bulging, which is commonly used to define EPE, appears to be less specific. The use of a highly conservative definition of an EPE+ erMRI might result in underestimation of test performance. Furthermore, current and future studies may be enhanced by multiparametric MRI, whereas this study used only T2-weighted images. Third, the definition of pathologic EPE was inclusive of seminal vesicle invasion in this study. While we contend the definition of EPE used in this study is most relevant to clinical practice, including seminal vesicle invasion within the context of EPE constitutes a deviation from convention.

The use of prostate brachytherapy monotherapy for men with GS 7 prostate cancer continues to evolve. The Radiation Therapy Oncology Group (RTOG) is nearing accrual completion of RTOG 0232; a phase III randomized trial comparing brachytherapy plus supplemental external beam radiation versus brachytherapy alone. In addition, MD Anderson continues to accrue patients to a single-arm prospective trial of brachytherapy monotherapy in men with intermediate-risk prostate cancer. Gross EPE on erMRI is one of the exclusion criteria for this trial. The results of this trial are likely to further define the role of erMRI and prostate brachytherapy monotherapy in this patient subset.

Conclusion

In this group of selected men with clinical stage T1c–T2c, GS 7 prostate cancer, erMRI findings predicted the presence and extent EPE. The overall sensitivity, specificity, and accuracy of erMRI to detect any degree of EPE (50.9%, 83.3%, and 72.1%) were consistent with those reported in the literature to date. Test performance improved with increasing radial distance of EPE; the NPV for EPE > 5 mm was >95%. Men with clinical stage T1c, GS 7, PSA < 10 ng/mL, and an EPE– erMRI were highly likely to have capsule-confined disease, and no EPE beyond 2 mm was identified in this favorable group. These pretreatment factors can aid in the appropriate selection of men with GS 7 prostate cancer for brachytherapy monotherapy and may be useful in designing radiation treatment target volumes.

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LIST OF ABBREVIATIONS

erMRI	endorectal magnetic resonance imaging
EPE	extraprostatic extension
GS	Gleason score
PSA	prostate specific antigen
EPE+	extraprostatic extension positive
EPE-	extraprostatic extension negative
DRE	digital rectal exam
PPV	positive predictive value
NPV	negative predictive value
RTOG	Radiation Therapy Oncology Group
SD	standard deviation
CI	confidence interval

Table 1

Clinical and pathologic characteristics of the study sample

Characteristic	No. (%) (<i>n</i> = 171)
Age at diagnosis in years, median (range)	60 (42–76)
Race	
White	141 (82)
Black	15 (9)
Other	15 (9)
Clinical T stage	
T1c	87 (51)
T2a	43 (25)
T2b	36 (21)
T2c	5 (3)
Gleason score	
3+4	104 (61)
4+3	67 (39)
PSA in ng/mL, median (range)	4.9 (0.4–9.9)
Percentage of positive core biopsies	
50%	79 (46)
<50%	92 (54)
Pathologic T stage	
T2a	114 (67)
T3a	38 (22)
T3b	19 (11)

PSA = prostate-specific antigen.

Table 2

Factors associated with extraprostatic extension of prostate cancer

Variable	Pathologic findings		<i>p</i> Value
	EPE (<i>n</i> = 57)	No EPE (<i>n</i> = 114)	
Clinical T stage			<0.0001
T1c	4 (5)	83 (95)	
T2a	18 (42)	25 (58)	
T2b	30 (83)	6 (17)	
T2c	5 (100)	0 (0)	
erMRI findings			<0.0001
EPE+	29 (60)	19 (40)	
EPE–	28 (23)	95 (77)	
Percentage of positive core biopsies			0.15
50%	31 (39)	48 (61)	
<50%	26 (28)	66 (72)	
Gleason score			0.14
3+4	30 (29)	74 (71)	
4+3	27 (40)	40 (60)	
PSA in ng/mL, mean ± SD	5.13 ± 1.86	5.37 ± 2.02	0.41

EPE = extraprostatic extension; erMRI = endorectal coil magnetic resonance imaging; PSA = prostate-specific antigen; SD = standard deviation.

Table 3

Multivariate logistic regression analysis of factors associated with extraprostatic extension of prostate cancer

Variable	<i>p</i> Value	Odds ratio	95% CI
Clinical T stage	<0.0001	45.1	12.1–168
erMRI findings	0.04	3.06	1.04–9.00
Gleason score	0.06	2.65	0.97–7.24
Percentage of positive core biopsies	0.14	2.01	0.79–5.13
Pretreatment PSA	0.40	1.49	0.58–3.80

CI = confidence interval; erMRI = endorectal coil magnetic resonance imaging; PSA = prostate-specific antigen.

Table 4

Multivariate logistic regression analysis of factors associated with extraprostatic extension of prostate cancer > 5 mm outside the prostatic capsule

Variable	<i>p</i> Value	Odds ratio	95% CI
Clinical T stage	<0.0001	25.0	6.63–94.5
erMRI findings	0.02	3.75	1.21–11.6
Gleason score	0.30	1.81	0.59–5.59
Percentage of positive core biopsies	0.39	1.58	0.56–4.43
Pretreatment PSA	0.81	1.13	0.40–3.18

CI = confidence interval; erMRI = endorectal coil magnetic resonance imaging; PSA = prostate-specific antigen.

Table 5
Predicting radial distance of extraprostatic extension of prostate cancer using a combination of clinical T stage and erMRI findings

Clinical		No. (%)						
T stage	No EPE on erMRI			EPE on erMRI				
	Total	Pathologic findings			Total	Pathologic findings		
		Any	EPE > 3 mm	EPE > 5 mm		Any	EPE > 3 mm	EPE > 5 mm
T1c	71 (100)	2 (3)	0 (0)	0 (0)	16 (100)	2 (13)	1 (6)	1 (6)
T2a	28 (100)	8 (28)	2 (7)	1 (4)	15 (100)	10 (67)	5 (33)	4 (27)
T2b	22 (100)	16 (72)	8 (36)	3 (14)	14 (100)	14 (100)	8 (57)	8 (57)
T2c	2 (100)	2 (100)	1 (50)	1 (50)	3 (100)	3 (100)	1 (33)	0 (0)

EPE = extraprostatic extension; erMRI = endorectal coil magnetic resonance imaging.