

Prostate MRI prior to radical prostatectomy: effects on nerve sparing and pathological margin status

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Objectives: The aim of this study was to assess the positive surgical margin (PSM) and nerve sparing (NS) rates in patients who underwent prostate MRI (pMRI) prior to radical prostatectomy (RP) and compare them with matched, nonimaged control RP patients.

Methods: We identified 204 men who underwent preoperative pelvic MRI (pelMRI), of whom 176 (86.3%) underwent pMRIs, within 60 days of RP, and compared them (1:1) with a nonimaged control group matched by surgeon, age, race, body mass index (BMI), prostate-specific antigen (PSA), pathological Gleason score, prostate specimen weight, and RP year.

Results: The rates of nonfocal extracapsular extension (nfECE) on RP pathology in the MRI and control groups were similar. PSM rates were lower in the MRI group (13.7% vs 19.3%; $P=0.14$), but the difference did not meet statistical significance; this was also the case in patients with nfECE on RP pathology (27.7% vs 39.5%; $P=0.3$). NS rates were similar between groups. In the MRI group, 54 (26.5%) patients had an MRI suspicious for nfECE; their PSM rate (20.4%) was higher than that of patients with an MRI not suspicious for nfECE (11.3%; $P=0.11$), but the difference lacked statistical significance; the former group had significantly lower rates of NS. Limitations of the study include sample power and nonuniform heeding of MRI results by each surgeon.

Conclusion: MRI did not significantly decrease the rates of PSM, including in the subset of patients with nfECE on final pathology. Even wider resection may be necessary in patients with MRIs suggesting locally-advanced disease. Studies with greater power are needed.

Keywords: MRI, positive surgical margins, nerve sparing, extracapsular extension, radical prostatectomy

Introduction

Positive surgical margins (PSMs) after radical prostatectomy (RP) may increase the risk of biochemical recurrence (BCR)¹ and cancer-specific mortality,² which has led to guidelines^{3,4} recommending adjuvant radiation therapy for individuals with PSMs. Minimizing PSMs is thus of importance, though sometimes at odds with other surgical goals, such as preserving continence and potency. These convalescence issues are likely dependent on the preservation of the periprostatic tissues, including the neurovascular bundle (NVB) and investing fascias of the prostate.^{5–8} PSMs are frequently located at regions of extracapsular extension (ECE),^{9,10} where preserving pericapsular tissues may leave behind prostate cancer. Preoperative knowledge of the presence and location of ECE may benefit surgical planning, and perhaps minimize PSM, since that information could guide NVB resection on the involved side.

Prostate MRI (pMRI) has shown promise with regard to detecting ECE. pMRI refers to a type of pelvic MRI (pelMRI) in which there is a specific focus on the

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prostate. It typically includes T1- and T2-weighted images and is referred to as multiparametric MRI (mpMRI) if diffusion-weighted imaging (DWI) and/or dynamic contrast-enhanced (DCE) imaging are/is included. These additional imaging sequences are frequently included since they have a role in defining and characterizing prostate nodules and yield improved assessment of ECE (Figure 1).¹¹ Currently, sensitivities and specificities as high as 75% and 100%, respectively, have been reported for ECE detection by pMRI,¹² and in general, it is nonfocal ECE (nfECE) that is detected.¹³ In 2013, Somford et al¹⁴ reported the performance of preoperative pMRI with endorectal coil and a 3.0 T magnet for determining the presence of ECE. The sensitivity/specificity/PPV/NPV for low-, intermediate-, and high-risk

groups was 33.3/86.7/33.3/86.7%, 50.0/92.3/90.0/57.1%, and 64.9/72.7/88.9/38.1%, respectively. The sensitivity of pMRI for ECE improved with higher risk disease, and specificity was robust across all risk levels. We hypothesized that preoperative pMRI, by identifying nfECE, would help surgeons plan the periprostatic dissection and potentially decrease the rates of PSM. This is a retrospective study comparing PSM outcomes in a cohort with preoperative pMRI with a matched cohort without preoperative pMRI.

Methods

This study was approved by the Institutional Review Board (IRB) of the Johns Hopkins Medical Institutions; the IRB deemed that individual patient consent is not required for

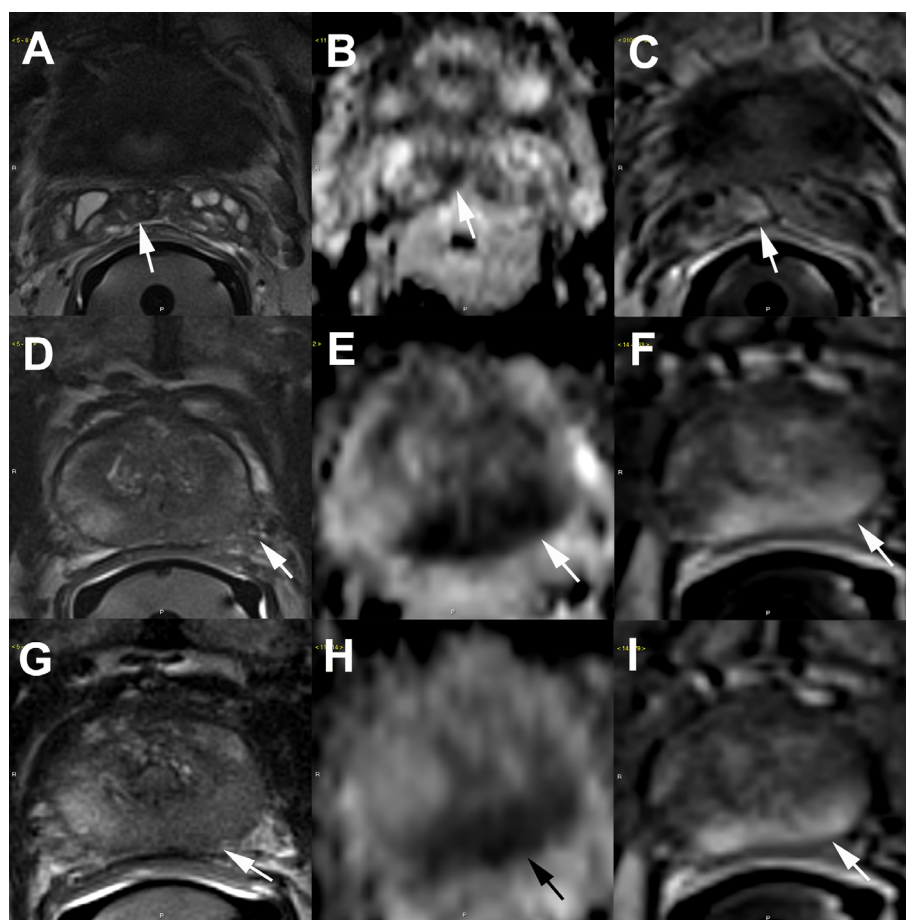


Figure 1 Example of extracapsular extension detected on multiparametric prostate MRI.

Notes: On mpMRI, T2W imaging provides a high-resolution anatomical image of the prostate capsule. ECE is suggested where there is hypointense tumor²² transgressing the prostatic capsule and there is an associated loss of capsular definition.²³ DWI and DCE imaging complement the T2W images, and when there are concordant suspicious signal abnormalities on T2W, DWI, and DCE images at the same region, the confidence in cancer localization increases.²⁴ In the peripheral zone, DWI provides further indication of tumor aggressiveness through a quantitative measure of ADC, with decreasing ADC value suggesting a higher likelihood of high-grade cancer and, therefore, a higher risk for ECE.²³ The images shown are from an mpMRI performed at 3.0 T with an endorectal coil in a single patient. (A–C) Right seminal vesicle invasion with a dark signal on T2W imaging (arrow; A), a low signal on the DWI–ADC map (arrow; B), and DCE enhancement (arrow; C). (D–F, mid gland; G–I, apex) Left-sided ECE and left neurovascular bundle invasion. On T2W imaging, the tumor is observed to have >2 cm abutment of the capsule along the left lateral posterior mid-apex with capsular blurring and loss of capsular and neurovascular bundle definition (arrows; D and G). The DWI–ADC map shows restricted diffusion (ADC value <900 s/mm²) that involves a large portion of the left peripheral zone mid-apex (arrows; E and H), correlating with the T2 signal abnormality. Corresponding DCE images show matching tumor enhancement (arrows; F and I).

Abbreviations: ADC, apparent diffusion coefficient; DCE, dynamic contrast-enhanced; DWI, diffusion-weighted imaging; ECE, extracapsular extension; mpMRI, multiparametric MRI; T2W, T2-weighted.

retrospective chart review. Compliance with the Health Insurance Portability and Accountability Act was maintained at all times. Data of all patients included were obtained from a prospectively maintained database of all men undergoing RP between 2006 and 2015 at two hospitals serviced by the department. A database search revealed that 204 of these men had undergone preoperative pelMRI, of whom 176 (86.3%) underwent pMRIs, within 60 days before surgery. While 68.1% of the MRIs were conducted at our institution, all outside studies were reviewed by our expert radiologists. A comparison cohort of 204 men who had not undergone pelMRI was constructed from the main RP database and matched with the index cohort by surgeon, age, race, body mass index (BMI), prostate-specific antigen (PSA), pathological Gleason score, prostate specimen weight, and RP year. Simple 1:1 random matching was used to select this control group. After matching, patients from 13 surgeons were included. MRI results were utilized by each surgeon as they saw fit. The studied outcomes included rates of PSM and nerve sparing (NS). Comparisons between groups were made using Wilcoxon–Mann–Whitney and Fisher’s exact tests computed using Stata Version 14.0 (StataCorp, College Station, TX, USA).

Results

Baseline demographic, oncologic, and imaging variables are summarized in Table 1. There were no statistically significant differences between MRI and control groups.

Table 2 summarizes the oncologic and surgical outcomes between groups, none of which were significantly different. This holds for both the total pelMRI group and the pMRI subgroup. Rates of any ECE were similar between the groups (pelMRI group 39.2% and control group 34.8%; $P=0.4$), as were the rates of nfECE (pelMRI group 23.0% and control group 22.1%; $P=0.9$), indicating adequate matching. Despite these similar rates of ECE, PSM rates in the pelMRI and control groups were statistically similar (13.7% vs 19.3%; $P=0.14$). This was also the case for the pMRI (12.5%) and control groups ($P=0.092$). This relationship was also observed when we looked separately at patients with clinical stage T1c disease (11.0% pelMRI group and 18.1% control group; $P=0.13$) and palpable disease (21.4% pelMRI group and 25.0% control group; $P=0.8$). In the 90 patients who had nfECE on final pathology, whom we would expect to benefit most from preoperative MRI, those with and without pelMRI had statistically similar rates of PSM (27.7% vs 39.5%; $P=0.3$). Interestingly, we did not observe significantly

Table 1 Baseline characteristics

Characteristics	Control group	MRI group	P
N	204	204	
Age (years, mean)	60.2	60.4	0.7
PSA ^a (ng/mL, mean)	7.4	8.7	0.4
BMI ^b (kg/m ² , mean)	27.5	27.6	0.8
Biopsy Gleason score (%)			
5	0.0	1.0	0.5
6	50.0	41.7	0.11
7	33.3	39.2	0.3
8	10.3	7.4	0.4
9	5.4	8.3	0.3
10	1.0	1.5	1.0
Cancer other than adenocarcinoma	0.0	0.5	1.0
No cancer	0.0	0.5	1.0
Clinical T-stage (%)			
T1c	70.6	66.7	0.5
T2, not otherwise specified	0.0	0.5	1.0
T2a	12.7	14.7	0.7
T2b	10.3	7.8	0.5
T2c	2.0	3.4	0.5
T3, not otherwise specified	0.5	1.0	1.0
T3a	0.5	0.0	1.0
Tx	3.4	5.9	0.3
Family history of prostate cancer ^c (%)	42.1	35.1	0.2
Race (%)			
African-American	6.9	6.4	1.0
American Indian or Alaskan native	0.0	0.5	1.0
Asian	1.0	1.5	1.0
Caucasian	89.7	85.8	0.3
Multiracial	0.5	0.0	1.0
Others	2.0	4.4	0.3
Unknown	0.0	1.5	0.3
Surgery type (%)			
LRP	0.5	0.0	1.0
RARP	58.3	58.8	1.0
RRP	41.2	41.2	1.0
pMRI (%)		86.3	
MRI conducted at our institution (%)		68.1	
T2 weighted (%)		100	
DWI (%)		81.9	
DCE imaging (%)		75.5	
pMRI with DWI and/or DCE imaging (mpMRI) (%)		84.3	
Endorectal coil used (%)		32.8	
MRI Tesla (%)			
3.0		78.4	
1.5		20.1	
<1.5 or unknown		1.5	

Notes: ^aExcludes three patients in the control group and three patients in the MRI group with unknown PSA. ^bExcludes 42 patients in the control group and 31 patients in the MRI group with unknown BMI. ^cExcludes two patients in the control group and two patients in the MRI group with unknown family history.

Abbreviations: BMI, body mass index; DCE, dynamic contrast-enhanced; DWI, diffusion-weighted imaging; LRP, laparoscopic radical prostatectomy; mpMRI, multiparametric MRI; pMRI, prostate MRI; PSA, prostate-specific antigen; RARP, robotic-assisted laparoscopic radical prostatectomy; RRP, (open) retropubic radical prostatectomy.

Table 2 Oncologic and nerve sparing outcomes in the MRI group versus controls

Outcome	Control group (%)	pelMRI group (%)	pMRI subgroup (%)	P-value for controls vs pelMRI	P-value for controls vs pMRI ^a
N	204	204	176		
Any NS ^b	91.5	89.7	90.3	0.6	0.7
Bilateral NS	68.7	73.5	75.0	0.3	0.2
Unilateral NS	22.9	16.2	15.3	0.10	0.069
Bilateral optimal NS ^b	58.2	56.9	57.4	0.8	0.9
Optimal NS on at least one side ^b	88.1	84.7	85.1	0.4	0.5
Pathological Gleason score					
No cancer	0.5	0.5	0.6	1.0	1.0
5	0	0.5	0.6	1.0	0.5
6	31.4	29.4	28.4	0.8	0.6
7	49.5	51.0	51.1	0.8	0.8
8	7.8	5.4	5.7	0.4	0.4
9	10.8	13.2	13.6	0.5	0.4
10	0	0	0	N/A	N/A
Any ECE on final pathology	34.8	39.2	39.2	0.4	0.4
Focal ECE	12.8	16.2	15.9	0.4	0.4
Nonfocal ECE	22.1	23.0	23.3	0.9	0.8
Pathological LNI	3.3 ^e	6.9	7.4	0.2	0.10
Pathological SVI	7.8	9.8	10.8	0.6	0.4
Capsular incision into cancer ^c	3.0	1.5	1.7	0.3	0.5
PSM, all-comers ^d	19.3	13.7	12.5	0.14	0.092
PSM, cT1c only	18.1	11.0	11.0	0.13	0.12
PSM, cT2/3 only	25.0	21.4	16.7	0.8	0.3
PSM, only patients with nonfocal ECE on final pathology	39.5	27.7	24.4	0.3	0.2

Notes: ^aThe 176 patients with pMRI are here compared with the entire control group (of 204 patients); no rematching was undertaken for this subset analysis. ^bThe three patients with unknown nerve sparing status were excluded from these analyses. Where applicable, one patient with unilateral nerve sparing but unknown levels of nerve sparing was excluded from analysis as well. ^cExcludes 10, 5, and 3 patients with unknown capsular incision into cancer status in the control, pelMRI, and pMRI groups, respectively. ^dOne patient with equivocal margins and one patient with an unknown margin, both in the control group, were excluded from these analyses. ^eExcludes 23 patients with unknown lymph node invasion.

Abbreviations: ECE, extracapsular extension; LNI, lymph node invasion; N/A, not applicable; NS, nerve sparing; pelMRI, pelvic MRI; pMRI, prostate MRI; PSM, positive surgical margin; SVI, seminal vesicle invasion.

lower rates of NS in the pelMRI group when compared with the control group (any NS in 89.7% and optimal NS on at least one side in 84.7% of the pelMRI group vs 91.5% and 88.1% of the control group, respectively; P -values both >0.05) despite MRI readings suggesting nECE in some of the pelMRI group patients. All of these calculations were repeated for the pMRI group and had similar results.

Table 3 summarizes the outcomes of patients with concern for ECE on MRI vs patients without. As expected, those with an MRI concerning for ECE (54 patients) had a higher rate of ECE on final pathology (57.4% vs 32.7%; $P=0.002$). Focal ECE was similar between the two groups, but nECE was much higher in the group with MRIs showing concern for ECE (40.7% vs 16.7%; $P=0.001$), supporting that MRI is useful in identifying only nECE rather than focal ECE. Those with concern for ECE on MRI had lower rates of NS, including any bilateral NS, bilateral optimal NS, and optimal NS on at least one side. In those with and without concern on MRI for ECE, the rates of PSM were similar (20.4% vs

11.3%; $P=0.11$). It must be noted, however, that more than one-third of PSMs in the subgroup of men with concern for ECE on MRI occurred at a location different than the ECE suggested on the MRI. We also assessed how unilateral ECE suggested by MRI (which was the case 88.9% of the time) affected NS decisions by the surgeons. The only statistically significant outcome in this regard was optimal NS on the right side, which was present in a greater proportion (80.8%) of patients with concern on MRI for ECE on only the left side compared to those with MRIs suggesting only right-sided ECE (50%) ($P=0.034$).

Finally, Table 4 summarizes the performance characteristics of pelMRI (again, 86.3% of which are pMRI) to detect nECE. The sensitivity was 33.9%, the specificity was 89.0%, the PPV was 35.6%, and the NPV was 88.2%.

Discussion

Several studies have, to our knowledge, examined PSM rates and/or NS after preoperative pMRI, but none except

Table 3 Outcomes in those with and without concern for extracapsular extension on MRI

Outcome	MRI without concern for ECE (N=150, 73.5%) (%)	MRI with concern for ECE (N=54 ^a , 26.5%) (%)	P
PSM	11.3	20.4	0.11
PSM at location of ECE on MRI		13.0	
PSM not at location of ECE on MRI		7.4	
Any NS	93.3	79.6	0.008
Bilateral NS	78.7	59.3	0.007
Unilateral NS	14.7	20.4	0.4
Bilateral optimal NS	62.7	40.7	0.006
Optimal NS on at least one side ^b	89.9	70.4	0.001
Any ECE	32.7	57.4	0.002
Focal ECE	16.0	16.7	1.0
Nonfocal ECE	16.7	40.7	0.001
	MRI with concern for only right-sided ECE (N=22) (%)	MRI with concern for only left-sided ECE (N=26) (%)	P
Right-sided optimal NS	50.0	80.8	0.034
Right-sided suboptimal NS	13.6	7.7	0.7
Right-sided non-NS	36.4	11.5	0.082
Left-sided optimal NS	54.5	50.0	0.8
Left-sided suboptimal NS	13.6	15.4	1.0
Left-sided non-NS	31.8	34.6	1.0

Notes: ^aIn total, 88.9% had unilateral ECE; 96.3% of MRIs were pMRIs. ^bOne patient with unilateral nerve sparing but unknown levels of nerve sparing was excluded from analysis. Significant P-values (<0.05) are shown in bold.

Abbreviations: ECE, extracapsular extension; NS, nerve sparing; PSM, positive surgical margin.

the present retrospective comparative analysis and the recent randomized controlled trial (RCT) by Rud et al¹⁵ have included a nonimaged comparison group.

In 1996, D'amico et al¹⁶ published a study of 445 men having RP after a 1.5 T MRI with endorectal coil and found that ECE on MRI was associated with PSM on multivariate analysis. In 2007, Zhang et al¹⁷ reported on 110 men undergoing RP after MRI and found that having ECE on MRI was not associated with having a PSM, a finding echoed by McClure et al¹⁸ and Roethke et al,¹⁹ suggesting that surgeons are resecting tissue more widely on sides of MRI-demonstrated ECE. Meanwhile, Brown et al²⁰ reported on 62 patients undergoing RP after MRI with endorectal coil and suggested that ECE on MRI did not affect the rates of bilateral NS in this very small cohort. Finally, in 2015, Rud et al¹⁵ reported a landmark single-institution RCT of 438 patients undergoing RARP by one of the four surgeons, in which half of the patients underwent 1.5 T mpMRI without endorectal coil or DCE. There was no statistically significant difference in the rates of PSM between the MRI and no-MRI groups when looking at all-comers, a similar result to our study. For patients with cT1 disease, however, they found a 41% relative risk reduction of PSM in the MRI group ($P=0.035$), despite their finding of similar rates of NS between the groups. Those with cT2/3 disease had similar rates of PSM whether imaged or not, even though the imaged group had less NS (wider excisions) performed. A large proportion of PSMs (89%) were caused

Table 4 The performance of pelvic MRI to detect nonfocal extracapsular extension

Sensitivity (%) ^a	33.9
Specificity (%) ^a	89.0
Positive predictive value (%) ^a	35.6
Negative predictive value (%) ^a	88.2

Note: ^aMRI performance was calculated by determining the 2x2 contingency tables for pelvic MRI to detect nonfocal ECE on the right and left sides of the prostate independently, using nonfocal ECE on final pathology as the "gold standard", and combining the corresponding segments of the two 2x2 contingency tables. Thus, pelvic MRI was tested for its ability to detect ECE twice in each patient, once on the right side and once on the left side. One patient with nonfocal ECE but without information on location of the ECE was excluded from analysis.

Abbreviation: ECE, extracapsular extension.

by a dominant (index) tumor, more often than not associated with ECE, and almost all of these dominant lesions (98%) were detected by MRI, suggesting that even wider excisions are necessary to lower PSM rates.

The RCT by Rud et al¹⁵ was a significant contribution to the literature, though patients were imaged at 1.5 T. The present study adds to it by examining, for the first time, a contemporary MRI-imaged cohort using primarily (~80%) 3 T pMRI. Despite the 3 T MRI imaging protocol, we also did not find any statistically significant difference in PSM between those who did and those who did not have a pre-operative MRI, just as in the trial of Rud et al.¹⁵ We did not find any significant difference in PSM rates when stratifying by clinical stage either. One reason for this lack of a significant difference may be due to insufficient heeding of

the MRI results by the surgeons; in other words, surgeons may not be resecting widely enough in areas suspicious for advanced disease on MRI. This is illustrated by the fact that of the 54 patients with ECE on MRI, 13% had a PSM at the location of the ECE on MRI. More aggressive resection at those sights may have reduced the rate of PSM. Alternatively, limited sample size may account for this lack of statistical significance. We estimate that a sample size of 510 per group would be necessary to show a significant difference, using an alpha of 0.05 and a power of 0.8 for this two-sample one-sided test of proportions. Certainly, post hoc power calculations are subject to error;²¹ this information nonetheless aids in future study design.

We also did not find a statistically significant difference in the rates of PSM within the MRI group between those with MRIs suggesting ECE and those with MRIs not suggesting ECE. Surgeons resected more of the NVB when ECE was demonstrated on MRI and, thus, may have brought down the PSM rate in such higher risk patients to approach that of lower risk patients. Underpowering may also be contributing to this lack of statistical significance.

On the diagnostic performance of MRI to detect nfECE, MRI detected ECE in 26.5% of the patients, and on final pathology, 39.2% of those patients had ECE, over half of whom had nfECE. Despite a similar percentage of nfECE on final pathology and ECE detected on MRI, MRI was poorly sensitive (33.9%) for nfECE but rather specific (89.0%), which may in part be due to MRI detecting ECE on one side of the prostate but not on the other side in cases of bilateral nfECE. Nonetheless, this sensitivity is similar to that observed in low-risk patients in the trial by Somford et al¹⁴ but inferior to the performance of MRI observed in the higher risk groups in that study. This may be due to study heterogeneity and contamination of the MRI group by the 13.7% of patients who received a non-pMRI pelMRI discussed later. In addition, >93% of MRI patients were clinically gland confined, illustrating that ECE is challenging to diagnose on clinical examination. Preoperative imaging appears to be a more useful tool for detecting ECE, despite its limited performance.

This study is not without its limitations. First, there is considerable heterogeneity in our cohort, with regard to disease aggressiveness, surgery type, and MRI type. While that heterogeneity may contribute to our lack of statistically significant findings, it is in some ways a strength of the study since it represents a “real-world” cohort with minimal selection bias. Of those who had a pelMRI, 13.7% (28 patients) did not receive a pMRI but instead had an MRI

of the pelvis that included the prostate. pelMRI without a specific prostate focus (ie, without being a pMRI) is expected to have subpar ability to diagnose ECE and thus may be diluting our performance calculations, as mentioned earlier. Nonetheless, this does again portray the real-world scenario, where many patients are referred in to a tertiary care center with imaging performed at various locations. We believe that this study is marginally limited by this small number of patients who had non-pMRI pelMRI. Indeed, subset analysis of the pMRI-only subgroup (Table 2) shows similar results to calculations using the full pelMRI cohort. Second, each surgeon’s technique and skill level, as well as the degree to which they heeded the results of the MRI, are likely to be variable and this likely had an effect on the PSM and NS rates observed in this study. We attempted to correct for this variability by matching our cohorts by surgeon, so while the absolute rates of PSM and NS may not be generalizable since they may be surgeon specific, the comparison between the MRI and non-MRI groups takes into account this variability between surgeons. Third, we discovered several differences between patients undergoing RRP vs RARP (Tables S1 and S2). Patients in the RRP group had higher PSA and lower degrees of NS. However, since the control and MRI groups each had roughly equivalent proportions of patients undergoing RRP and RARP, we believe that the inclusion of both RRP and RARP group patients in our study should have minimal effect on our conclusions. Fourth, as noted earlier, sample size may have been a limiting factor.

Conclusion

With the added information afforded by MRI, one would expect lower rates of PSM than those in a matched, oncologically similar, nonimaged comparison group, which was not observed, including in the subset of patients with nfECE on final pathology. Furthermore, we observed several PSMs in regions where MRI suggested ECE. These findings suggest that even wider resection may be necessary in patients with preoperative MRIs suggestive of locally-advanced disease. The study was limited by patient sample size and heterogeneity. Our findings support the continued need for investigating the utility of preoperative MRI, using the latest MRI technology in larger cohorts of men.

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Disclosure

The authors report no conflicts of interest in this work.

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Supplementary materials

Table S1 Patients' characteristics by surgery type: robotic-assisted laparoscopic vs open retropubic radical prostatectomy

Patients' characteristics	RRP (%)	RARP (%)	P-value
N	239	168	
Age (years, mean)	60.6	59.8	0.4
PSA (ng/mL mean) ^a	8.9	6.8	0.011
BMI (kg/m ² , mean) ^b	27.3	27.8	0.4
Biopsy Gleason score (%)			0.5
5	0.8	0	
6	42.3	51.2	
7	37.2	34.5	
8	9.2	8.3	
9	8.4	4.8	
10	1.3	1.2	
Cancer other than adenocarcinoma	0.4	0	
No cancer	0.4	0	
Clinical T-stage (%)			0.045
T1c	68.2	69.1	
T2, not otherwise specified	0.4	0	
T2a	13.4	14.3	
T2b	8.8	9.5	
T2c	4.6	0	
T3, not otherwise specified	0.8	0.6	
T3a	0.4	0	
Tx	3.4	6.6	
Family history of prostate cancer ^c (%)	37.8	39.8	0.8
Race (%)			0.13
African-American	8.4	4.2	
American Indian or Alaskan native	0.4	0	
Asian	2.1	0	
Caucasian	84.9	91.7	
Multiracial	0	0.6	
Others	3.4	3.0	
Unknown	0.8	0.6	

Notes: ^aExcludes two patients in the RRP group and four patients in the RARP group with unknown PSA. ^bExcludes 53 patients in the RRP group and 20 patients in the RARP group with unknown BMI. ^cExcludes one patient in the RRP group and two patients in the RARP group with unknown family history. Significant P-values (<0.05) are shown in bold.

Abbreviations: BMI, body mass index; PSA, prostate-specific antigen; RARP, robotic-assisted laparoscopic radical prostatectomy; RRP, (open) retropubic radical prostatectomy.

Table S2 Pathological and surgical outcomes by surgery type: robotic-assisted laparoscopic vs open retropubic radical prostatectomy

Outcomes	RRP (%)	RARP (%)	P-value
N	239	168	
Any NS ^a	89.0	92.8	0.2
Bilateral NS	64.1	80.8	<0.001
Unilateral NS	24.9	12.0	0.001
Bilateral optimal NS ^a	51.1	67.1	0.002
Optimal NS on at least one side ^a	84.0	89.8	0.11
Pathological Gleason score			0.3
No cancer	0.8	0	
5	0	0.6	
6	28.0	33.9	
7	50.2	50.6	
8	8.0	4.8	
9	13.0	10.1	
10	0	0	
Any ECE on final pathology	37.7	36.3	0.8
Focal ECE	14.6	14.3	1.0
Nonfocal ECE	23.0	22.0	0.9
Pathological LNI ^b	5.9	4.1	0.5
Pathological SVI	8.4	9.5	0.7
Capsular incision into cancer ^c	3.5	0.6	0.087
PSM, all-comers ^d	17.7	15.0	0.5
PSM, cT1c only	14.1	15.5	0.7
PSM, cT2/3 only	26.5	17.5	0.4
PSM, only patients with nonfocal ECE on final pathology	31.5	36.1	0.7

Notes: ^aThe three patients with unknown nerve sparing status were excluded from these analyses. Where applicable, one patient with unilateral nerve sparing but unknown levels of nerve sparing was excluded from analysis as well. ^bExcludes two patients in the RRP group and 21 patients in the RARP group with unknown lymph node invasion. ^cExcludes nine patients in the RRP group and six patients in the RARP group with unknown capsular incision into cancer status. ^dOne patient with equivocal margins (RRP group) and one patient with an unknown margin (RARP group) were excluded from these analyses. Significant P-values (<0.05) are shown in bold.

Abbreviations: ECE, extracapsular extension; LNI, lymph node invasion; NS, nerve sparing; PSM, positive surgical margin; RARP, robotic-assisted laparoscopic radical prostatectomy; RRP, (open) retropubic radical prostatectomy; SVI, seminal vesicle invasion.

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