The utility of magnetic resonance imaging and spectroscopy for predicting insignificant prostate cancer: an initial analysis

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OBJECTIVE

To design new models that combine clinical variables and biopsy data with magnetic resonance imaging (MRI) and MR spectroscopic imaging (MRSI) data, and assess their value in predicting the probability of insignificant prostate cancer.

PATIENTS AND METHODS

In all, 220 patients (cT stage T1c or T2a, prostate-specific antigen level <20 ng/mL, biopsy Gleason score 6) had MRI/MRSI before surgery and met the inclusion criteria for the study. The probability of insignificant cancer was recorded retrospectively and separately for MRI and combined MRI/MRSI on a 0–3 scale (0, definitely insignificant; −3, definitely significant). Insignificant cancer was defined from surgical pathology as organ-confined cancer of ≤0.5 cm^3 with no poorly differentiated elements. The accuracy of predicting insignificant prostate cancer was assessed using areas under receiver operating characteristic curves (AUCs), for previously reported clinical models and for newly generated MR models combining clinical variables, and biopsy data with MRI data (MRI model) and MRI/MRSI data (MRI/MRSI model).

RESULTS

At pathology, 41% of patients had insignificant cancer; both MRI (AUC 0.803) and MRI/MRSI (AUC 0.854) models incorporating clinical, biopsy and MR data performed significantly better than the basic (AUC 0.574) and more comprehensive medium (AUC 0.726) clinical models. The *P* values for the differences between the models were: base vs medium model, <0.001; base vs MRI model, <0.001; base vs MRI/MRSI model, <0.001; medium vs MRI model, <0.018; medium vs MRI/MRSI model, <0.001.

CONCLUSIONS

The new MRI and MRI/MRSI models performed better than the clinical models for predicting the probability of insignificant prostate cancer. After appropriate validation, the new MRI and MRI/MRSI models might help in counselling patients who are considering choosing deferred therapy.

KEYWORDS

prostate cancer, nomogram, MRI, magnetic resonance spectroscopic imaging

INTRODUCTION

Prostate cancer is the most frequently diagnosed cancer amongst men in the Western world. With the widespread use of PSA screening there has been a dramatic shift to early-stage cancers [1], raising concerns about possible over-diagnosis and over-treatment [2,3]. Accordingly, 'insignificant' cancer has been defined as pathologically organ-confined cancer with a total volume of ≤0.5 cm^3 and no poorly differentiated component on histology [4–6]. Using this definition, reported studies found insignificant cancer in up to 30% of all prostate cancer cases detected by PSA screening [5,7–14].

Clinical models (algorithms) to predict insignificant prostate cancer have been designed using preoperative clinical variables (clinical stage, serum PSA level) and/or biopsy data [4,5,7,10,11,15,16]. Although these clinical models do not have sufficient accuracy to direct a patient toward deferred therapy (i.e. expectant management of low-risk, localized prostate cancer with definitive treatment deferred until evidence of cancer progression), they can be useful for counselling patients who are considering deferred therapy.

Non-invasive diagnostic imaging, especially MRI with MR spectroscopic imaging (MRSI), has improved in recent years and is gaining widespread acceptance for aiding diagnosis, tumour localization, staging, assessment of tumour aggressiveness, treatment planning, and follow-up in patients with prostate cancer [17–25]. Recently the incremental value of MRI/MRSI to the staging nomograms for predicting organ-confined prostate cancer has been reported [23]. Preoperative neural network software has been developed using combined MRI variables, PSA level and Gleason score to predict prostate cancer recurrence after radical prostatectomy (RP) [26]. However, to our knowledge, the utility of combining MRI/MRSI data with clinical and biopsy data in predicting the probability of insignificant prostate cancer has not been investigated. The aim of the present study

was to design new models combining clinical variables and biopsy data with MRI and MRSI data, and assess their value in predicting the probability of insignificant prostate cancer.

PATIENTS AND METHODS

In all, 220 patients with prostate cancer who had combined endorectal MRI/MRSI before RP, between October 2000 and October 2004, met the inclusion criteria for the study, and had whole-mount step-section pathology maps available for image correlation; map generation was directed by the clinical need with no intervention by study investigators. The inclusion criteria were the same as those used previously by the group for developing the preoperative clinical nomogram [15]: (i) clinical stage T1c or T2a; (ii) primary and secondary biopsy Gleason grade 1–3 (score ≤6); (iii) pretreatment PSA level of <20 ng/mL; and (iv) ≤50% of biopsy cores positive. All the patients studied had a biopsy Gleason score of 3 + 3.

All patients were recruited as part of an ongoing National Institutes of Health study investigating the use of MRI and MRSI in patients with prostate cancer. Written informed consent was obtained from each patient before MR studies. Subsequently, the Institutional Review Board approved our retrospective study and waived the informed consent requirement. This study was compliant with the Health Insurance Portability and Accountability Act. Patient data were collected and handled in accordance with institutional and federal guidelines.

For the endorectal MRI/MRSI, data were acquired on a 1.5 T Signa Horizon scanner (General Electric, Milwaukee, WI, USA) using software developed at the University of California at San Francisco [20], now commercially available from GE Medical Systems. MRI was done using a pelvic phased-array coil and an expandable endorectal coil; T1- and T2-weighted spin-echo MR images were obtained using a previously described standard prostate imaging protocol (total time ≈30 min) [19,22–24]. Image acquisition was followed by a standard MRSI protocol with point-resolved spectroscopy voxel excitation, and water and lipid suppression (total time 17 min) in a voxel array with an in-plane resolution of 6.25 mm and the SI dimension zero filled to 16 slices (3.1-mm resolution) [20,25]. Data were processed as described previously [20,25]. Peak areas were calculated by numerical integration. In each patient data set, (choline + creatine)/citrate (CC/C) ratios were calculated for all diagnostic voxels [20,21,25].

All endorectal MRI examinations were interpreted retrospectively by one radiologist with >10 years of experience in reading prostate endorectal MRI. The reader was unaware of the clinical data and surgical pathology findings. The MR images were evaluated for the presence of prostate cancer in the peripheral zone (PZ) and the transition zone (TZ) based on previously reported MR features [17–19,23,24]. Tumour volumes were estimated using a picture archiving and communications system [18]. MRI is limited in predicting exact tumour volumes because of confounding factors such as haemorrhage after biopsy, or prostatitis [27,28], which typically increase the suspected tumour volume. On MRI focal nodular regions of abnormal low T2-weighted signal are usually due to tumour, while focal non-nodular regions of abnormal low T2-weighted signal can be due either to tumour or to confounding factors [27,28]. With awareness of these limitations, the criteria for the probability of insignificant prostate cancer on MRI readings were conservatively set and expressed on a 0–3 scale: 0, definitely insignificant prostate cancer (no regions with abnormal T2-weighted signal); 1, probably insignificant (non-nodular decreased T2-weighted signal, <0.5 cm^3); 2, indeterminate (non-nodular reduced T2-weighted signal, >0.5 cm^3 or nodular <0.5 cm^3); 3, definitely significant (nodular reduced T2-weighted signal, >0.5 cm^3).

The combined MRI/MRSI score was determined by comparing and integrating tumour volume estimates on MRI and MRSI. MRSI data were interpreted by one spectroscopist with 5 years of experience in reading prostate MRSI based on previously established metabolic criteria [20,21,25,29], with no reference to the MRI findings, and with no knowledge of the clinical and pathology results. MRSI data from the PZ were considered suspicious for cancer if the CC/C ratio was at least two SDs above the average healthy ratio for the PZ [20,21]. The criteria for suspicion of cancer are well established and validated for the PZ, but for the TZ the identification of cancer is based on one retrospective study [29]. Therefore, the MRSI score was given only for the PZ. The MRSI tumour volumes were estimated by multiplying the voxel size (0.12 cm^3) by the number of suspicious voxels. The same radiologist who read MRI data assigned an overall score for the probability of insignificant prostate cancer on MRI/MRSI (0–3 scale): 0, definitely insignificant (no abnormality on MRI or no suspicious volume on MRSI); 1, probably insignificant (total combined MRI and MRSI suspicious volume of <0.5 cm^3); 2, indeterminate (total combined MRI and MRSI suspicious volume of ≈0.5 cm^3); 3, definitely significant (combined MRI and MRSI volume >0.5 cm^3). The radiologist combined the MRI and MRSI results for the overall MRI/MRSI score. Non-nodular regions of low T2-weighted signal with normal MRSI were dismissed, while in the presence of abnormal MRSI the decision was made based on abnormal volumes on MRI and MRSI. For the purpose of statistical analysis, patients with MRI or MRI/MRSI scores of 0 or 1 were considered to have insignificant prostate cancer.

For the pathology, whole-mount transverse serial sections of the prostate were prepared as described previously [30]. Insignificant prostate cancer was defined as tumour confined to the prostate (no extracapsular extension or seminal vesicle invasion in the surgical specimen), ≤0.5 cm^3 in total volume with no poorly differentiated elements (no Gleason pattern 4 or 5). The volumes of individual tumour foci were calculated by the pathologist using computerized planimetry with image analysis and measurement software (Image-Pro Plus 4.0, Media Cybernetics, Inc., Silver Spring, MD, USA) as previously described [6,31].

For the statistical analysis, four models were tested for prediction of probability of insignificant prostate cancer: the base and the more comprehensive medium clinical models previously published [15], and the newly developed MRI model and MRI/MRSI model. The base model of the previously published clinical nomogram includes PSA level, clinical stage, and primary and secondary biopsy Gleason grades. The medium model of the nomogram adds to this the percentage of biopsy cores positive (%BC+) and the prostate volume measured on imaging. While the original clinical nomogram uses TRUS-based volume measurements, half

of the TRUS imaging studies in the present study were done at other institutions, and the data were incomplete; we therefore calculated all prostate volumes from the MRI studies, using the ellipsoid formula: (right-left diameter × anteroposterior diameter × superior-inferior diameter) × 0.5 cm^3. The previously published clinical nomogram also included a 'full model' that was not included in the present analysis because it replaced the %BC+ with the length of cancerous and non-cancerous tissue in all biopsy cores, data that were not available for >90% of the patients whose biopsies were taken at other institutions.

The new MRI model included PSA level, clinical stage, %BC+, prostate volume on MRI, and MRI score; the new MRI/MRSI model included the same clinical predictor variables as the MRI model but replaced MRI score with overall MRI/MRSI score. The primary and secondary biopsy Gleason grades were omitted from both of the MR nomogram models because all of the patients in the study had Gleason grade 3 + 3 cancer. Furthermore, the data set collected in this study had 96 events, which suggests a maximum of 10 model degrees of freedom, limiting the number of predictors to consider.

The predictive accuracy of the nomogram models was quantified with the area under the receiver operating characteristic curve (AUC). The four models were compared to determine whether any of them provided suitable accuracy and to quantify the potential benefit of the extra data collected. To examine this with no bias we used 'leave-one-out' ('jack-knife') analysis to obtain the prediction probabilities and then examined the predictive ability of the jack-knife probabilities. This approach systematically computes the predicted probability for each patient by fitting a model based on all other patients. All analyses were done using SAS (Version 9.0, SAS institute, Cary, NC, USA) and S-Plus (Version 6.2, Insightful, Seattle, Washington, USA) with the Design, Hmisc and Roc libraries [32].

RESULTS

Table 1 lists the clinical predictor variables stratified by insignificant and significant prostate cancer as determined on final surgical pathology. Of the 129 significant cancers, 71, 16 and 42 were significant because the tumour was >0.5 cm^3, the Gleason score in the RP specimen was >6, or the tumour was >0.5 cm^3 and the Gleason score >6, respectively (Tables 2 and 3). Figure 1 shows a representative normal-appearing PZ of the prostate in a man with an insignificant prostate cancer. The cancer is not apparent by imaging or spectroscopy. Figure 2 shows a significant prostate cancer, outlined in the histological section and evident on MRI and MRSI.

Variable	Features of cancer in RP specimen	
	Insignificant	Significant
Number of patients	91	129
Clinical (T) stage, n (%)		
T1c	72 (79)	95 (74)
T2a	19 (21)	34 (26)
PSA level, ng/mL		
Mean (range)	5.3 (0.6–16.6)	6.1 (1.1–17.9)
Median (IQR)	5.1 (3.9–6.7)	5.5 (4.4–7.1)
MRI prostate volume, cm^3		
Mean (range)	43 (11–124)	35 (12–93)
Median (IQR)	38 (28–49)	31 (23–45)
%BC+		
Mean (range)	16.3 (2.0–50.0)	24.1 (4.0–50.0)
Median (IQR)	13.4 (7.7–25.0)	20.0 (12.5–33.9)

TABLE 1
The predictor variables stratified by the extent of the cancer in the RP specimen in the study group: insignificant or significant prostate cancer

The biopsy Gleason grade in all patients was 3 + 3 (score 6). IQR, interquartile range.

Gleason grade	Biopsy, n	RP*, n
3 + 2	0	1
3 + 3	220	160
3 + 4	0	49
4 + 3	0	8
4 + 4	0	1
No tumour	0	1
Total	220	220

**Compared with the Gleason grade in the biopsy specimen, the score in the RP specimen was unchanged in 160/220 (73%), higher in 58/220 (26%), lower in 1/220 (0.5%); no tumour was found in the RP specimen in 1/220 (0.5%).*

TABLE 2
Gleason grades in the biopsy specimens compared to those in the RP specimens

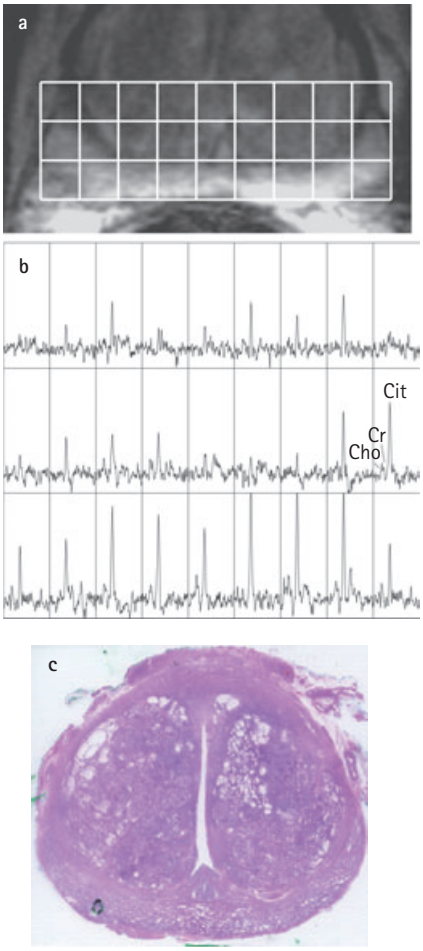
Both the MRI model and the MRI/MRSI model were more accurate than the clinical models for discriminating insignificant from significant prostate cancer (Figs 3 and 4). Both MR models also had good calibration (Fig. 5). When the base and medium clinical models were applied to the present patients the AUCs were 0.574 and 0.726, respectively; the medium model was significantly better than the base model ($P < 0.001$). The MRI model (AUC 0.803) performed significantly better than either clinical model ($P < 0.001$ vs the base, and $P < 0.018$ vs the medium model). The MRI/MRSI model was the most discriminating (AUC 0.854) and performed significantly better than either clinical model ($P < 0.001$ in both cases; Fig. 6).

Table 3 shows that MR data is useful in distinguishing the two extremes, i.e. definitely or probably insignificant prostate cancer (MR score 0 or 1), and definitely significant prostate cancer (MR score 3). Indeed, 30 of 32 (94%) patients with an MRI score of 0 or 1 had a tumour volume of <0.5 cm^3, and 25 of 32 (78%) had insignificant cancer. For most cancers misclassified as definitely or probably insignificant cancer by MRI (five of seven), the misclassification was due to underestimation of the Gleason grade (i.e. the Gleason grade was judged to be higher on reviewing the surgical specimen). Similarly, 57 of 67 (85%) patients with an MRI score of 3 (definitely significant cancer) had a tumour of >0.5 cm^3. As expected, the finding of a non-nodular region of reduced T2-weighted signal

TABLE 3 Patients with insignificant or significant cancer in the RP specimen stratified by MRI and MRI/MRSI scores

Pathologically defined cancer	Tumour volume, cm^3	Gleason score	MRI score	MRI/MRSI score 0,1	2	3	Total
Insignificant	<0.5	6	0,1	21	4	0	25
Insignificant	<0.5	6	2	22	37	0	59
Insignificant	<0.5	6	3	0	4	3	7
Total				43	45	3	91
Significant	<0.5	>6	0,1	5	0	0	5
Significant	<0.5	>6	2	2	6	0	8
Significant	<0.5	>6	3	0	0	3	3
Total				7	6	3	16
Significant	>0.5	6	0,1	1	1	0	2
Significant	>0.5	6	2	0	24	10	34
Significant	>0.5	6	3	0	1	34	35
Total				1	26	44	71
Significant	>0.5	>6	0,1	0	0	0	0
Significant	>0.5	>6	2	0	12	8	20
Significant	>0.5	>6	3	0	0	22	22
Total				0	12	30	42

FIG. 1. Insignificant prostate cancer: A 61-year-old patient presenting with a PSA level of 4.6 ng/mL, clinical stage T1c, and Gleason grade 3 + 3. Axial T2-weighted MR image (a) and corresponding MR spectroscopic grid (b) show a healthy PZ. The histopathology step-section (c) shows a small focus of cancer (circled) in the right posterior PZ (total tumour volume of 0.055 cm^3).



>0.5 cm^3 (indeterminate MRI category) was not specific (67 and 54 of 121 patients had tumours of <0.5 cm^3 and >0.5 cm^3, respectively). However, overall adding MRI was helpful, increasing the predictive accuracy (the AUC) of the model significantly, from 0.726 (medium model) to 0.803 (MRI model; $P < 0.018$; Fig. 6).

Combining MRSI and MRI allowed a more definite classification of 42 patients who had been assigned to the indeterminate category based on MRI. The reclassification with MRSI was correct in 22 of 24 patients whose classification was changed from indeterminate to insignificant (the two exceptions were patients who had a tumour of <0.5 cm^3 but Gleason score >6), and in all 18 whose classification was changed from indeterminate to significant (all had a tumour of >0.5 cm^3). MRSI increased the uncertainty of MRI results in only 10 patients. Overall, adding MRSI improved the predictive accuracy, increasing the AUC from 0.803 (MRI model) to 0.854 (MRI/MRSI model).

DISCUSSION

The increasing incidence of small-volume, low-grade cancers on pathology in PSA-screened populations [1] and the slow natural history of prostate cancer have raised concerns that some patients with clinically insignificant cancers are being over-treated [2,3,11,15,33]. Computer simulation models of the probability of prostate cancer over-diagnosis due to PSA screening [2] suggest that mean lead times, and rates of over-detection, depend on a man's age at screening; e.g. in single screening tests at ages 55 and 75 years, the estimated mean lead times were 12.3 and 6.0 years, and the over-detection rates were 27% and 56%, respectively. Etzoni *et al.* [3] suggested that 29% of prostate cancers in White men and 44% in Black men are over-diagnosed. However, patients with insignificant prostate cancer are difficult to identify clinically.

Statistical models (nomograms) based on pretreatment clinical variables and/or biopsy data have been developed that predict the probability of pathologically defined insignificant prostate cancer [5,7,10,11,15]. The reported accuracy of these models, as measured by the AUC, is up to 0.79, depending on the number of clinical variables and/or biopsy data included [5,7,15]. Although none of these clinical models has sufficient accuracy to direct a patient towards deferred therapy, they can be useful for counselling patients, and might lessen the anxiety in men who are considering deferred therapy. While deferred therapy [34] postpones the morbidity (and occasional mortality) of radical local therapy, the risk is that the extent and grade of the initial cancer might be underestimated, and the cancer might metastasize and become incurable before signs of progression are discernible; this risk leads most physicians and many patients to choose active therapy soon after diagnosis.

We hypothesized that MRI and/or MRI/MRSI might provide added value to current clinical nomograms for predicting the probability of insignificant cancer. It was shown that MRI is more accurate than a DRE in locating tumour within the prostate and seminal vesicles [22]. MRI and MRSI data add incremental value to clinical staging nomograms in predicting organ-confined prostate cancer [23], and a combination of MR data and clinical variables has been used to design preoperative neural

FIG. 2. Significant cancer in 40-year-old patient presenting with a PSA level of 4.7 ng/mL, clinical stage T1c, and Gleason grade 3 + 3. Axial T2-weighted MR image (a) and corresponding MR spectroscopic grid (b) show voxels suspicious for cancer (asterisks) in the left PZ. (c) Histopathology step-section with Gleason grade 3 + 3 area outlined (total tumour volume 1.923 cm^3).

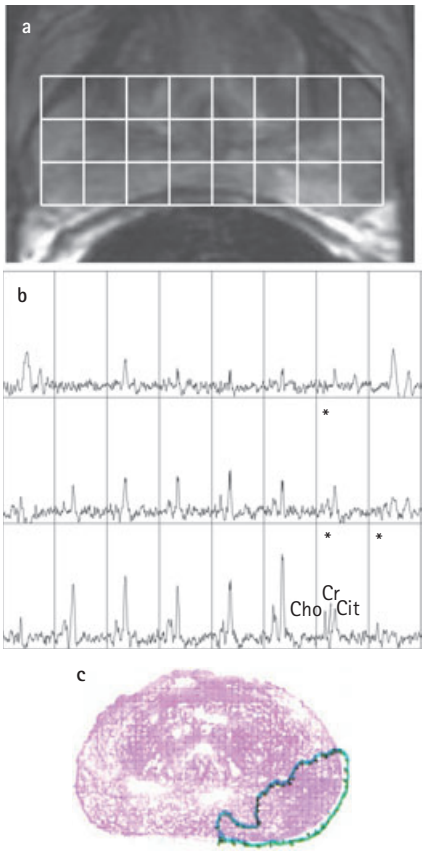
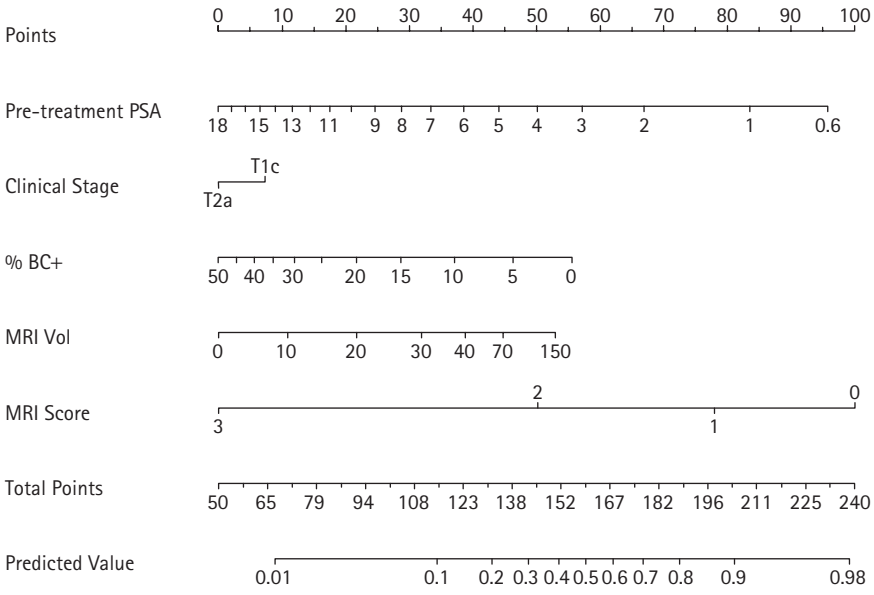


*FIG. 3. The MRI model for predicting the probability of insignificant cancer in an individual patient. The MRI nomogram includes pretreatment PSA, clinical stage, %BC+, pretreatment MRI volume of prostate and MRI score. In the MRI model, locate the patient's pretreatment PSA on the axis, then draw a line straight upwards to the **Points** axis to determine how many points towards having an insignificant prostate cancer the patient receives for his PSA level. The process is repeated for the remaining axes, each time drawing straight upward to the **Points** axis. The points are summed for each predictor and the sum is located on the **Total Points** axis. A straight line down is the patient's predictive value, i.e. probability of having insignificant prostate cancer.*



network software for predicting prostate cancer recurrence after surgery [26].

The results (Table 3) in the present study show that MR findings are very accurate in predicting either definitely insignificant or definitely significant disease. However, there is a grey zone (i.e. the indeterminate MR score) in which MR volume estimation is limited by confounding factors. Nevertheless, when MR data were added to the clinical and biopsy data, the accuracy of the more comprehensive clinical model (the medium model) improved significantly ($P < 0.001$), from 0.726 to 0.854 (MRI/MRSI model).

The major limitation of the models is that they are vulnerable to upgrading of the biopsy Gleason grade after RP; 26% of the present

FIG. 4. The MRI/MRSI model for predicting the probability of insignificant cancer in an individual patient. The MRI/MRSI nomogram includes pretreatment PSA, clinical stage, %BC+, pretreatment MRI volume of prostate, and overall MRI/MRSI score. The nomogram is used as detailed in Fig. 3.

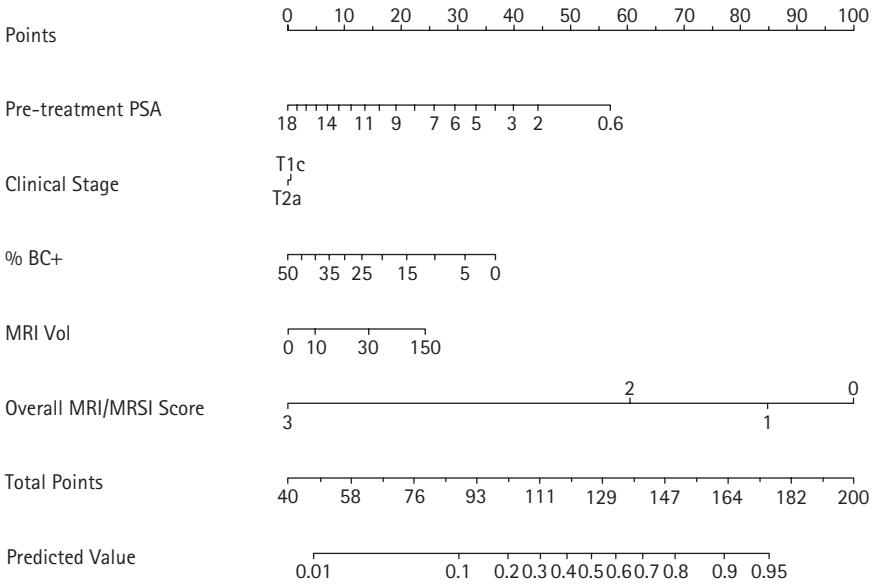
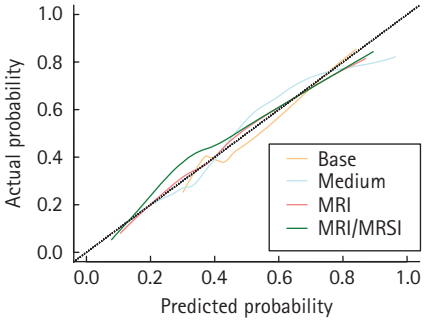
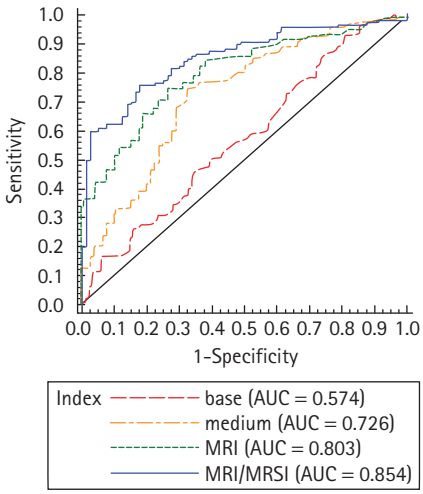


FIG. 5. Calibration of the four models; at the extreme, the initial testing of the MRI model predicted 6% too high (i.e. 88% prediction is associated with 82% proportion of insignificant prostate cancer), and the MRI/MRSI model predicted 7% too high (i.e. 92% prediction is associated with 84% proportion of insignificant prostate cancer).



patients had their Gleason scores upgraded. This was particularly important in 7% (16/220) patients with tumour of <0.5 cm^3 and a surgical Gleason score of >6, in whom accurate prediction of tumour <0.5 cm^3 resulted in an inaccurate prediction of insignificant cancer, and an inaccurate prediction of tumour >0.5 cm^3 resulted in an accurate prediction of significant cancer. This is a theoretical limitation of this approach that can be overcome either by improving the accuracy of the biopsy or by discovering new methods to predict surgical Gleason score using combined MRI/MRSI data in patients with small organ-confined prostate cancer. It was reported that the saturation approach might improve the accuracy of biopsy; applying saturation biopsy to 103 specimens after surgery with Gleason grade 3 + 3 before surgery showed that nine of 17 patients upgraded at surgical pathology from standard 12-core biopsy could be correctly identified as Gleason score >6 on saturation biopsy (mean number of cores 44) [4]. One study showed a trend toward increasing metabolic abnormality (CC/C ratio) at MRSI with increasing Gleason score, but the overlap was too high to allow determination of a threshold CC/C ratio that would separate Gleason score 6 from Gleason score >6 [25]. However, MRSI technology is being actively developed, and the testing of higher field-strength clinical magnets (3 or 4 T) that improve the spectral resolution might lead to the identification of new peaks or better resolution of peaks, such as polyamines, that are overlapped between the choline and

FIG. 6. A comparison of receiver operating characteristic curves for clinical nomogram models (base and medium) and MRI and MRI/MRSI nomogram models. The base model consists of the predictors PSA, primary and secondary biopsy Gleason grades, and clinical stage; the medium model includes the same predictors as the base model but also incorporates %BC+ and prostate volume on MRI. The MRI model includes PSA, clinical stage, %BC+, prostate volume on MRI and MRI score; the MRI/MRSI model is the same as the MRI model except that instead of MRI score, it includes overall MRI/MRSI score. The P values for the differences between the models were: base vs medium model, <0.001; base vs MRI model, <0.001; base vs MRI/MRSI model, <0.001; medium vs MRI model, <0.018; medium vs MRI/MRSI model, <0.001.



creatine peaks at 1.5 T [35,36]. In turn, this might lead to better prostate cancer characterization by MRSI.

The present study has several limitations; the MRI and MRSI tests were interpreted by a radiologist and a spectroscopist who both had considerable experience in prostate imaging. Therefore, the results might only represent the performance of these techniques at institutions where they are used routinely. The analysis was also limited to patients who had whole-mount step-section pathology maps available.

We selected a group of patients who met the inclusion criteria used in our previous models for predicting the probability of insignificant cancer. In the present study the percentage of patients with pathologically defined insignificant cancer (41%) was higher than that in the general population with prostate cancer, as these models were not designed for that general population. Moreover, the aim of this study was not to produce MR models ready for clinical use, but rather to test the feasibility of creating such models. The results of our initial analysis and the MRI and MRI/MRSI models we have developed need to be validated prospectively within and outside our institution before they can be recommended for widespread clinical application. After validation, the MR models could be used initially in academic settings where MR is used routinely and no added costs are involved. Before MR models can be used routinely, they must be shown to provide better accuracy than the less costly alternatives available [26].

In conclusion, this initial analysis shows that MRI and MRI/MRSI models might be useful in predicting the probability of insignificant cancer. Although they were limited in determining exact tumour volume, combined MRI and MRSI could be used to separate with reasonable accuracy tumours of <0.5 cm^3 from those of >0.5 cm^3, and improved the overall accuracy of our previously published clinical models for predicting the probability of insignificant prostate cancer.

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CONFLICT OF INTEREST

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Abbreviations: **MRSI**, MR spectroscopic imaging; **CC/C**, (choline + creatine)/citrate (ratio); **TZ**, **PZ**, transition, peripheral zone; **%BC+**, percentage of biopsy cores positive; **RP**, radical prostatectomy; **AUC**, area under the receiver operating characteristic curve.