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The value of diffusion-weighted and T2W-weighted magnetic resonance imaging in evaluate extracapsular extension in prostate cancer

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Abstract

Objective: The objective of our study was to evaluate the value of diffusion and T2-Weighted on magnetic resonance imaging for predicting extracapsular extension (ECE) in patients with prostate cancer.

Materials and methods: We evaluated ECE with T2-weighted imaging based on the Prostate Imaging Reporting and Data System (PI-RADS). The results we confirm by surgical pathology. We compared MRI characteristics between patients with ECE Prostate carcinoma (PA), and those without ECE Prostate carcinoma (pica) using independent sample t-tests, Chi- square tests, as appropriate. Analyzing ROC curve to find the value of T2W score in ECE and those without ECE to have a high specificity for ECE of prostate cancer.

Results: Age mean in ECE PCa was 67.03 ± 7.26. ECE PCa had 54.55%. Patients with ECE PCa have mean T2 scores was 3.64 ± 1.29, mean ADC values was 494.58 ± 95.06x10^{-6} mm^2/s, mean ADC ratio was 39.45 ± 9,05%. On ROC curve, using the discrimination threshold of T2W score > 2, AUC was 0.938, sensitivity 83.3%, specificity was 96.7%, positive predictive value was 96.8%, negative predictive value was 82.9%, mean ADC value was 477.41 ± 86.48x10^{-6} mm^2/s, mean ADC ratio was 38.37 ± 8.68%.

Conclusion: MRI is benefit from evaluate extracapsular extension (ECE) in patients with prostate cancer. T2W score > 2, AUC is 0.938, sensitivity 83.3%, specificity is 96.7%, positive predictive value is 96.8%, negative predictive value is 82.9%, mean ADC value is 477.41 ± 86.48 x10^{-6} mm^2/s, mean ADC ratio is 38.37 ± 8.68%.

Keywords: Prostatic carcinoma (PCa), Extracapsular extension (ECE), Magnetic resonance imaging (MRI), T2-weighted imaging score (T2W score).

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1. INTRODUCTION

Prostate cancer (PCa) is the commonest malignancy in men and the second leading cause of male cancer-related mortality [1]. Extracapsular extension (ECE) is found in a significant number of patients with clinically localized prostate cancer, poses a risk for an increased likelihood of postoperative biochemical recurrence. Distinguishing between organ-confined disease and extracapsular extension is associated with higher rates of positive surgical margins, biochemical recurrence, and micrometastasis [2,3]. It would be valuable to assess the risk of ECE before surgery for therapeutic planning in terms of not only selecting the treatment modality, but also making decisions regarding the balance between optimal cancer control and potency preservation. Assessment of ECE on conventional MRI is based on T2 images. However, with the advent of

technological advances in MRI, functional MRI such as diffusion weighted imaging (DWI) has gained significant value in predicting extracapsular extension in prostate cancer [4,5].

The objective of our study was to evaluate the value of diffusion and T2-Weighted on magnetic resonance imaging for predicting extracapsular extension (ECE) in patients with prostate cancer.

2. MATERIALS AND METHODS

We searched the electronic medical records of our institution to identify patients who had undergone prostate MRI followed by radical prostatectomy performed from May 2018 to May 2019 at Binh Dan Hospital, having surgical report and post-operative pathological result of prostate cancer. Inclusion criteria were patients had prostate cancer and had preoperative prostate MRI at Binh Dan Hospital, had surgical report, had post-operative pathology result showing prostate cancer. Exclusion criteria were patients who have been treated for prostate cancer before, poor MR imaging quality.

Prostate MRI was performed using a 1.5T MRI system (GE, USA) with consistent institutional protocol as followed:

Coronal T2 SSFSE (Coronal T2-weighted single shot fast spin echo).

Sagittal T2 PROP (Sagittal T2-weighted Propeller technique).

Coronal T2 FS PROP (Coronal T2-weighted with fat saturation Propeller technique).

Axial T2 PROP (Axial T2-weighted Propeller technique).

Axial T1 FSE (Axial T1-weighted fast spin echo).

DWI multi B values b50- 1000- 1400.

3D axial DCE FSPGR (3-dimensional axial fast spoiled gradient echo (FSPGR) sequences before and after Gadolinium injection).

Water 3D coronal LAVA FLEX after injection.

MRI criteria for extra-capsular extension of PCa are abutment; irregularity and neurovascular bundle thickening; bulge, loss of capsule and capsular enhancement; measurable extracapsular disease; obliteration of the recto-prostatic angle [6]; Each patient was assigned a T2-weighted imaging score from 1 to 5 regarding ECE (1 = abutment, 3 = irregularity, 4 = neurovascular bundles thickening, bulge or loss of capsule, 5 = measurable extracapsular disease) according to the Prostate Imaging Reporting and Data System (PIRADS) proposed by the European Society of Urogenital Radiology (ESUR) [6]. If the tumor was not definitely visible or did not show significant contact with the prostatic capsule, it was given a score of 0. Evaluated whether there was an apparent tumor with diffusion restriction on the ADC map at the tumor location and measured the corresponding ADC value of the tumor. When there was no definitely visible tumor on the ADC map, an ROI of approximately 0.20 cm^2 was placed in the peripheral zone near the posterolateral capsule because this region is not only the most common site of ECE but also the area in greatest proximity to the NVB [7].

A retrospective study was conducted on 66 consecutive patients with PCa. All patients underwent prostate MRI, radical prostatectomy and had pathologically confirmed PCa.

Our study record data from medical records, prostate MRI results, surgical reports, and pathological results. Patients were divided into 2 groups based on the presence of ECE. Survey variables are age, capsular extension on pathology results, lesion signal on T2W, DWI-ADC, capsular extension signs on T2W, ADC value. Data

processing was performed using SPSS 20 software. Qualitative variables are described by frequencies and percentages. Quantitative variables are described by means and standard deviations if normally distributed or by medians and interquartile ranges if skewed. Proportions were compared using the $\chi 2$ test. Mean values were compared using the T-Test. ROC curve analysis of T2W score variable to evaluate cancer with ECE and cancer without ECE to derive threshold value with sensitivity and specificity. All MR images were interpreted by 2 radiologists with over 5 years of experience.

The study was approved by the Ethics Council in Biomedical Research of Pham Ngoc Thach University of Medicine No. 36/HDDD dated April 23, 2019.

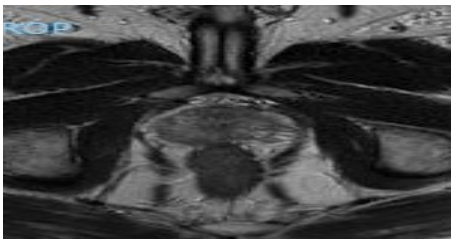

Figure 1. T2W image, right capsule contact sign, T2W score = 1
(64-year-old man, PCa with ECE)

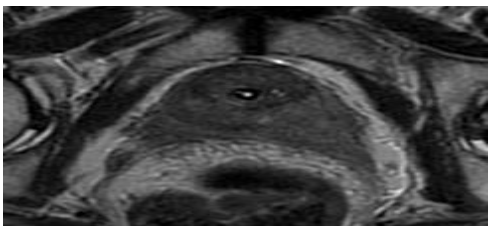

Figure 2. T2W image, bilateral neurovascular bundle thickening, T2W score = 4
(65-year-old-man, PCa with ECE)

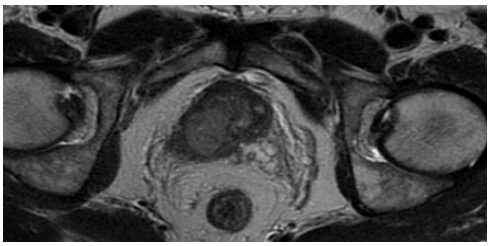

Figure 3. T2W image, right capsule extension, T2W score = 5
(63-year-old-man, PCa with ECE)

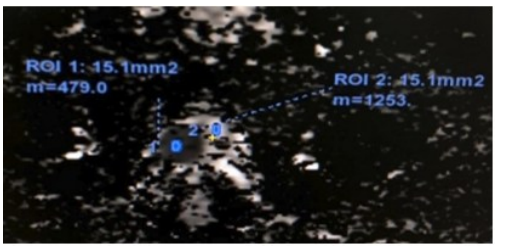

Figure 4. Region-of-interest (ROI) placement on ADC map
(63-year-old-man, PCa with ECE)

3. RESULTS

The study of 66 patients with prostate carcinoma histology, there were 36 patients with ECE accounting for 54.55%, 30 patients without ECE accounting for 45.45%. The mean age of the group without ECE was 67.33 ± 8.44; the mean age of the group with ECE was 67.03 ± 7.26. There was no significant difference between the mean age of the group without ECE and the group with ECE (p = 0.875).

Table 1. Diffusion-weighted and T2-weighted MR imaging features of prostate cancer.

MRI characteristics		ECE (-) (n=30)	ECE (+) (n=36)	p-value
Lesion signal on T2W	Low	19 (63.3%)	17 (47.2%)	p>0.05
	Mixed	11 (36.7%)	19 (52.8%)	
Lesion signal on T2W on DWI – ADC	High - low	25 (83.3%)	30 (83.3%)	p>0.05
	Mixed - low	4 (13.3%)	2 (5.6%)	
	High - mixed	1 (3.3%)	2 (5.6%)	
	Mixed-mixed	0 (0%)	2 (5.6%)	

MRI characteristics		ECE (-) (n=30)	ECE (+) (n=36)	p-value
ADC value of lesion (x10^{-6} mm^2/s)	Medium	585.07 ± 129.33	494.58 ± 95.06	**p<0.05**
ADC value of normal tissue (x10^{-6} mm^2/s)	Medium	1399.20 ± 217.57	1273.68 ± 181.58	**p<0.05**
ADC value ratio of lesion/ normal tissue (%)	Medium	40.02 ± 8.16	39.45 ± 9.05	p>0.05
ECE characteristics of the lesion on T2W	No capsule contact	9 (30%)	0 (0%)	**p<0.05**
	Capsule contact	20 (66.7%)	6 (16.7%)	
	Irregular capsule, retraction	1 (3.3%)	2 (5.6%)	
	Neurovascular bundle thickening	0 (0%)	9 (25%)	
	Capsule protrusion or discontinuity	0 (0%)	12 (33.3%)	
	Tumor extending beyond the capsule	0 (0%)	7 (19.4%)	
ECE score of the lesion on T2W (qualitative)	0	9 (30%)	0 (0%)	**p<0.05**
	1	20 (66.7%)	6 (16.7%)	
	3	1 (3.3%)	2 (5.6%)	
	4	0 (0%)	21 (58.3%)	
	5	0 (0%)	7 (19.4%)	
ECE score of the lesion on T2W (quantitative)	Medium	0.77 ± 0.626	3.64 ± 1.291	**p<0.05**

Table 2. ADC values and the presence of ECE according to the ECE assessment score of the lesion on T2W.

T2W score	Mean ADC of the lesion (x10^{-6} mm^2/s)	Percentage of lesions with ECE
0	641.70 ± 138.08	0
1	568.53 ± 113.83	23.1
3	441.88 ± 42.41	66.7
4	496.77 ± 89.94	100
5	434.57 ± 75.82	100

The difference in ADC value of lesions according to the assessment score of ECE of lesions on T2W (qualitative) was statistically significant (p <0.05).

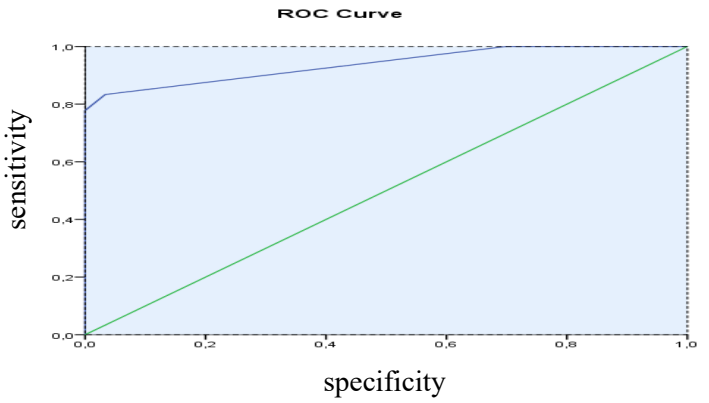

Figure 5. ROC curve of T2W score value to assess ECE of lesions distinguishing between ECE group and non-ECE group.

From the ROC curve, we chose the threshold value of T2W score as 2 (T2W score > 2 is a lesion with ECE), with a sensitivity of 83.3%, a specificity of 96.7%, and an area under the curve of 0.938. With the threshold of T2W score > 2, the lesion has ECE, with a positive predictive value of 96.8% and a negative predictive value of 82.9%.

Table 3. ADC value according to threshold value T2W score > 2 to assess ECE.

Characteristics		T2W score > 2 (n=31)	T2W score < 2 (n = 35)	p-value
ADC value of lesion ($x10^{-6}$ mm^2/s)	Medium	477.41 ± 86.48	587.35 ± 122.74	**p<0.05**
ADC value of normal tissue ($x10^{-6}$ mm^2/s)	Medium	1227.84 ± 180.88	1367.77 ± 221.99	**p<0.05**
ADC value ratio of lesion/ normal tissue (%)	Medium	38.37 ± 8.68	42.61 ± 8.31	**p<0.05**

4. DISCUSSION

The mean age of non-ECE group was 67.33 ± 8.44; the mean age of ECE group was 67.03 ± 7.26. The mean age between non-ECE and ECE groups was almost equal. In the study of Wooil Kim MD et al., the mean age of non-ECE group was 64.3; the mean age of ECE group was 65. The mean age between the non-ECE and ECE groups was almost equal [8]. Thus, the mean age in the study of Wooil Kim MD et al. was slightly lower than that in our study. There was no statistically significant difference between non-ECE and ECE groups, similar to our study [8].

In the study, there were 30 cases of non-ECE, accounting for 45.45%, and 36 cases of ECE, accounting for 54.55%. Thus, the group with ECE accounted for a higher proportion than the group without ECE in the study. Compared with the study of Sungmin Woo et al., the rate of ECE in prostate cancer was 42.7% [9], In Byung Dal Min's study, 56/126 cases had ECE, accounting for 44.44% [10]. Thus, the rate of ECE of the authors is lower than that of our study at 54.55%.

In the study, there were no statistically significant differences between the two groups in T2W signal, restricted diffusion signal, the ratio of ADC value of the lesion/normal prostate tissue. Therefore, the T2W signal, restricted diffusion signal, the ratio of ADC value of the lesion/normal

prostate tissue only represent the overall cancer lesion and do not predict the ECE of the lesion.

The mean ADC value of the lesion in the ECE group was lower than that in the non-ECE group (494.58 ± 95.06x$10^{-6}$$mm^2$/s and 585.07 ± 129.33x$10^{-6}$$mm^2$/s). The mean ADC value of normal tissue in the ECE group was lower than that in the non-ECE group (1273.68 ± 181.58x$10^{-6}$$mm^2$/s and 1399.20 ± 217.57x$10^{-6}$$mm^2$/s). The difference in the mean ADC value of the lesion and of normal tissue was statistically significant between two groups.

In prostate MRI, T2W images are very valuable for assessing ECE of prostate cancer. In our study, we found that the ECE characteristics of lesions on T2W, the ECE score of lesions on T2W (qualitative) and the ECE score of lesions on T2W (quantitative), had statistically significant differences between the non-ECE and ECE groups. Our study is also consistent with the study of Sungmin Woo et al. in assessing ECE on T2W, which also showed statistically significant differences in the ECE score of lesions on T2W (qualitative) and the ECE score of lesions on T2W (quantitative) between the non-ECE and ECE groups [9]. In the non-ECE group, the mean T2W score was 0.77 ± 0.626. According to the study of Sungmin Woo et al., the mean T2W score in the non-ECE group was 1.1 ± 1.2 [9]. Thus, the average T2W score of the non-ECE group in our study was lower than that of Sungmin Woo et al. In the ECE group, T2W score = 4 accounted for the most, about 58.3%. T2W score = 5 was the second most common, accounting for 19.4%. The average T2W score was 3.64 ± 1.291. The average T2W score in the ECE group study was significantly higher than that in the non-ECE group. According to the study of Sungmin Woo et al., the average T2W score was 2.4 ± 1.4 [9]. Thus, the average T2W score of the ECE group in our study was higher than that of Sungmin Woo et al.

We evaluated the mean ADC of the lesion and ECE according to the ECE assessment score of the lesion on T2W (qualitative) and found a statistically significant difference, consistent with the study of Sungmin Woo et al [9]. In our study, the mean ADC of the lesion had the lowest value in the T2W score = 5 (434.57 ± 75.82 x$10^{-6}$$mm^2$/s). The mean ADC of the lesion had the highest value in the T2W score = 0 (641.70 ± 138.08x10^{-6} mm^2/s). The mean ADC value of the lesion in our study was lower than that of Sungmin Woo et al., the mean ADC of the lesion in the T2W score = 5 (0.66 ± 0.06x10^{-3} mm^2/s). the mean ADC of the lesion in the T2W score = 0 (1.25 ± 0.4x10^{-3} mm^2/s) [9]. In our study, the rate of ECE was high in the T2W score = 4 (100%) and T2W score = 5 (100%). The rate of ECE in the T2W score = 3 (66.7%), T2W score = 1 (23.1%), T2W score = 0 (0%). Compared with the study of Sungmin Woo et al., the rate of ECE was high in the T2W score = 5 (100%), T2W score = 4 (72.2%), T2W score = 3 (68.4%), T2W score = 1 (38.9%), T2W score = 0 (4.2%) [9]. Therefore, the ECE lesions in the T2W score = 5 and the T2W score = 3 were almost equivalent to the author's study, while the ECE lesions in the T2W score = 4 in our study were higher than the author's study, the ECE lesions in the T2W score = 1 and the T2W score = 0 were lower than the author's study.

We analyzed the ROC curve of T2W score value to evaluate ECE of lesions to differentiate between ECE group and non-ECE group. From the ROC curve, we chose the threshold value of T2W score as 2 (T2W score > 2 is a lesion with ECE), with a sensitivity of 83.3%, specificity of

96.7%, area under the curve of 0.938. With the threshold of T2W score > 2 is a lesion with ECE, with a positive predictive value of 96.8%, negative predictive value of 82.9%. Meanwhile, the study of Sungmin Woo et al., chose the threshold of T2W score > 3, area under the curve was 0.770, sensitivity was 30%, specificity was 92.5% [9]. The study by Boesen L et al. selected the threshold T2W score ≥ 4, the area under the curve was 0.65 - 0.86, the sensitivity was 81%, the specificity was 78% [11], thus, our study chose a lower threshold than the authors T2W score > 2, with a higher area under the curve, sensitivity and specificity than the authors.

We found that the lesion ADC value, normal tissue ADC value, and the ratio of lesion/normal tissue ADC value compared to the threshold of T2W score > 2 were lower than that of T2W score < 2, and this difference was statistically significant. With the threshold of T2W score > 2, the lesion ADC value was 477.41 ± 86.48x10^{-6} mm^2/s, the normal tissue ADC value was 1227.84 ± 180.88x10^{-6} mm^2/s, and the ratio of lesion/normal prostate tissue ADC value was 38.37 ± 8.68%. With a T2W score threshold < 2, the lesion ADC value was 587.35 ± 122.74x10^{-6} mm^2/s, the normal tissue ADC value was 1367.77 ± 221.99x10^{-6} mm^2/s, the ratio of the lesion ADC value/normal prostate tissue was 42.61 ± 8.31. The study by Sungmin Woo et al. also found a statistically significant difference in the ADC value at a T2W score threshold > 3 [9].

We found that the combination of ECE on T2W and apparent diffusion coefficient (ADC) values obtained from DWI can be used as markers in the assessment of ECE in prostate cancer patients. Furthermore, compared with findings on T2 images, ADC values were shown to have comparable accuracy in predicting ECE [12]. We believe that the detection of ECE can be improved in prostate cancer patients with unclear ECE on T2-weighted images by using ADC to assess tumor invasion. Classification at a threshold value of T2W score > 2 (T2W score > 2 is a lesion with ECE), with a sensitivity of 83.3%, a specificity of 96.7%, and combined with the lesion ADC value, helps to more accurately diagnose the ECE of prostate cancer.

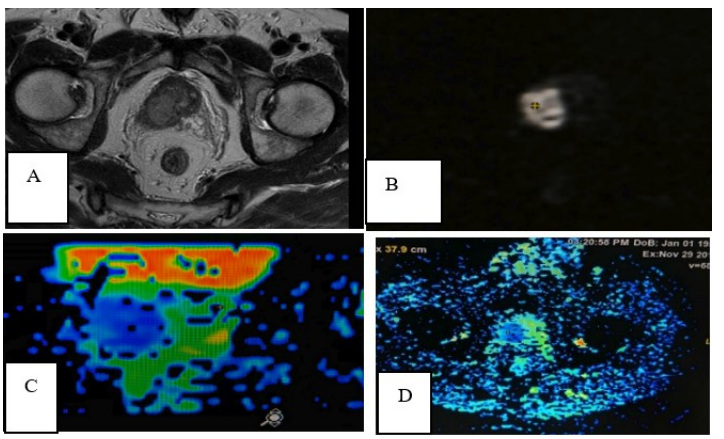

Figure 6. 63-year-old man has PCa with ECE

(A). T2W image, right peripheral lesion, mixed signal (low-intermediate), sign of extension outside the right capsule, T2W score = 5.

(B). DWI image with high signal.

(C)(D). ADC color map (coronal and axial images). Mean ADC value of lesion # 391,67x10^{-6} mm^2/s

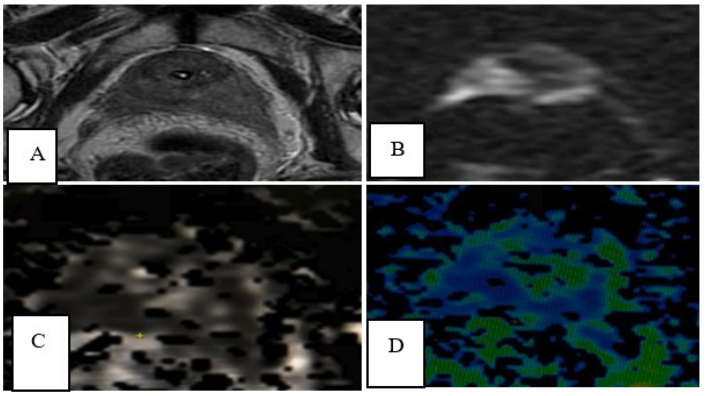

Figure 7. 65-year-old man, PCa with ECE.

(A). T2W image, scattered lesions in the peripheral and central areas on both sides, mixed signal (low-intermediate), bilateral neurovascular bundle thickening, T2W score = 4.

(B). DWI image with high signal.

(C)(D). ADC map and ADC color map. Mean ADC value of the lesion # 425.67x$10^{-6}$$mm^2$/s

5. CONCLUSION

MRI is benefit from evaluate extracapsular extension (ECE) in patients with prostate cancer. Prostate cancer with ECE has a mean ADC value of 494.58 ± 95,06x$10^{-6}$$mm^2$/s. The mean ADC value ratio of the lesion/normal prostate tissue is 39.45 ± 9.05%. The mean T2W score is 3.64 ± 1.29. T2W score > 2, AUC is 0.938, sensitivity 83.3%, specificity is 96.7%, positive predictive value is 96.8%, negative predictive value is 82.9%, mean ADC value is 477.41 ± 86.48x10^{-6} mm^2/s, mean ADC ratio is 38.37 ± 8.68%.

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