Oncology and Translational Medicine
DOI 10.1007/s10330-020-0414-4

February 2021, Vol. 7, No. 1, P–P

ORIGINAL ARTICLE

Application of dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) combined with magnetic resonance spectroscopy (MRS) in prostate cancer diagnosis

Yakun He, Min Wang (✉), Heping Deng, Jin Ren

Department of Radiology, Sichuan Cancer Hospital, Chengdu 610041, China

Abstract

Objective The aim of the study was to investigate the application of dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) combined with magnetic resonance spectroscopy (MRS) in prostate cancer diagnosis.

Methods In the outpatient department of our hospital (Sichuan Cancer Hospital, Chengdu, China), 60 patients diagnosed with prostate disease were selected randomly and included in a prostate cancer group, 60 patients with benign prostatic hyperplasia were included in a proliferation group, and 60 healthy subjects were included in a control group, from January 2013 to January 2017. Using Siemens Avanto 1.5 T high-field superconducting MRI for DCE-MRI and MRS scans, after the MRS scan was completed, we used the workstation spectroscopy tab spectral analysis, and eventually obtained the crest lines of the prostate metabolites choline (Cho), creatine (Cr), citrate (Cit), and the values of Cho/Cit, and (Cho + Cr)/Cit.

Results Participants who had undergone 21-s, 1-min, and 2-min dynamic contrast-enhanced MR revealed significant variations among the three groups. The spectral analysis of the three groups revealed a significant variation as well. DCE-MRI and MRS combined had a sensitivity of 89.67%, specificity of 95.78%, and accuracy of 94.34%.

Conclusion DCE-MRI combined with MRS is of great value in the diagnosis of prostate cancer.

Received: 27 March 2020
Revised: 28 August 2020
Accepted: 20 December 2020

Key words: prostate cancer; magnetic resonance imaging (MRI); dynamic contrast-enhanced (DCE); spectroscopy

Today, with the change in diet and lifestyle due to westernization, the extension of life expectancy, the aging of the population, and the popularity of prostate-specific antigen (PSA) examinations in China, the incidence of prostate cancer in China has increased significantly [1]. It has become one of the most common malignant tumors that endangers the health of middle-aged and elderly males [2]. In order to ensure the proper treatment and physical health of prostate cancer patients, a reasonable treatment plan is required. The patient's treatment plan and prognosis mainly depend on the early diagnosis of patients and the stage of the disease before the operation [3]. Early examination is beneficial for early detection, diagnosis, and treatment of prostate cancer [4].

In recent years, reports from the United States have shown that PSA audits in a large population have reduced the incidence of and overall mortality due to advanced prostate cancer in the United States by 50% and 30%, respectively, compared with the rates in the early 1990s [5]. In addition, recent reports reveal about 90% of newly diagnosed prostate cancer cases in Europe and the United States as localized prostate cancer at the first diagnosis, and 85% of localized prostate cancer can be cured by radical prostatectomy, thereby reducing the overall mortality rate of prostate cancer and improving the survival rate and quality of life of patients [6].

Magnetic resonance imaging (MRI) has a high applied value in the diagnosis of prostate cancer. Dynamic contrast-enhanced MRI (DCE-MRI) has a higher sensitivity in evaluating hemodynamics, morphology,

✉ Correspondence to: Min Wang. Email: 273795600@qq.com

and functionality, and can improve the diagnostic rate and staging accuracy of MRI in prostate cancer. At present, magnetic resonance spectroscopy (MRS) has also been widely used in the diagnosis of breast, brain, and prostate disease [7–8]. The purpose of this study was to investigate the application of DCE-MRI combined with MRS in prostate cancer diagnosis.

Materials and methods

Baseline characteristics of participants

In the outpatient department of our hospital (Sichuan Cancer Hospital, Chengdu, China), 60 patients diagnosed with prostate disease (confirmed by biopsy, surgical pathology, or follow-up) were selected randomly and included in a prostate cancer group, 60 patients with benign prostatic hyperplasia were included in a proliferation group, and 60 healthy subjects were included in a control group, from January 2013 to January 2017. The age ranges of the three groups were 48–78 years, 45–75 years, and 43–83 years; the mean age was 65.47 years, 60.56 years, and 68.43 years, respectively. There was no significant difference in the age factor among the three groups, which ensured the comparability of the subsequent data.

Equipment and inspection methods

The magnetic resonance examination was performed using a Siemens Avanto 1.5 T high-field intensity superconducting MR imager, and a body phased array coil. Before examination, the patient was cleaned intestinal tract, and after confirming that there was no stool in the rectum, the patient was examined by MRS.

DCE-MRI

The parameters and conditions of the DCE-MRI: TR 5.56 ms, TE 2.72 ms, the length of the echo chain (ETL) 1, Average 1, matrix 64 × 265, the layer thickness was 3 mm, the layer spacing was 0.6 mm, field of view (FOV) 350 mm × 250 mm, dynamic enhancement scan of the horizontal axis was 60 layers, scanning time 22 s. Prior to scanning, Gd-DTPA was injected through the anterior cubital vein at an injection flow rate of approximately 2 mL/s by a high-pressure syringe. Then, we performed the first scan after 21 s, and it was scanned once every minute. We obtained three scans in total.

MRS

An MRS scan is a three-dimensional imaging sequence of the axial plane. First the patients were scanned in the coronal, transverse, and sagittal sections. Then, the scanning was performed on the location phase in three directions, and the range of the scan included the entire prostate of the patients. After localization, eight saturated bands were added around the scanning area, and the saturation bands were as close as possible to the prostate, in order to suppress the influence of the surrounding tissue on the area of concern to the greatest extent. Prior to MRS scanning, band shimming was performed. The MRS scan was carried out under the following parameters: TR 700 ms and TE 120 ms scan sequence. The average number was 6 times, the reverse angle was 90°, the layer thickness was 50 mm, and the scanning time was 12 min. After scanning, spectrum analysis was performed on the spectroscopy TAB of the workstation to obtain the crest spectra of the prostatic metabolites choline (Cho), creatine (Cr), and citrate (Cit), and the ratio and mean values of Cho/Cit and (Cho + Cr)/Cit.

Image analysis

All images were analyzed by two MRI experts without knowledge of the patients' physical condition. In different impact conditions, the scope of the location of the tumor, hyperplasia and capsule invasion, seminal vesicle, and involvement of the neurovascular bundle were determined, and the results were compared with pathological results.

DCE-MRI

The signals of the same patient at the same position on the same level were measured at different times. The positions of the three measurements were as follows: the cancerous signals of patients with prostate cancer were measured separately, as well as the signals of the hyperplasia sites of patients with benign prostatic hyperplasia. The signals of the central glandular region and peripheral zone of members in the control group were measured and averaged. At the same time, the signal values of the obturator internus muscle at the same level for all participants were measured, and the relative signal intensity values were obtained after comparing the two signal values. During the measurement process, each partition of each research object had more than three selected districts, the values were recorded, and the average value was calculated.

MRS

MRS data were processed by a post-processing workstation. Three or more layers with the most clear lesions were selected to observe and measure the wave peaks of metabolites in the periprostatic region and central glandular region of the control group, in the lesion zone of the prostatic hyperplasia and prostate cancer groups, respectively. The data of Cho, Cr, and Cit were recorded, and calculated the ratio, and took the average value.

Data statistical analysis

SPSS 18.0 software was used for data analysis. Continuous variables were expressed as mean ± standard deviation and were analyzed by a *t*-test. The measurement data were analyzed using the chi-square test, and $P < 0.05$ indicated that the difference was statistically significant.

Results

The results of the three groups by DCE-MRI are shown in Table 1. Statistical software 18.0 was used for data analysis, and the *P*-values obtained were 0.042, 0.024, and 0.034, respectively, indicating that the comparison of the results between the three groups by DCE-MRI at 21 sec, 1 min, and 2 min showed significant differences.

The results of the three groups by MRS are shown in Table 2. Statistical software 18.0 was used to conduct statistical analysis on the data, and the *P*-values obtained were all < 0.05, indicating that the comparison between the spectral analysis results of the three groups was statistically significant, and there were significant differences.

The comparison results between the DCE-MRI and the MRS in diagnosis of prostate cancer are shown in Table 3.

Table 1 The comparison of the three groups by DCE-MRI

Groups	*n*	$\overline{\chi} \pm s$		
		21 s	1 min	2 min
Prostate cancer group	60	1.01 ± 0.09	1.51 ± 0.23	1.56 ± 0.20
Hyperplasia group	60	0.90 ± 0.09	1.23 ± 0.20	1.10 ± 0.16
Control group	60	0.80 ± 0.08	0.98 ± 0.19	0.97 ± 0.04
P value		0.042	0.024	0.034

Table 2 The comparison of the three groups by MRS

Indicators	Prostate cancer group	Hyperplasia group	Control group	*P* value
Cho/Cit	2.45 ± 1.01	0.38 ± 0.23	0.28 ± 0.13	< 0.05
(Cho + Cr)/Cit	2.83 ± 0.65	0.59 ± 0.34	0.39 ± 0.14	< 0.05

Table 3 The comparison between the DCE-MRI and the MRS in diagnosis of prostate cancer

Methods	Sensitivity (%)	Specificity (%)	Accuracy (%)
DCE-MRI	76.32	95.45	89.97
MRS	72.13	93.02	90.79
DCE-MRI + MRS	89.67	95.78	94.34

Discussion

Currently, the main detection methods for prostate cancer include PSA level examination, ultrasound-guided puncture biopsy, and MRI. Among them, the specificity of PSA level examination is low. Thus, it is difficult to distinguish benign lesions from prostate cancer and prostatic hyperplasia just from PSA levels [9–10]. The accuracy of ultrasound-guided puncture biopsy is relatively high, but the results are subjective and invasive. MRI is a non-invasive imaging method with high resolution for soft tissues. It can accurately and quickly distinguish the situation of different anatomical regions in the prostate. Coronal, transversal, and sagittal imaging can show the relationship between the gland and the surrounding structure in the pelvic cavity in a three-dimensional space, and the effect on tumor invasion of the nerves, blood vessels, capsule, bladder, seminal vesicle, and rectum is clear and obvious. Fat suppression of T2-weighted images (T2WI) clearly showed peripheral prostate cancer in patients better than other imaging studies [11]. However, MRI also has certain disadvantages, such as lack of specificity and high cost [12]. Furthermore, various functional imaging techniques such as diffusion-weighted imaging (DWI), DCE-MRI, and MRS have been gradually developed, and the advantages of MRI in the diagnosis of prostate cancer with high accuracy have been widely studied in clinical medicine [13–16].

DCE-MRI reflects the morphological and functional information of various parts of the prostate with its dynamic enhancement method. In this study, the relative signal strength values and strengthening methods are consistent with the results of other similar studies. The main manifestations of our results are as follows: the reinforcement of the normal peripheral zone was slow and uniform, and no obvious abnormal reinforcement was observed; the enhancement peak of prostate hyperplasia appeared later; prostate cancer appeared as a fast-forward and fast-out enhancement method, which strengthens the earliest peak appearance, reaching approximately 1.0 at 21 s after contrast injection. The different expression, peak value, and presenting time of these three types of enhancement methods are closely related to the blood supply of the study participants. It can be seen that the density of normal peripheral microvasculature was significantly lower than that of benign prostatic hyperplasia and prostate cancer, and the enhancement degree was significantly lower as well [17].

It has been reported that MRS analysis shows that the peak value of Cho significantly increases and the peak value of Cit significantly decreases or disappears in a prostate cancer [18]. In this study, it can be seen that the ratio of (Cho + Cr)/Cit and Cho/Cit in the prostate cancer group was compared with the data of the prostate hyperplasia and control groups, and the differences were significant, indicating that the results of this study were consistent with those of other studies. It can also be seen that the marked increase in the Cho peak and the marked decrease or disappearance of the Cit peak are one of the characteristic manifestations of prostate cancer in MRS. The Cho/Cit and (Cho + Cr)/Cit ratios are important bases for the diagnosis of prostate cancer [19]. The contents of Cho and Cit in prostate cancer show significantly abnormal changes. In this study, the changes in the above metabolites showed characteristic crest changes in the MRS spectrum analysis, which was also consistent with other research results [20–21]. Patients with prostate cancer

had Cho/Cit ≥ 1.0, (Cho + Cr)/Cit ≥ 2.0, and neither benign prostatic hyperplasia nor normal prostate tissue had abnormal changes in the above metabolites, with a specificity of 93.02%. The results indicate that it has high value in the diagnosis and of prostate cancer. However, the MRS examination required a long time and is affected by signals from surrounding tissues of the prostate. Thus, the spectrum was prone to clutter, leading to inaccurate measurements.

From the discussion above, it can be seen that DCE-MRI combined with MRS can greatly improve the value of MRI in the diagnosis of prostate cancer.

Conflict of interest

The authors indicated no potential conflicts of interest.

References

1. Li M, Zhang SW, Ma JH, *et al*. A comparative study on incidence trends of prostate cancer in part of cities and counties in China. Chin J Urol (Chinese), 2009, 30: 368–370.
2. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2016. CA Cancer J Clin, 2016, 66: 7–30.
3. Collin SM, Martin RM, Metcalfe C, *et al*. Prostate-cancer mortality in the USA and UK in 1975–2004: an ecological study. Lancet Oncol, 2008, 9: 445–452.
4. Zheng RS, Zeng HM, Zhang SW, *et al*. Estimates of cancer incidence and mortality in China, 2013. Chin J Cancer, 2017, 36: 384–389.
5. Xu JQ, Humphrey PA, Kibel AS, *et al*. Magnetic resonance diffusion characteristics of histologically defined prostate cancer in humans. Magn Reson Med, 2009, 61: 842–850.
6. Langer DL, van der Kwast TH, Evans AJ, *et al*. Intermixed normal tissue within prostate cancer: effect on MR imaging measurements of apparent diffusion coefficient and T2 – sparse versus dense cancers. Radiology, 2008, 249: 900–908.
7. Langer DL, van der Kwast TH, Evans AJ, *et al*. Prostate cancer detection with multi-parametric MRI: logistic regression analysis of quantitative T2, diffusion-weighted imaging, and dynamic contrast-enhanced MRI. J Magn Reson Imaging, 2009, 30: 327–334.
8. Knight SP, Browne JE, Meaney JFM, *et al*. Quantitative effects of acquisition duration and temporal resolution on the measurement accuracy of prostate dynamic contrast-enhanced MRI data: a phantom study. MAGMA, 2017, 30: 461–471.
9. Vos PC, Hambrock T, Hulsbergen-van de Kaa CA, Fütterer JJ, *et al*. Computerized analysis of prostate lesions in the peripheral zone using dynamic contrast enhanced MRI. Med Phys, 2008, 35: 888–899.
10. Cheikh AB, Girouin N, Colombel M, *et al*. Evaluation of T2-weighted and dynamic contrast-enhanced MRI in localizing prostate cancer before repeat biopsy. Eur Radiol, 2009, 19: 770–778.
11. McMahon CJ, Bloch BN, Lenkinski RE, *et al*. Dynamic contrast-enhanced MR imaging in the evaluation of patients with prostate cancer. Magn Reson Imaging Clin N Am, 2009, 17: 363–383.
12. Bonekamp D, Macura KJ. Dynamic contrast-enhanced magnetic resonance imaging in the evaluation of the prostate. Top Magn Reson Imaging, 2008, 19: 273–284.
13. Kim CK, Park BK, Kim B. High-b-value diffusion-weighted imaging at 3 T to detect prostate cancer: comparisons between b values of 1000 and 2000 s/mm^2. AJR Am J Roentgenol, 2010, 194: W33–W37.
14. Casciani E, Polettini E, Carmenini E, *et al*. Endorectal and dynamic contrast-enhanced MRI for detection of local recurrence after radical prostatectomy. AJR Am J Roentgenol, 2008, 190: 1187–1192.
15. Wang XY, Zhou LP, Li FY, *et al*. MR spectroscopy of prostate cancer: correlation study of metabolic characters with Gleason score. Chin J Radiol (Chinese), 2006, 40: 1181–1184.
16. Zhang P. Dynamic contrast enhanced MRI and PSA for diagnosis and differentiation of prostate cancer. J Prac Med Techniq (Chinese), 2009, 16: 168–170.
17. Shi H, Wu LB, Ding HY, *et al*. Prostate cancer: diagnostic value of dynamic contrast-enhanced MRI, diffusion weighted imaging and 3D ^{1}H-MR spectroscopy. Chin J Radiol (Chinese), 2006, 40: 678–683.
18. Wu DQ, Chen ZQ. An investigation on the feasibility of using MRS for the diagnosis of prostate diseases by comparing MRS with pathological results. Funct Mol Med Imaging (Electro Edit) (Chinese), 2016, 5: 842–847.
19. Westphalen AC, Kurhanewicz J, Cunha RMG, *et al*. T2-weighted endorectal magnetic resonance imaging of prostate cancer after external beam radiation therapy. Int Braz J Urol, 2009, 35: 171–182.
20. Fuchsjäger M, Akin O, Shukla-Dave A, *et al*. The role of MRI and MRSI in diagnosis, treatment selection, and post-treatment follow-up for prostate cancer. Clin Adv Hematol Oncol, 2009, 7: 193–202.
21. Nong SJ, Guan YB, Wang ZW, *et al*. Clinical study of IL-18 and NANOG gene polymorphisms in prostate cancer patients. Oncol Transl Med, 2018, 4: 247–254.

DOI 10.1007/s10330-020-0414-4
Cite this article as: He YK, Wang M, Deng HP, *et al*. Application of dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) combined with magnetic resonance spectroscopy (MRS) in prostate cancer diagnosis. Oncol Transl Med, 2021, 7: –.