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RESEARCH LETTER

Blood Oxygen Level Dependent Magnetic Resonance Imaging To Predict Split Renal Function Improvement After Renal Artery Stenting

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Atherosclerotic renal artery stenosis (ARAS) is the most common cause of secondary hypertension.[1] Renal artery stenting (RAS) is the first line revascularisation option with a high technical success rate, but the clinical response rate is indeterminate.[2] Blood oxygen level dependent magnetic resonance imaging (BOLD-MRI) is a non-invasive imaging technique that can assess the kidney's oxygenation.[3] It uses endogenous deoxygenated haemoglobin as a contrast agent and detects magnetic field disturbances caused by changes of oxygenated haemoglobin.[3] The R2* score correlates positively with deoxyhaemoglobin levels and can evaluate the severity of ischaemia caused by ARAS.[4,5] A normally perfused kidney has a low R2* score in the cortex and a higher R2* score in the deeper medullary region, which is consistent with the gradient of hypoxia in deep medullary regions. A low R2* score is observed if there is adequate perfusion and tissue function, but can also be seen if the kidney is non-functioning as the oxygenated blood passes through without oxygen utilisation or consumption by atrophic tissue.[3,4] High R2* appears when there is a substantial decrease in renal blood flow and the kidney remains salvageable, which is exactly the situation in which patients with ARAS may benefit from RAS. This study aimed to investigate the feasibility and accuracy of BOLD-MRI in predicting split renal function (SRF) improvement after RAS in patients with ARAS.

Patients with severe ARAS were enrolled consecutively between 1 May 2018 and 30 November 2018. Symptomatic patients were enrolled if the ARAS caused hypertension, impaired renal function, acute pulmonary oedema, or unstable angina pectoris. Patients whose renal artery stenosis was caused by non-atherosclerotic factors, with severe renal dysfunction (serum creatinine $>$ 3.0 mg/dL), or atrophied kidney (length $<$ 7 cm) were excluded.

For the patients with severe stenoses or occlusions, RAS was performed. All BOLD-MRI examinations were performed with a MAGNETOM Aera 1.5T MR scanner (Siemens Healthcare GmbH, Erlangen, Germany). Four regions of interest were traced: one on the cortex and three on the upper, middle, and lower poles of the medulla (Fig. 1A). The T2* values of the BOLD-MRI images were measured and converted into R2* values according to the formula: $R2^* = 1/T2^*$. Clinical follow up visits were scheduled one month after discharge from the outpatient department. SRF was evaluated by nuclear renal dynamic imaging at baseline and follow up. Change of glomerular filtration rate (GFR) was defined as the difference between the GFR taken at the one month follow up and the baseline GFR. SRF improvement of the affected kidney was defined when the change in GFR was $\geq$ 15% of the baseline GFR. The antihypertensive drugs were not altered after RAS.

Pearson correlation coefficient was used to evaluate the correlation between R2* and change of GFR. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the performance of baseline cortical and medullary R2*. The area under the curve (AUC) was used to evaluate the overall accuracy.

Thirty patients with ARAS were included in this study and nine patients had bilateral lesions. The average age was 64 $\pm$ 9 years, and 73% of patients were male. All patients suffered from high blood pressure. Overall, 35 renal arteries were treated successfully with stents. Four renal artery occlusions were not treated successfully.

All patients completed a one month clinical follow up. The average systolic and diastolic blood pressure decreased (systolic: 161 $\pm$ 20 mmHg *vs.* 133 $\pm$ 11 mmHg, diastolic: 88 $\pm$ 12 mmHg *vs.* 78 $\pm$ 9 mmHg, both $p < .001$). No instent restenosis was found. The estimated GFR value was calculated for each patient. The average eGFR was 52.64 $\pm$ 18.72 mL/min/1.73 m^2 at baseline and 53.39 $\pm$ 17.16 mL/min/1.73 m^2 at one month follow up. One patient did not complete the nuclear renal dynamic imaging. SRF improvement occurred in 19/34 of the stented kidneys in 17/29 of patients. There was a moderate

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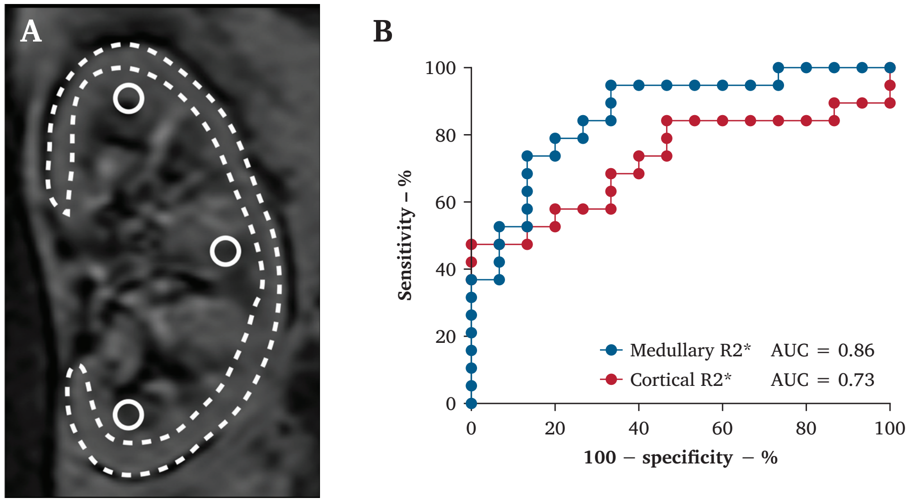

Figure 1. (A) Four regions of interests (ROIs) were traced in blood oxygen level dependent magnetic resonance imaging of kidney: one ROI of the cortex was placed on the outline of the long and narrow area of the renal cortex, excluding the renal medulla, collecting system, incidental cysts, and hilar vessels; while the other three ROIs of the medulla were placed in circular areas on the upper, middle, and lower poles of the renal medulla, with a diameter of about 3 mm. (B) The receiver operating characteristic curve of cortical R2* score and medullary R2* score in predicting split renal function improvement after renal artery stenting. AUC = area under the curve.

positive correlation between the GFR change and baseline cortical R2* value ($r = 0.67$; $p < .001$) and medullary R2* value ($r = 0.48$; $p = .004$). The baseline cortical and medullary R2* in the SRF improvement group (14 ± 2 s^{-1} and 29 ± 3 s^{-1}, respectively) were higher (both $p < .001$) than those in the non-improvement group (12 ± 1 s^{-1} and 25 ± 3 s^{-1}, respectively). For patients with SRF improvement, the serum creatinine level did not decrease ($p = .340$). The ROC curves of cortical R2* and medullary R2* are shown in Fig. 1B. The AUC of medullary R2* was 0.86 (95% CI 0.74 − 0.99), which was larger than that of cortical R2* (0.73, 95% CI 0.55 − 0.90), indicating that medullary R2* was more accurate and may be a better predictor. The cutoff value of baseline medullary R2* was 23.7 s^{-1}, the sensitivity was 0.95 (95% CI 0.74 − 1.00), and the specificity was 0.67 (95% CI 0.38 − 0.88).

The limitations of the present study included small sample size, limited follow up time, and single centre experience.

BOLD-MRI may identify patients with severe ARAS whose SRF could benefit from RAS. This study found that medullary R2* $\geq$ 23.7 s^{-1} had good sensitivity and moderate specificity, making this a promising predictor of SRF improvement after RAS.

CONFLICT OF INTEREST

None.

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