MEASUREMENT OF RENAL CORTICAL THICKNESS USING NON-CONTRAST-ENHANCED STEADY-STATE FREE PRECESSION (SSFP) MRI WITH SPATIALLY SELECTIVE IR PULSE: ASSOCIATION WITH RENAL FUNCTION

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Purpose: Early detection and diagnosis of chronic kidney disease (CKD) is particularly important because early treatment may not only prevent the progress to end-stage renal disease (ESRD), but also lead to the possibility of the remission of CKD. Renal cortical thickness reportedly correlated with renal function, however, few imaging studies have been conducted to evaluate this correlation. This is primarily because there is less than distinct corticomedullary differentiation in non-contrast-enhanced imaging studies including MRI in patients with renal insufficiency. The purposes of this study were to assess whether noncontrast-enhanced steady-state free precession (SSFP) MRI with a spatially selective IR pulse can improve the visibility of renal corticomedullary differentiation to measure renal cortical thickness in patients showing renal dysfunction, and to investigate the correlation between renal cortical thickness and estimated glomerular filtration rate (eGFR) by depicting renal corticomedullary differentiation using SSFP MRI with a spatially selective IR pulse.

Materials and Methods: This study included a total of 65 patients with or without CKD (39 men, 26 women; range, 28-85 years) who underwent abdominal MRI including non-contrast-enhanced SSFP sequences with spatially selective IR pulse. No patients had any histories of chronic liver disease, hypertension, or other vascular diseases, and had ipsilaterally atrophic kidney. Patients were referred for MRI examinations for further evaluation of CKD or the screening of benign abdominal diseases. eGFR was measured in all patients. All patients underwent non-contrast-enhanced SSFP MRI with spatially selective IR pulse. Imaging parameters were as follows: TR/TE=4.2/2.1 ms; number of acquisitions = 1; flip angle = 90°; slice thickness = 7 mm; field-of-view = 400 × 400 mm^2; and acquisition matrix = 256 × 256. A series of topographically identical SSFP sequences with a spatially selective IR pulse were performed using various inversion times (TI) (700, 800, 900, 1000, 1100, 1200, 1300, 1400 and 1500 ms) to determine the optimal TI to best visualize renal corticomedullary differentiation which showed serial signal changes according to TI. Signal intensity (SI) of the renal cortex and medulla were measured using the region-of-interest (ROI) to calculate the renal corticomedullary contrast ratio (SI cortex/SI medulla). Next, optimal TI values for best visualization of corticomedullary differentiation were determined based on a series of SSFP images with variable TI. In addition, using the optimal TI, minimal renal cortical thickness were measured. In-phase (IP) T1-weighted gradient-echo MR images were obtained during a respiratory suspension to compare the visibility of corticomedullary differentiation as well as the corticomedullary contrast ratio of SSFP MR images with a spatially selective IR pulse. Additionally, the visibility of the corticomedullary differentiation was also compared qualitatively between optimal SSFP images and IP images using a following 4-point scale (1 = poor; 2 = fair; 3 = good; 4 = excellent). For statistical analysis, Spearman's correlation test, Kruskal-Wallis test, and Mann-Whitney test were used.

Result: Mean eGFR of all patients was 79.7 mL/min/1.73 m^2 (range, 36.1-125.9). Based on eGFR, patients were divided into 3 groups as follows: Group 1, eGFR <60 mL/min/1.73 m^2 (n=16); Group 2, eGFR = 60-90 mL/min/1.73 m^2 (n=35); and Group 3, eGFR >90 mL/min/1.73 m^2 (n= 14). Mean corticomedullary contrast ratio was significantly higher in SSFP images with optimal TI than in IP images in all 3 groups (Group 1, 4.51±1.34 vs. 1.37 ± 0.14; Group 2, 5.06 ± 1.43 vs. 1.37 ± 0.18; Group 3, 6.01 ± 1.84 vs. 1.50 ± 0.12) ($P < 0.001$, $P < 0.001$, $P = 0.001$, respectively). Additionally, the visibility of corticomedullary differentiation was significantly better in SSFP images with optimal TI than in IP images in all 3 groups (averaged grade in Group1, 4.0 versus 1.7; Group2, 4.0 versus 2.4; Group3, 4.0 versus 2.4) ($p<0.001$, $p <0.001$, $p=0.001$, respectively), indicating that SSFP images with optimal TI can visualize corticomedullary junction even in patients with decreased eGFR. Regarding the relationship between corticomedullary contrast ratio and eGFR, a positive correlation was seen between corticomedullary contrast ratio in SSFP images with optimal TI and eGFR ($p= 0.011$, $r= 0.314$). Mean minimal renal cortical thickness measured on SSFP images with optimal TI was 4.7 mm (range, 1.9-7.8). A significantly positive correlation was observed between minimal renal cortical thickness and eGFR ($p<0.01$, $r=0.495$), showing decreased renal cortical thickness according to the decline of eGFR. Mean minimal renal cortical thickness was 3.99 ±1.55 mm in Group 1, 4.63 ± 1.00 mm in Group 2, and 5.59 ± 1.08 mm in Group 3, respectively. Among the 3 eGFR groups, a significant difference was seen in minimal renal cortical thickness measured on SSFP images ($P= 0.02$). In the comparison between the groups, significant differences were seen between Group1 and Group3 ($p= 0.001$), and between Group2 and Group3 ($p= 0.036$). These facts suggested that measurement of minimal renal cortical thickness will be an important indicator for the assessment of renal function.

Conclusion: Noncontrast-enhanced SSFP MRI with a spatially selective IR pulse using optimal TI can improve the visibility of renal corticomedullary differentiation even in patients with renal insufficiency. The decrease in renal cortical thickness measured using this technique correlated significantly with eGFR as a marker of renal function.

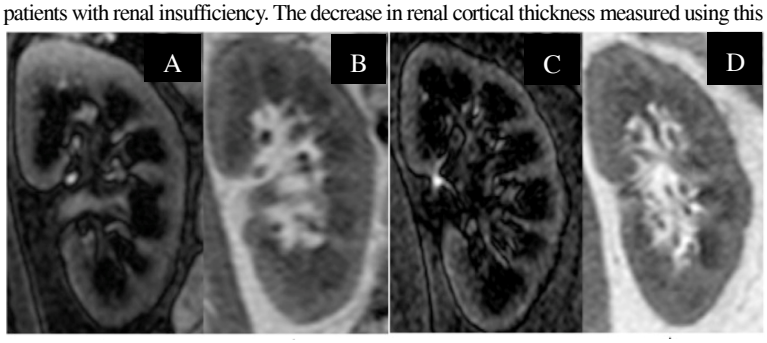

Figure1.
(A) SSFP image and (B) IP image in a patient in Group 3 (normal eGFR group; eGFR= 109.8 mL/min/1.73 m^2). (C) SSFP image and (D) IP image in a patient in Group 1 (decreased eGFR group; eGFR= 48.2 mL/min/1.73 m^2).

Renal corticomedullary differentiation was unclear in an IP image. Additionally, Minimal renal cortical thickness measured on SSFP image in a patient in Group 1 (4.5 mm) was thinner than that in a patient in Group 3 (6.7 mm).