

ADC Measurement of Abdominal Organs and Lesions using Parallel Imaging Technique

T. Yoshikawa¹, H. Kawamitsu¹, D. G. Mitchell², Y. Ohno¹, K. Kubo¹, M. Fujii¹, K. Sugimura¹

¹Department of Radiology, Kobe University Graduate School of Medicine, Kobe, Hyogo, Japan, ²Department of Radiology, Division of Magnetic Resonance Imaging, Thomas Jefferson University, Philadelphia, PA, United States

BACKGROUND. Diffusion-weighted MR imaging (DWI) and apparent diffusion coefficient (ADC) measurement have been applied in the abdomen and have reported to be useful. However, blurring and susceptibility artifacts diminish the image quality and reliability of the values. Parallel imaging can reduce readout time, improving image quality. However, signal intensity and SNR on the image can change depending on the location in section plane. Only one report described the reliability of ADC using parallel imaging, restricted to the right hepatic lobe in young healthy volunteers. Systematic study using phantoms to evaluate changes of ADCs related to parallel imaging factor and location relative to coil geometry has not been described.

OBJECTIVE. To assess the reliability and usefulness of parallel imaging for ADC measurement of abdominal organs and lesions.

SUBJECTS AND METHODS. Single-shot spin-echo echo-planar diffusion-weighted MRI (DWI) (TE=66, **Table 1.** ADCs of Water ($\times 10^{-3}$ mm²/sec, at 24 °C)

b=0, 600 sec/mm²) was performed in phantom and clinical studies. Bottle phantoms were scanned with various parallel imaging factors and at various positions to evaluate the effects of parallel imaging on ADCs. In 200 consecutive clinical patients (122 men and 78 women: mean age 61.9 years) ADCs were calculated for liver (four segments), spleen, pancreas (head, body, tail), gallbladder, renal parenchyma, back muscle and compared to evaluate the reliability of clinical ADC measurements with parallel imaging. ADCs were also calculated for diffuse diseases and focal lesions (96 malignant and 88 benign) of abdominal organs to evaluate the clinical usefulness.

RESULTS. Location-dependent changes in water ADCs were minimal with parallel imaging factors first of 3 and then of 4, and were small except for measurements at the image periphery (Table 1). Acetone ADCs were saturated at 4.00×10^{-3} mm²/sec. Degraded image quality prevented ADC measurement of the left hepatic lobe and pancreas in 7 - 18 patients (Table 2). There was no significant difference among ADCs of four liver segments and between ADCs of right and left kidney. ADC of pancreas tail was significantly lower than those of head and body (p < 0.005). Renal ADCs were significantly lower in patients with renal failure than those without disease (p < 0.005). ADC of pancreatic cancer was significantly higher than that of normal pancreas (p < 0.05) (Table 3). ADC of renal angiomyolipoma was significantly lower than those of renal cell carcinoma and normal renal parenchyma (p < 0.0005).

CONCLUSION. Clinical ADC measurements of abdominal organs and lesions using parallel imaging appear to be reliable and useful, and the effect of parallel imaging on calculated values is considered to be minimal. Problems still remain in measurement at left lobe of the liver and pancreas. Measurement at periphery of the image should be avoided.

Table 2: ADCs of Lesions ($\times 10^{-3}$ mm²/sec)

| Organs | Overall | Without disease | With disease | | Measurement failure due to poor image quality |
|------------------|-----------------------|-----------------------|-----------------------|--------------------------------|---|
| Liver | | | Chronic hepatitis | Cirrhosis | |
| Rt. Post. Seg, | 1.52 ± 0.28 (n = 197) | 1.55 ± 0.30 (n = 74) | 1.50 ± 0.14 (n = 21) | 1.45 ± 0.13 (n = 17) | 1 |
| Rt. Ant. Seg, | 1.50 ± 0.24 (n = 192) | 1.55 ± 0.17 (n = 69) | 1.46 ± 0.13 (n = 21) | 1.47 ± 0.12 (n = 17) | 1 |
| Lt. Med. Seg, | 1.56 ± 0.28 (n = 162) | 1.61 ± 0.21 (n = 51) | 1.60 ± 0.28 (n = 19) | 1.60 ± 0.19 (n = 16) | 7 |
| Lt. Lat. Seg, | 1.56 ± 0.31 (n = 149) | 1.63 ± 0.31 (n = 45) | 1.60 ± 0.36 (n = 18) | 1.53 ± 0.21 (n = 15) | 18 |
| Pancreas | | | Chronic pancreatitis | Acute pancreatitis | |
| Head | 1.81 ± 0.40 (n = 174) | 1.82 ± 0.40 (n = 131) | 1.71 ± 0.20 (n = 3) | 1.88 ± 0.25 (n = 3) | 16 |
| Body | 1.81 ± 0.41 (n = 167) | 1.81 ± 0.41 (n = 124) | 1.67 ± 0.17 (n = 3) | 1.57 ± 0.10 (n = 3) | 16 |
| Tail | 1.65 ± 0.37 (n = 171) | 1.65 ± 0.34 (n = 129) | 1.58 ± 0.39 (n = 3) | 1.56 ± 0.18 (n = 3) | 10 |
| Spleen | 1.26 ± 0.23 (n = 185) | | | | 0 |
| Gallbladder | 3.50 ± 0.51 (n = 151) | | | | 0 |
| Renal parenchyma | | | Chronic renal failure | Hydronephrosis, ureteral stone | |
| Rt. | 2.65 ± 0.30 (n = 193) | 2.67 ± 0.29 (n = 145) | 2.15 ± 0.30 (n = 5) | 2.68 ± 0.08 (n = 2) | 1 |
| Lt. | 2.59 ± 0.33 (n = 191) | 2.60 ± 0.32 (n = 144) | 2.11 ± 0.25 (n = 5) | 2.49 ± 0.15 (n = 5) | 1 |
| Back muscle | 2.13 ± 0.25 (n = 198) | | | | 1 |

| Parallel Imaging (Factor) | Center of the image | Adjacent to the receiver coils | Intermediate position | Periphery of the image |
|---------------------------|---------------------|--------------------------------|-----------------------|------------------------|
| None | 2.48 ± 0.00 | 2.60 ± 0.01 | 2.50 ± 0.00 | 2.72 ± 0.08 |
| 1.0 | 2.50 ± 0.01 | 2.56 ± 0.01 | 2.50 ± 0.01 | 2.66 ± 0.03 |
| 2.0 | 2.53 ± 0.00 | 2.54 ± 0.00 | 2.56 ± 0.00 | 2.62 ± 0.02 |
| 3.0 | 2.51 ± 0.00 | 2.53 ± 0.01 | 2.54 ± 0.00 | 2.53 ± 0.02 |
| 4.0 | 2.50 ± 0.01 | 2.52 ± 0.00 | 2.52 ± 0.00 | 2.56 ± 0.04 |

Table 3. ADCs of Abdominal Organs and Focal Lesions ($\times 10^{-3}$ mm²/sec)

| Organs | Lesion type | ADC |
|--------------------|---|-------------|
| Liver | Primary cancer (n = 28) | 1.60 ± 0.37 |
| | Secondary cancer (n = 26) | 1.51 ± 0.35 |
| | Hemangioma (n = 19) | 2.28 ± 0.67 |
| | Cyst (n = 13) | 3.81 ± 0.43 |
| | Overall liver parenchyma (n = 700) | 1.53 ± 0.28 |
| Pancreas | Primary cancer (n = 5) | 2.32 ± 0.26 |
| | Simple cyst (n = 3) | 3.96 ± 0.14 |
| | Pseudocyst (n = 3) | 3.60 ± 0.69 |
| | Overall pancreatic parenchyma (n = 512) | 1.76 ± 0.40 |
| Kidney | Renal cell carcinoma (n = 12) | 2.49 ± 0.72 |
| | Angiomyolipoma (n = 8) | 1.81 ± 0.41 |
| | Cyst (n = 42) | 3.82 ± 0.39 |
| | Complicated cyst (n = 5) | 2.78 ± 0.71 |
| | Overall renal parenchyma (n = 384) | 2.62 ± 0.32 |
| Stomach, intestine | Primary cancer (n = 6) | 2.31 ± 0.53 |
| Lymph node | Metastasis (n = 17) | 1.56 ± 0.27 |