

Diffusion-weighted imaging in normal pancreas: Apparent diffusion coefficient test-retest repeatability

Shiyue Chen

Changhai Hospital of Shanghai

Ri Liu

Changhai Hospital of Shanghai

Chao Ma (✉ mengqihi@gmail.com)

Changhai hospital of Shanghai <https://orcid.org/0000-0002-2473-387X>

Yun Bian

Changhai Hospital of Shanghai

Jing Li

Changhai Hospital of Shanghai

Panpan Yang

Changhai Hospital of Shanghai

Minjie Wang

Changhai Hospital of Shanghai

Jianping Lu

Changhai Hospital of Shanghai

Research article

Keywords: Magnetic resonance imaging; Pancreas; DWI; ADC; Repeatability

Posted Date: August 19th, 2019

DOI: <https://doi.org/10.21203/rs.2.13164/v1>

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Abstract

Background The assessment of apparent diffusion coefficient (ADC) repeatability is important to body diffusion weighted imaging (DWI). However, data onto evaluating the repeatability of ADC values for normal pancreas are limited. The aim of this study was to evaluate the ADC test-retest repeatability of the normal pancreas. **Methods** Twenty-six healthy volunteers (mean 47.6 years; 13 men) were included and scanned twice with reposition using a DWI sequence at 3.0-T. ADCs of the pancreatic head, body and tail for two DWIs were measured by two readers. The mean ADCs of the pancreatic head, body and tail were calculated as the global pancreatic ADC. Test-retest repeatability and agreement of ADC measurement were evaluated by the Bland-Altman analysis, intra-class correlation coefficient (ICC) and coefficient of variation (CV). **Results** The global pancreatic ADC showed the best test-retest repeatability (mean difference \pm limits of agreement were $0.05 \pm 0.25 \times 10^{-3} \text{ mm}^2/\text{s}$; ICC, 0.79; CV, 6%). Test-retest repeatabilities for ADC of pancreatic head, body or tail were scattered, with mean difference \pm limits of agreement between two tests were 0.03 ± 0.47 , 0.05 ± 0.42 and 0.06 ± 0.31 ($\times 10^{-3} \text{ mm}^2/\text{s}$), respectively (ICCs, 0.81, 0.52 and 0.68; CVs, 9%, 8% and 8%). Both intra-observer repeatability and inter-observer reproducibility were acceptable for whole pancreas between ADC measurements of the two DWIs. **Conclusions** ADC values of the pancreas are technically challenging and repeatability is variable. Cautions should be taken when interpreting longitudinal clinical changes in ADC values of the normal pancreas because the measurements do have an inherent variability by locations.

Background

Magnetic resonance imaging (MRI) is an important tool for the diagnosis and evaluation of many abdominal diseases with quantitative and qualitative methods. For the imaging of pancreas, MRI is widely used to detect and to differentiate pancreatic diseases [1]. Specifically, as a quantitative MRI technology, diffusion weighted imaging (DWI) with derived apparent diffusion coefficient (ADC) was introduced to quantify water diffusion in vivo [2]. With a quasi-exponential growth of research applications as well as clinical practice, DWI provides an additional information on the pancreas as a supplement to conventional techniques such as T1/T2- weighted imaging [3].

As a biomarker, ADC is helpful in the characterization of pancreatic diseases including chronic pancreatitis, cystic and solid pancreatic tumors [2]. Some previous studies have reported that pancreatic cancer had lower mean ADC value than the normal pancreas [4–11]. Ideally, changes in ADC value should principally reflect the composition and/or cellularity of tissue, whilst at the same time not being susceptible to variations associated with measurement repeatability. Therefore, in order to detect meaningful difference in ADC, it is desirable that the uncertainty of the ADC measurement should be lower than the difference between the normal and abnormal pancreatic tissues.

It is actually an important point to assess ADC repeatability in body DWI [2]. Data on evaluating the repeatability of ADC for normal pancreas are limited: one study only reported the mean coefficient of variations (CV) of 10.6% for ADC in the normal pancreatic body at 3.0-T [12]. As most of the studies have

used normal pancreas as control group when comparing ADC in different pancreatic entities, the ADC test-retest repeatability in the normal pancreas was few reported, especially for different anatomical regions of the pancreas. To better to understand the magnitude in change of ADC and obtain useful metrics for ADC, the aim of this study was to investigate the ADC test-retest repeatability in the normal pancreas.

Methods

Clinical Study

This prospective study was approved by our ethics review board. Before MRI examination, informed consents were signed by the volunteers. Twenty-six volunteers (mean age 47.6 ± 10.5 years; range 24–67 years; 13 men, 13 women) were enrolled in the study at January 6 and 7, 2018. Exclusion criteria were set as subjects with pancreatic disease, diabetes, hepatic cirrhosis history and any contraindication of MRI examination.

MR imaging

Volunteers underwent MRI examinations at 3.0-T (MR 750, GE Healthcare, Milwaukee, USA) with 32-element coil used for signal reception. MRI images were acquired with pancreas MRI protocol and two fat saturated axial free breathing DWIs (b-values = 50, 800 s/mm²). A single shot echo-planar-imaging sequence used for DWI weighted with 3 orthogonal gradient directions. The first DWI was acquired after the positioning of the examination and the second one was acquired with repositioning of the volunteers with a new localizer after getting the participant out and back in. Six hours fasting were required before MRI examination for all the volunteers. A median delay between two DWIs was about 10 minutes. The main parameters of DWI were: repetition time/echo time (TR/TE), 4000/76 ms; matrix size, 132×128; field of view (FOV), 380×304 mm²; number of excitations (NEX), 1 and 4 for b₅₀ and b₈₀₀, respectively; slice thickness/gap, 6.0/1.0 mm; number of slices, 26; acceleration factor, 2.0; bandwidth, 250 kHz.

Data analysis

Two radiologists issued the diagnostic reports of MRI examination for all volunteer and did not find any abnormalities of the pancreas. The head, body and tail regions of the pancreas [13] were clearly displayed on the DW images in all subjects.

To evaluate the variability, two observers (both with over 8 years experience in radiology) measured the ADCs of pancreatic head, body and tail for the two DWIs. One of the observers (as observer 1) measured ADCs again with an interval of four weeks for the two DWIs. Mean ADC values were obtained from an oval or round region of interest (ROI, *Figure 1*) on the ADC maps. The area of ROI was between 31–119 mm² (mean 71.6 mm²). Vessels, ducts and common bile duct were avoided with reference to T2WI/T1WI

in the measurements of ADC. The mean ADC values of the pancreatic head, body and tail was calculated as the global pancreatic ADC.

Statistical analysis

Statistical analyses were performed using MedCalc, version 13.0.0.0 (MedCalc Software, Ostend, Belgium). Intra-/inter-observer variability and test-retest repeatability of ADC measurements for each anatomical region of the pancreas and whole pancreas were analyzed by Bland-Altman analysis [14], CV and intra-class correlation coefficient (ICC: 0–20 = poor correlation, etc) [15]. The first ADC measurements of observer 1 were used for the calculation of inter-observer variability. The mean ADC value of the twice measurements of observer 1 was used for the further analyses. The CVs were calculated by the standard deviation and mean ADC values of the two DWIs (test and retest DWIs) for pancreatic head, body, tail and whole pancreas, respectively. ADC values between test-retest DWIs were compared by paired sample t-test. Comparisons of the mean ADCs among three anatomical regions of the pancreas were performed by using one way analysis of variance (ANOVA) and post-hoc analyses.

Results

The typical images of test-retest DWIs and ADC measurements were demonstrated in Figure 1. The mean ADC values of different regions and the whole pancreas for the two DWIs were summarized and shown in Table 1.

Intra-observer variability of ADC

For the first DWI, the bias and limits of agreement (LOAs) between two ADC measurements were $0.02 [-0.16-0.20] \times 10^{-3} \text{ mm}^2/\text{s}$ for pancreatic head (ICC, 0.97), $-0.08 [-0.47 - 0.30] \times 10^{-3} \text{ mm}^2/\text{s}$ for pancreatic body (ICCs, 0.71), $0.02 [-0.21 - 0.18] \times 10^{-3} \text{ mm}^2/\text{s}$ for pancreatic tail (ICC, 0.85) and $-0.03 [-0.21 - 0.15] \times 10^{-3} \text{ mm}^2/\text{s}$ for the whole pancreas (ICC, 0.89). The mean ADCs in pancreatic body were more scattered than the other 3 groups. The mean CVs for the twice ADC measurements were between 3%–7% for the 4 groups. ANOVA results showed that the mean ADCs of different anatomical regions were different ($P < 0.05$). Post hoc analyses results demonstrated ADC were higher in pancreatic body than that in pancreatic tail ($P = 0.035$). Graphic illustrations of Bland-Altman analyses were shown in Figure 2. For the reposition DWI, similar results were also found as the first DWI.

Inter-observer variability of ADC

For the first DWI, the bias and LOAs between ADC measurements of two observers were $0.07 [-0.50 - 0.63] \times 10^{-3} \text{ mm}^2/\text{s}$ for pancreatic head (ICC, 0.58), $-0.08 [-0.35 - 0.52] \times 10^{-3} \text{ mm}^2/\text{s}$ for pancreatic body (ICCs, 0.55), $0.03 [-0.34 - 0.27] \times 10^{-3} \text{ mm}^2/\text{s}$ for pancreatic tail (ICC, 0.57) and $-0.04 [-0.26 - 0.34] \times 10^{-3}$

mm²/s for the whole pancreas (ICC, 0.63). The ADC of whole pancreas had the best reproducibility among the 4 groups. The mean CVs for the ADC measurements of two observers were between 5%–9% for the 4 groups. Graphic illustrations of Bland-Altman analyses were shown in Figure 3. Similar results were also found in the reposition DWI.

Test-retest repeatability

For the test-retest DWIs, the bias and LOAs between two ADC measurements of two DWIs were 0.03 [–0.44 - 0.50] ×10⁻³ mm²/s for pancreatic head (ICC, 0.81), 0.05 [–0.37 - 0.47] ×10⁻³ mm²/s for pancreatic body (ICCs, 0.52), 0.06 [–0.24 - 0.37] ×10⁻³ mm²/s for pancreatic tail (ICC, 0.68) and 0.05 [–0.20 - 0.30] ×10⁻³ mm²/s for the whole pancreas (ICC, 0.79). The mean CVs for the ADC measurements of two DWIs were between 6%–9% for the 4 groups. ADC of pancreatic tail was lower in the reposition DWI (P = 0.045). There were no significant differences in ADCs between two DWIs at head, body or whole pancreas. Figure 4 showed the Bland-Altman analyses results.

Discussion

Our study demonstrated that ADCs of the normal pancreas and test-retest repeatability were dependent on the different anatomical regions of pancreas. Only the repeatability of mean ADC of whole pancreas were acceptable, because the test-retest bias of ADC measurements less than ± 0.10×10⁻³ mm²/s and the LOAs were less than ± 0.30×10⁻³ mm²/s [16]. The standardization of ADC measurement methods of pancreas is important to the healthy subjects as the control group in studies. The results of current study effectively recommend that caution should be taken when interpreting longitudinal clinical changes in ADC values of the pancreas because the measurements do have an inherent variability by location.

As a biomarker, the evaluation of repeatability in ADC measurements is important to diagnose diseases or to detect meaningful change in treatment. ADC repeatability has already been evaluated over time for breast [17], lung [18,19] and liver [20,21], but only few studies have evaluated the test-retest ADC repeatability in the pancreas. Rosenkrantz *et al* found that test-retest ADC repeatability was moderate in normal pancreatic body both at 1.5-T and 3.0-T [12]. However, the test-retest ADC repeatability was not acceptable to three anatomical regions of pancreas in our study. The inconsistent findings between two studies may be caused by the parameters differences in DWI, specifically in b values. In our study, two b values were used for DWI, and the choosing of the b values is according to the recommendation of ISMRM-Sponsored workshop [22]. Other two studies[23,24] reported that there was no significant effect of MRI systems on ADCs reproducibility of normal pancreas (including head, body and tail) over a short-term of normal pancreas at 1.5-T and 3.0-T for a given individual, respectively. Barral, et al [25] investigated the reproducibility and variations in ADCs for normal pancreas using repeated measurements method both at 1.5- and 3.0-Tesla, and found that intra- and inter-observer ADC measurements were acceptable and ADCs in different segments of pancreas were homogeneous at 3.0-Tesla. In the current study, we also evaluated the intra-/inter-observer variability of ADC measurements of

there regions of normal pancreas at 3.0-T, as well as the whole pancreas on ADC measurements for test-retest DWIs. However, the intra-observer repeatability of mean ADCs in pancreatic body was not acceptable. We also found that the ADC values were the lowest in the pancreatic tail, which was similar as being showed in some studies [26,27]. In addition to the features of tissues, DWI acquisition parameters, including field strength, b-values selection, respiratory compensation acquisition, and post-processing approach may influence the ADCs of pancreas [28]. The inconsistent findings in our study might be the differences in b-values and field strength. Additionally, the free-breathing technique used in our study might have some effects on the findings. The finding of a significantly lower ADC in the pancreatic tail in the second ADC measurement compared to the first one may be due to the effects of these factors. To limit the possible influence of field heterogeneity, b values and acquisition methods on the ADC measurements, a normalized ADC method is a promising tool [29–31]. An average value of 3 delineations will be more robust than the three small delineations. One of the main reasons why we investigated the global pancreatic ADC value is to consider the possible effect of the gradient nonlinearity (GNL) on the pancreatic ADC, because the pancreas is about 15 cms long in the abdominal cavity behind the stomach. Previous multi-scanner quality control studies have demonstrated that significant ADC errors (ranging from +25% to –50%) were detected away from the magnet isocenter for many systems [32–34].

Our study had some limitations. First, we included a relatively small number of volunteers. A larger sample is needed to confirm the findings. Secondly, all MRI exams were performed on a 3.0-T scanner within two days, this ideal experimental scheme might be difficult to achieve in daily work. Third, as GNL of MRI system causes the spatial nonuniformity to ADCs [34] and this fact may have an impact on the findings. Fourth, a relatively low b values (50 and 800 s/mm²) was used to reduce motion artifacts and to keep good signal-to-noise ratio in DWI, but DWI with higher b values might improve the pancreatic tumor delineation [35]. Furthermore, only two b-values were used in the study to reduce examination time, although multiple-b-values DWI might be more accurate to the calculation of ADCs. Finally, the effects of field strength and different b-value selection on ADC measurements of pancreas were not evaluated, which may affect the results.

Conclusions

This study demonstrated that the ADC measurements of the pancreas are technically challenging and repeatability is variable. Cautions should be taken when interpreting longitudinal clinical changes in ADC values of the normal pancreas because the measurements do have an inherent variability by location.

List Of Abbreviations

MRI: Magnetic resonance imaging; DWI: Diffusion-weighted imaging; ADC: Apparent diffusion coefficient; CV: Coefficient of variation; TR: Repetition time; TE: Echo time; FOV: Field of view; NEX: Number of excitations; ICC: Intra-class correlation coefficient; ANOVA: Analysis of variance; B_A: Bland Altman.

Declarations

- Ethics approval and consent to participate

This study was approved by our Institutional Review Board (Changhai Hospital Ethics committee). Signed written informed consent was obtained from all participants prior to the imaging.

- Consent for publication

Signed written informed consent was obtained from all participants to publish individual data.

- Availability of data and materials

Please contact author for data requests.

- Competing interests

The authors declare that they have no competing interests.

- Funding

This work was supported by the Key junior college of national clinical of China; National Natural Science Foundation of China (81601468, 81701689); Project of precision medical transformation application of SMMU (2017JZ42); Science and Technology Innovation Foundation of Shanghai (17411952200).

- Authors' contributions

Chen S, Liu R, Ma C, Li J, Wang M, and Lu J performed the majority of experiments, made substantial contributions to the data analysis and interpretation, and wrote the manuscript draft; Bian Y, participated in the design of the study and made substantial contribution to data analysis; Ma C and Lu J made substantial contributions to the study conception and design, critically revised the manuscript draft for important intellectual content, and gave final approval of the version to be published; all the authors read and approved the final manuscript.

- Acknowledgements

Not applicable

References

1. Muniraj T, Jamidar PA, Aslanian HR. Pancreatic cancer: a comprehensive review and update. *Dis Mon* 2013;59:368–402.
2. Barral M, Taouli B, Guiu B, Koh DM, Luciani A, Manfredi R, et al. Diffusion-weighted MR imaging of the pancreas: current status and recommendations. *Radiology* 2015;274:45–63.
3. Iima M, Le Bihan D. Clinical Intravoxel Incoherent Motion and Diffusion MR Imaging: Past, Present, and Future. *Radiology* 2016;278:13–32.

4. Fukukura Y, Takumi K, Kamimura K, Shindo T, Kumagae Y, Tateyama A, et al. Pancreatic adenocarcinoma: variability of diffusion-weighted MR imaging findings. *Radiology* 2012;263:732–740.
5. Legrand L, Duchatelle V, Molinié V, Boulay-Coletta I, Sibilleau E, Zins M. Pancreatic adenocarcinoma: MRI conspicuity and pathologic correlations. *Abdom Imaging* 2015;40:85–94.
6. Wang Y, Chen ZE, Nikolaidis P, McCarthy RJ, Merrick L, Sternick LA, et al. Diffusion-weighted magnetic resonance imaging of pancreatic adenocarcinomas: association with histopathology and tumor grade. *J Magn Reson Imaging* 2011;33: 136–42.
7. Lee SS, Byun JH, Park BJ, Park SH, Kim N, Park B, et al. Quantitative analysis of diffusion-weighted magnetic resonance imaging of the pancreas: usefulness in characterizing solid pancreatic masses. *J Magn Reson Imaging* 2008;28:928–36.
8. Rosenkrantz AB, Matza BW, Sabach A, Hajdu CH, Hindman N. Pancreatic cancer: Lack of association between apparent diffusion coefficient values and adverse pathological features. *Clin Radiol* 2013;68:e191–7.
9. Kamisawa T, Takuma K, Anjiki H, Egawa N, Hata T, Kurata M, et al. Differentiation of autoimmune pancreatitis from pancreatic cancer by diffusion-weighted MRI. *Am J Gastroenterol* 2010;105:1870–5.
10. Muraoka N, Uematsu H, Kimura H, Imamura Y, Fujiwara Y, Murakami M, et al. Apparent diffusion coefficient in pancreatic cancer: characterization and histopathological correlations. *J Magn Reson Imaging* 2008;27:1302–8.
11. Fattahi R, Balci NC, Perman WH, Hsueh EC, Alkaade S, Havlioglu N, Burton FR. Pancreatic diffusion-weighted imaging (DWI): comparison between mass-forming focal pancreatitis (FP), pancreatic cancer (PC), and normal pancreas. *J Magn Reson Imaging* 2009;29:350–6.
12. Rosenkrantz AB, Oei M, Babb JS, Niver BE, Taouli B. Diffusion-Weighted Imaging of the Abdomen at 3.0 Tesla: Image Quality and Apparent Diffusion Coefficient Reproducibility Compared With 1.5 Tesla. *J Magn Reson Imaging* 2011;33:128–35.
13. Ma C, Liu L, Li YJ, Chen LG, Pan CS, Zhang Y, et al. Intravoxel incoherent motion MRI of the healthy pancreas: Monoexponential and biexponential apparent diffusion parameters of the normal head, body and tail. *J Magn Reson Imaging* 2015;41:1236–41.
14. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;1:307–310.
15. Cohen J. Weighted kappa: nominal scale agreement with provision for scaled disagreement or partial credit. *Psychol Bull* 1968;70:213–220.
16. Ma C, Liu L, Li J, Wang L, Chen LG, Zhang Y, et al. Apparent diffusion coefficient (ADC) measurements in pancreatic adenocarcinoma: A preliminary study of the effect of region of interest on ADC values and interobserver variability. *J Magn Reson Imaging* 2016;43:407–13.
17. Sorace AG, Wu C, Barnes SL, Jarrett AM, Avery S, Patt D, et al. Repeatability, reproducibility, and accuracy of quantitative mri of the breast in the community radiology setting. *J Magn Reson*

Imaging 2018 Mar 23. DOI: 10.1002/jmri.26011.

18. Weller A, Papoutsaki MV, Waterton JC, Chiti A, Stroobants S, Kuijter J, et al. Diffusion-weighted (DW) MRI in lung cancers: ADC test-retest repeatability. *Eur Radiol* 2017;27:4552–62.
19. Jiang J, Yin J, Cui L, Gu X, Cai R, Gong S, et al. Lung Cancer: Short-Term Reproducibility of Intravoxel Incoherent Motion Parameters and Apparent Diffusion Coefficient at 3T. *J Magn Reson Imaging* 2018;47:1003–12.
20. Kakite S, Dyvorne H, Besa C, Cooper N, Facciuto M, Donnerhack C, Taouli B. Hepatocellular carcinoma: short-term reproducibility of apparent diffusion coefficient and intravoxel incoherent motion parameters at 3.0T. *J Magn Reson Imaging* 2015;41:149–56.
21. Girometti R, Maieron M, Lissandrello G, Bazzocchi M, Zuiani C. Test-retest reliability of diffusion tensor imaging of the liver at 3.0 T. *Radiol Med* 2015;120:489–97.
22. Taouli B, Beer AJ, Chenevert T, Collins D, Lehman C, Matos C, et al. Diffusion-weighted imaging outside the brain: consensus statement from an ISMRM-sponsored workshop. *J Magn Reson Imaging* 2016; 44: 521–40.
23. Ye XH, Gao JY, Yang ZH, Liu Y. Apparent Diffusion Coefficient Reproducibility of the Pancreas Measured at Different MR Scanners Using Diffusion-Weighted Imaging. *J Magn Reson Imaging* 2014;40:1375–81.
24. Braithwaite AC, Dale BM, Boll DT, Merkle EM. Short- and midterm reproducibility of apparent diffusion coefficient measurements at 3.0-T diffusion-weighted imaging of the abdomen. *Radiology* 2009;250:459–65.
25. Barral M, Soyer P, Ben Hassen W, Gayat E, Aout M, Chiaradia M, et al. Diffusion-weighted MR imaging of the normal pancreas: reproducibility and variations of apparent diffusion coefficient measurement at 1.5- and 3.0-Tesla. *Diagn Interv Imaging* 2013;94:418–27.
26. Schoennagel BP, Habermann CR, Roesch M, Hahne JD, Arndt C, Kleibeler L, et al. Diffusion-weighted imaging of the healthy pancreas: apparent diffusion coefficient values of the normal head, body, and tail calculated from different sets of b-values. *J Magn Reson Imaging* 2011;34:861–5.
27. Yoshikawa T, Kawamitsu H, Mitchell DG, Ohno Y, Ku Y, Seo Y, et al. ADC measurement of abdominal organs and lesions using parallel imaging technique. *AJR Am J Roentgenol* 2006;187:1521–30.
28. Dale BM, Braithwaite AC, Boll DT, Merkle EM. Field strength and diffusion encoding technique affect the apparent diffusion coefficient measurements in diffusion-weighted imaging of the abdomen. *Invest Radiol* 2010;45:104–8.
29. Soyer P, Kanematsu M, Taouli B, Koh DM, Manfredi R, Vilgrain V, et al. ADC normalization: a promising research track for diffusion-weighted MR imaging of the abdomen. *Diagn Interv Imaging* 2013;94:571–3.
30. Barral M, Sebbag-Sfez D, Hoeffel C, Chaput U, Dohan A, Eveno C, et al. Characterization of focal pancreatic lesions using normalized apparent diffusion coefficient at 1.5-Tesla: preliminary experience. *Diagn Interv Imaging* 2013;94:619–27.

31. Do RK, Chandarana H, Felker E, Hajdu CH, Babb JS, Kim D, Taouli B. Diagnosis of liver fibrosis and cirrhosis with diffusion-weighted imaging: value of normalized apparent diffusion coefficient using the spleen as reference organ. *AJR Am J Roentgenol* 2010;195:671–6.
32. Malyarenko D, Galbán CJ, Londy FJ, Meyer CR, Johnson TD, Rehemtulla A, et al. Multi-system repeatability and reproducibility of apparent diffusion coefficient measurement using an ice-water phantom. *J Magn Reson Imaging* 2013;37:1238–46.
33. Malyarenko DI, Wilmes LJ, Arlinghaus LR, Jacobs MA, Huang W, Helmer KG, et al. QIN DAWG Validation of Gradient Nonlinearity Bias Correction Workflow for Quantitative Diffusion-Weighted Imaging in Multicenter Trials. *Tomography* 2016;2:396–405.
34. Malyarenko DI, Newitt D, J Wilmes L, Tudorica A, Helmer KG, Arlinghaus LR, et al. Demonstration of nonlinearity bias in the measurement of the apparent diffusion coefficient in multicenter trials. *Magn Reson Med* 2016;75:1312–23.
35. Fukukura Y, Shindo T, Hakamada H, Takumi K, Umanodan T, Nakajo M, et al. Diffusion-weighted MR imaging of the pancreas: optimizing b-value for visualization of pancreatic adenocarcinoma. *Eur Radiol* 2016;26:3419–27.

Tables

Table 1. ADC values of three pancreas regions and whole pancreas for the test-retest DWIs and statistical analyses results.

	Head	Body	Tail	Whole pancreas
ADC of first DWI	1.37±0.38	1.43±0.24	1.24±0.18	1.35±0.19
	(1.02-2.69)	(1.07-1.84)	(0.95-1.53)	(1.09-1.80)
ROI size (mm ²) of first DWI*	83.2±9.0	75.5±15.1	76.6±13.4	235.4±30.7
	(44-101)	(44-106)	(35-119)	(166-272)
ADC of second DWI	1.34±0.40	1.39±0.20	1.17±0.21	1.30±0.21
	(0.92-2.31)	(1.07-1.83)	(0.87-1.69)	(0.96-1.70)
ROI size (mm ²) of second DWI	84.3±7.3	73.7±14.3	73.5±11.8	231.5±24.8
	(55-99)	(35-101)	(44-119)	(174-277.5)
ICC	0.81	0.52	0.68	0.79
B_A	0.03[-0.44-0.50]	0.05[-0.37-0.47]	0.06[-0.24-0.37]	0.05[-0.20-0.30]
CV	9%	8%	8%	6%
P values	0.48	0.48	0.045	0.07

Data are expressed as mean ± standard deviation ($\times 10^{-3}$ mm²/s); ICC, intra-class correlation coefficient; B_A, Bland Altman; CV, coefficient of variation; ADC, apparent diffusion coefficient; ROI, region of interest.

*No significant differences between ROI sizes in three regions and the whole pancreas for test-retest DWIs (p=0.20-0.58).

Figures

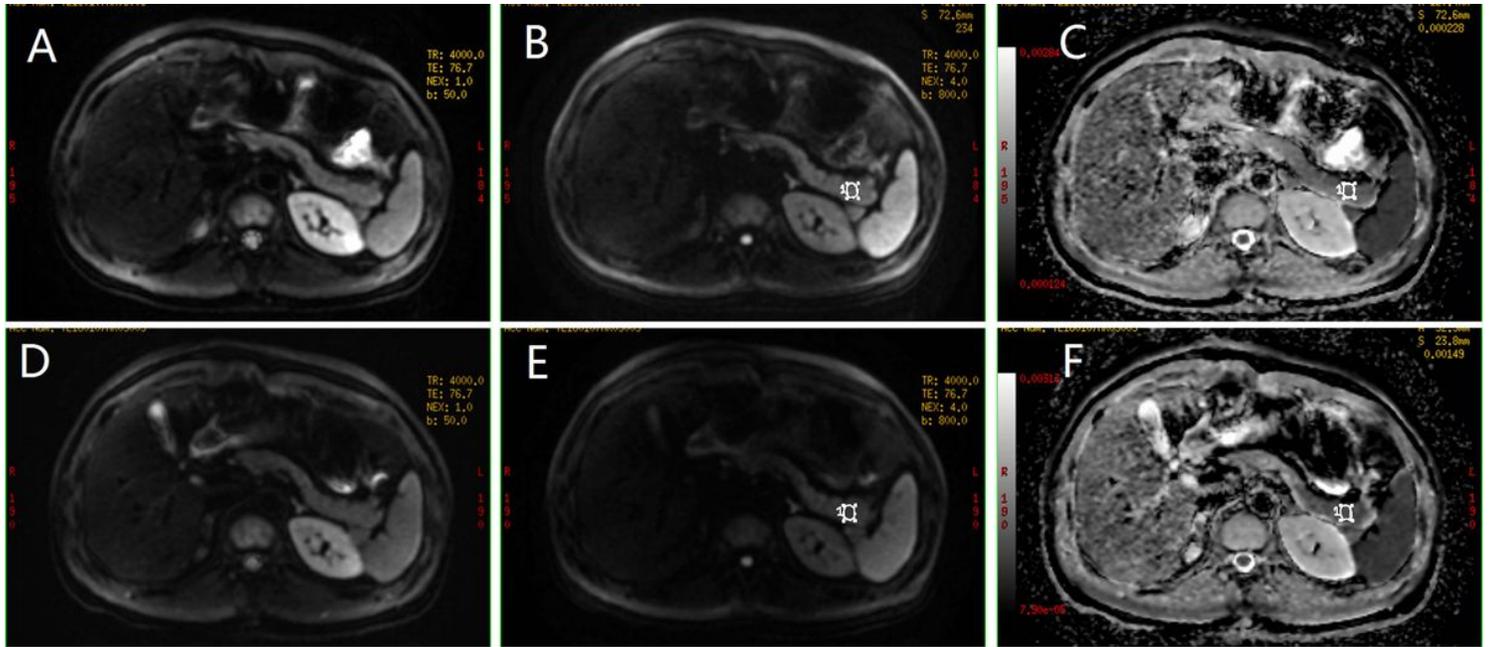


Figure 1

Representative images are acquired from a volunteer with test-retest DWIs. DWI images with b value of 50/800 s/mm² (A, B) and corresponding ADC map of first DWI (C); D-F represent images and the ADC map of the retest DWI.

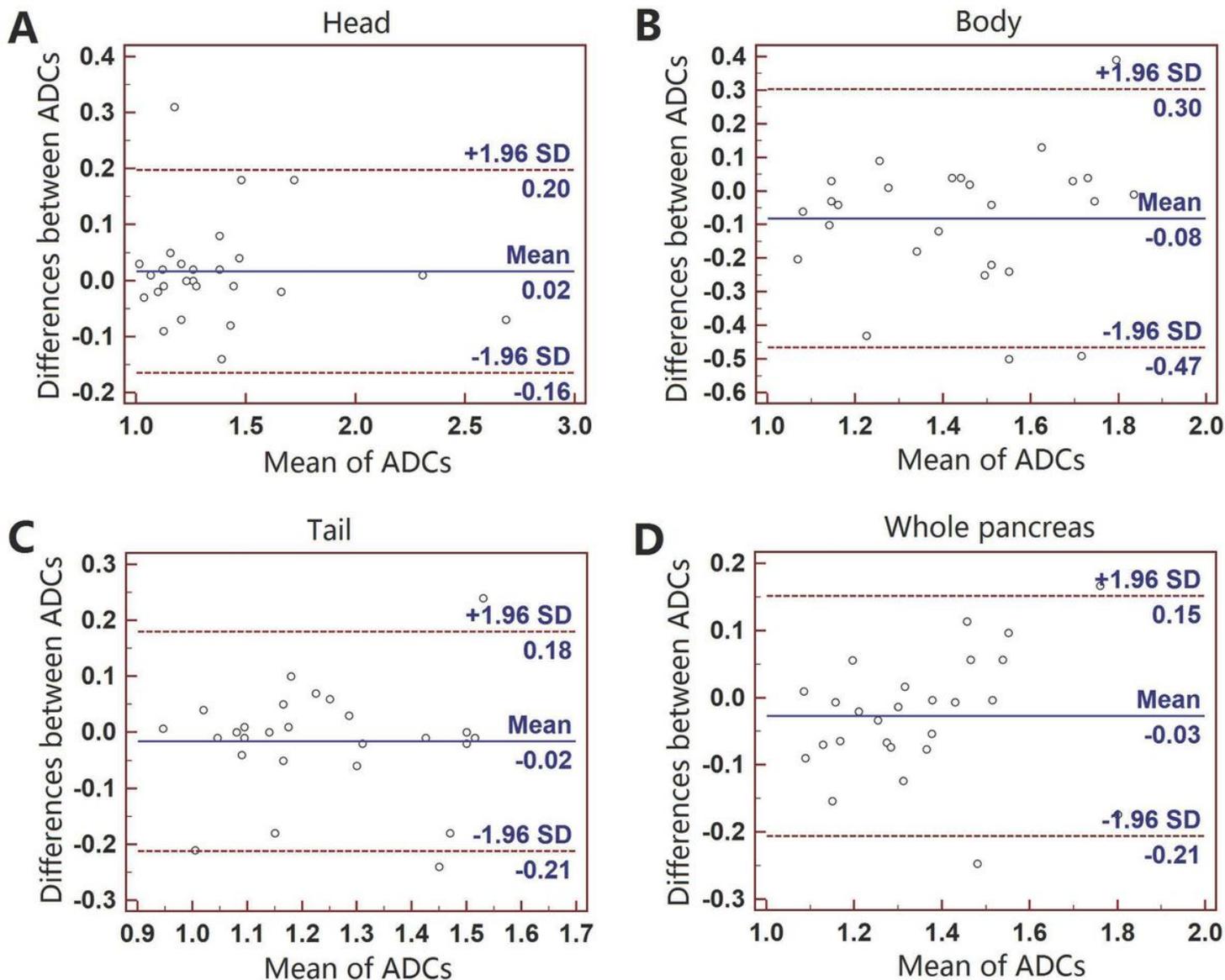


Figure 2

Bland-Altman plots of the intra-observer ADC measurements ($\times 10^{-3}$ mm²/s) for normal head (A), body (B), tail (C) and whole pancreas (D) on the first DWI. Y-axis: bias of ADC measurements; x-axis: the mean ADCs.

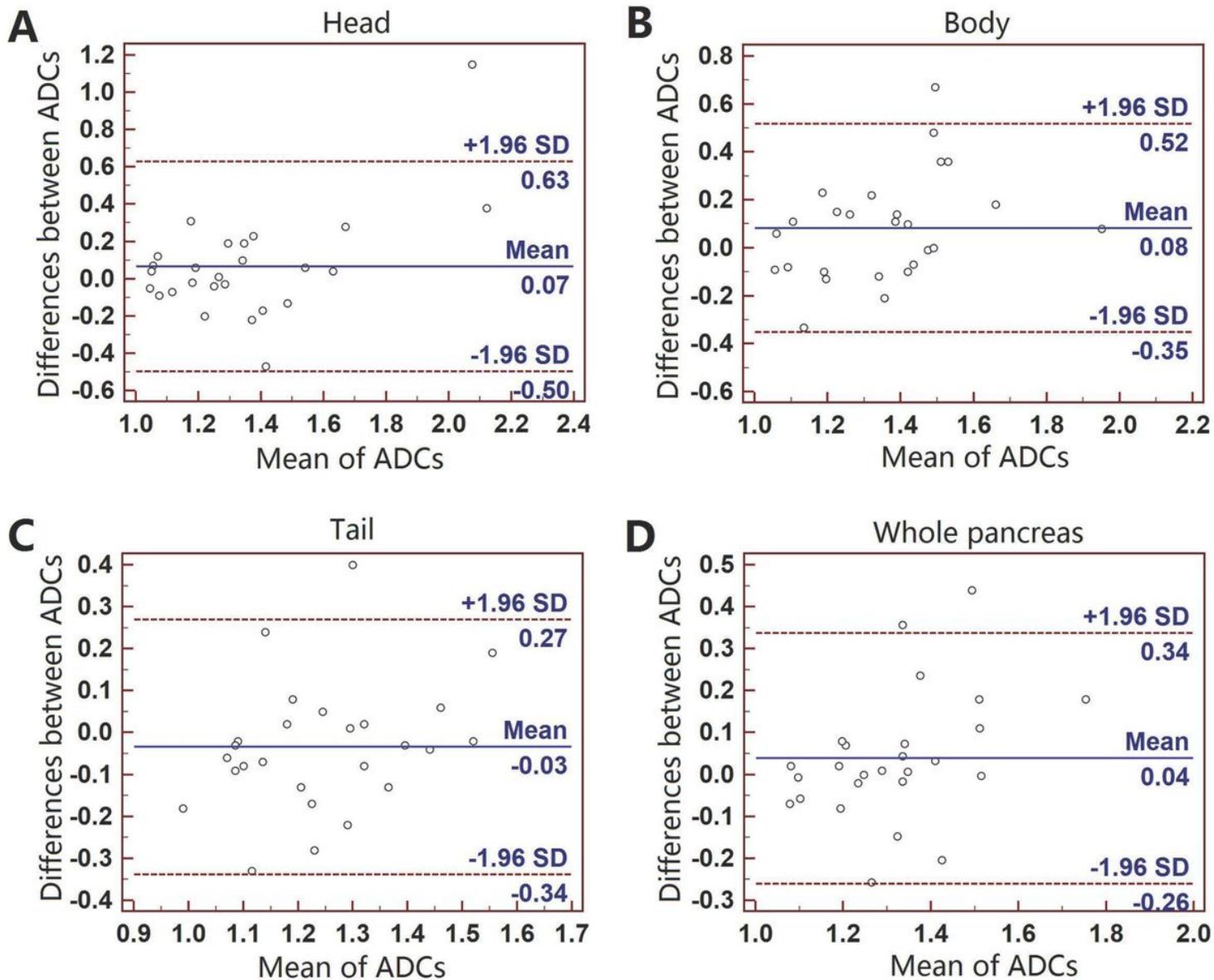


Figure 3

Bland-Altman plots of the inter-observer ADC measurements ($\times 10^{-3}$ mm²/s) for normal pancreatic head (A), body (B), tail (C) and whole pancreas (D) on the first DWI. Y-axis: bias of ADC measurements; x-axis: the mean ADCs.

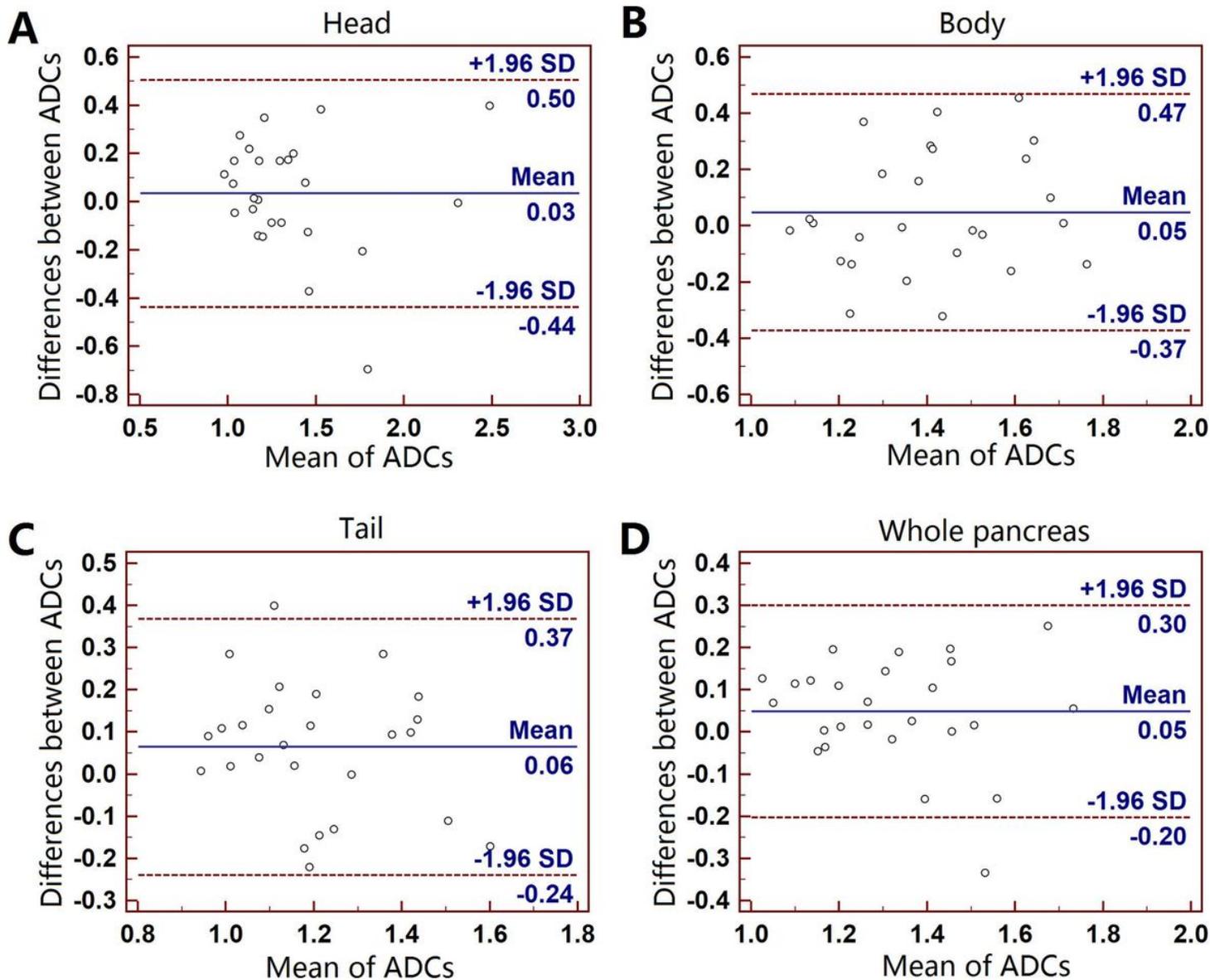


Figure 4

Bland-Altman plots of the mean ADC measurements ($\times 10^{-3}$ mm²/s) on test-retest DWIs for normal pancreatic head (A), body (B), tail (C) and whole pancreas (D). Y-axis: bias of ADC measurements; x-axis: the mean ADCs.