Effect of Motion Correction for CCTA in Quantifying the Pericoronary Adipose Tissue

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Abstract

Objective

To explore the effect of the motion correction in quantifying the pericoronary adipose tissue (PCAT) of coronary CT angiography (CCTA).

Methods

Forty patients who underwent CCTA were retrospectively enrolled in this study. Two CCTA series were reconstructed without motion correction (MC) and with motion correction. The image qualities were evaluated using a five-point Likert scale rating system. The right coronary artery (RCA) and PCAT were segmented. Volume of RCA, volume of PCAT and the fat attenuation index (FAI) were calculated and compared using paired sample t-test between two series. Pearson’s correlation analyses were performed to access the correlations between the image quality change and 3 parameters changes, respectively. The radiomics features of PCAT were also extracted and compared.

Results

The image qualities were significantly improved (without MC vs with MC, the percent of image quality score > 3, 52% vs 84%, $p < 0.001$). The volume of RCA was significantly increased after motion correction ($p < 0.05$), while FAI and the volume of PCAT were not. Besides, the changes of the volume of RCA and the volume of PCAT had significantly positive correlation with image quality change due to motion correction, while FAI change was not. Meanwhile, 521 of 1218 radiomics features of PCAT were significantly affected by motion correction.

Conclusion

Reconstruction with MC algorithm could improve the CCTA image quality, and had a significant impact on the quantization of PCAT.

Introduction

Atherogenesis caused by coronary inflammation could lead to coronary stenosis[1], which obstructed the blood supply to the heart, and in serious case, lead to myocardial infarction and death. Thus, early detection and treatment would significantly reduce the risk of patients[1].

Coronary CT angiography (CCTA) is a noninvasive imaging method to check coronary artery disease (CAD) in clinical routine. However, the diagnostic accuracy of CCTA is affected by the image quality. Due to the high heart rate of the patients, CCTA images always have variant degrees of motion artifact.

Recently, lots of motion correction (MC) reconstruction methods have been developed to reduce the motion artifact, and have been proved to improve the image quality significantly[2,3].

Pericoronary adipose tissue (PCAT) provides a new biomarker, fat attenuation index (FAI), to detect the coronary inflammation[1], which is conducive to early detection of CAD, and enhances cardiac risk prediction of future cardiovascular events[4]. Besides, Oikonomou et al. found CCTA-based radiomic profiling of PCAT were associated with adipose tissue fibrosis and microvascular remodelling[5].

CCTA reconstruction using MC algorithm could improve the image quality and reduce the motion artefact of the coronary. However, whether it would affect the PCAT quantification is uncertain. Therefore, the study aimed to investigate the effects of MC reconstruction in quantifying the FAI and radiomics features of pericoronary artery.

Materials And Methods

The study was approved by the Ethics Committee of Shanghai Jiading Central Hospital and the informed consents were waived for the retrospective study and only using the clinical routine images. All methods were performed in accordance with the relevant guidelines and regulations.

Study population

Forty consecutive patients were retrospectively collected from Jiading Central Hospital from April 2021 to May 2021. The patients met the following criteria were included: The patients with suspected or diagnosed coronary artery disease and were performed CCTA examinations using uCT 960+. The exclusion criteria were: (1) Allergy to iodine- contrast media historically; (2) Renal insufficiency (serum creatinine > 15 mg/L); (3) Hyperthyroidism; (4) Pregnancy; (5) Severe respiratory failure or heart failure; (6) The clinical state is unstable and can't follow the breath-holding guidance; (7) No atrial premature beats, ventricular premature beats, or paroxysmal arrhythmia.

Image acquisition and reconstruction

All CCTA examinations were performed using a 320-row detector CT scanner (uCT 960+, United-imaging Healthcare). The scanner’s detector is 160 mm, and the gantry rotation time is 0.25 s. The scan used a prospectively electrocardiography triggering in a single heartbeat with z-axis covered from the inferior carina to the bottom of heart. Iodinated contrast (Iopamidol, 370 mgI/ml) was administered by using a high-pressure syringe at a rate of 5 ml/s via median cubital vein and followed by 25 ml of saline solution. The dose was 0.7 ml/kg of body. The scanning was triggered using a BolusTracking technology, the region of interest (ROI) was in the descending aorta of the four chambers of the heart and the trigger threshold was set at 120 HU, when exceeded it, the CCTA scanning program is automatically started with a delay of 5.2 s.

In reconstruction, the scanner automatically selected the best phase with a best phase selection method (ePhase) according to ECG[6]. And all images were reconstructed using hybrid iterative reconstruction algorithms in a commercial workstation (United-imaging Healthcare). The filtered function was C-SOFT-BA, and other reconstruction parameters were 200 mm FOV, 512×512 matrix size, 0.5 mm slice thickness and 0.5 mm slice spacing. Besides, a second reconstruction was carried out by adding a motion correction algorithm (CardioCapture, an commercial AI-assisted motion correction algorithm, United-imaging Healthcare) to acquire another CCTA image series [3]. The details about CardioCapture could be found in Yan et al.' paper[3]. Finally, two CCTA series were obtained, one series was with MC, and the other was not.

Image quality

All images were evaluated by two independent and experienced radiologists who were blinded to clinical information and reconstruction methods. The quality of image was scored using five-point Likert scale rating system. According to the previous study [2], Score 1 indicated very poor image quality and severe motion artifacts and hard to distinguish the CCTA, Score 2 indicated poor image quality and severe motion artifacts and artery could be recognized. Score 3 indicated adequate, moderate artifacts and could be used in clinical diagnosis. Score 4 indicated good, minor artifacts, Score 5 indicated excellent, no motion artifacts. The image with score 3–5 were diagnostic, while score 4–5 were defined excellent.

RCA and PCAT segmentation

The coronary artery was segmented using a pretrained VNet model backend with niftynet[7,8], which were trained using 3000 CCTA images and achieved DICE 0.9. RCA was the targeted artery and saved as the ROI, then evaluate the segmentation results visually, if the segmentation was inaccurate, correct it manually. The pericoronary region was segmented using MITK (www.mitk.org, version: v2018.04.2), the specific steps included: dilating the ROI of RCA with the radius of the diameter of the RCA. The expanded part of the RCA was then re-segmented using – 190 - -30 HU threshold method, and the remained region was defined as PCAT.

Radiomics feature extraction

The radiomics features of the PCAT were extracted using pyradiomics software (pyradiomics.readthedocs.io/en/latest/, version: 3.0.0)[9], which complied with IBSI[10,11]. During feature extraction, the CCTA image was firstly resampled to 1*1*1 mm^3, then the gray values were discretized using binWidth with 25. Meanwhile, except for original image, the transformed images using Laplacian of Gaussian (LOG) transformation with sigma 2, 3, 4, 5 and wavelet transformation were also included. Finally, 1218 radiomics features were obtained, which could be classified into 5 classes, shape feature, first-order feature, texture feature, LOG feature and wavelet feature. In these features, 'original_firstorder_Mean' was weighted average attenuation of all voxels within PCAT and used an unadjusted FAI, and the 'original_shape_VoxelVolume' was the volume of the PCAT. Besides, the volume of RCA was also calculated using the number of voxel within ROI of RCA multiplying the volume of single voxel.

Statistical analysis

Statistical analyses were performed with R software (R Foundation, version 4.0.3, https://cran.r-project.org/), with statistical significance defined by $p < 0.05$. The relationship between the image quality and heart rate was analyzed using Pearson's correlation analysis. The image quality score of the CCTA images reconstructed with MC and without MC were compared using χ^2 test. The difference of FAI, volumes of PCAT and coronary RCA between 2 image series were compared using paired sample t-test. The pearson's correlation analyses were carried out to evaluate correlation between the change of FAI, volume of PCAT and the volume of RCA with the image quality change. Each radiomics features was also analyzed using the method mentioned above.

Results

Totally, 40 patients (57.1 ± 14.79 years old) were included in this study, 26 were male (65%). Their CCTA images were reconstructed twice, one with MC, another without MC, so 80 images were collected. The demographic information of the patients was shown in Table 1.

Table 1
The demographics of the patients in this study.

Parameter	Value	
Age	57.1 ± 14.79	
Gender		
	Male	Female
	24(65%)	16(35%)
Heart Rate	62.15 ± 9.59	

The representative images were shown in Fig. 1, the RCA boundary in CCTA with MC was clearer than the CCTA without MC.

The image quality of the CCTA images without MC reconstruction was significantly correlated with the average heart rate in scanning (r=-0.49, $p = 0.0013$). Compared to the images without MC, the MC reconstructed images had significantly higher image quality ($p < 0.001$). 80% of images' scores were > 3, while the images without MC were 52%. 90% of the images were improved at least 1 point, and 1 image's quality score decreased. The comparison results in detail were shown in Fig. 2.

To assess whether MC would affect the volumes of RCA and the PCAT, we used paired sample t-test to compare them between two CCTA image series. As shown in Fig. 3, the RCA volumes were significantly increased with MC ($p < 0.001$). However, the volume of the PCAT didn't change significantly ($p = 0.26$). FAI values were also compared, and no significant difference was observed ($p = 0.89$).

We assumed the volume change might correlate with the image quality change, so, the pearson's correlation analyses were conducted to test the relationship between the image quality and the volumes of RCA and PCAT. As shown in Fig. 4, The RCA volume change was significantly correlated with image quality change (R = 0.47, $p = 0.002$), and the same phenomenon was also observed in the volume of PCAT (R = 0.46, $p = 0.003$). But the FAI wasn't correlated with image quality change (R = 0.064, $p = 0.69$).

Besides, the radiomics features of PCAT were also compared and analyzed with image quality change. As shown in Fig. 5, lots of features (521/1218) were significantly changed and these changes were correlated with image quality change.

Discussion

In this paper, the effect the MC reconstruction in quantifying the pericoronary adipose tissue were investigated, which might deepen our knowledge about properties about CCTA-based PCAT, and conducive to its clinical applications.

The image quality of CCTA images was affected by the heart rate, and could be significantly improved by MC reconstruction, that's was same with previous published study[2,3]. In our study, 90% of images had at least 1 score improvement, one case even elevated with 3. That suggested motion correction was a useful algorithm to improve the CCTA image quality and helpful for clinical diagnosis.

The pretrained VNET was used in this study to extract the RCA artery. VNET is a widely used network to segment the organ and achieved high accuracy. The RCA volumes of CCTA images with motion correction were significantly increased compared with those without MC. That might be due to the motion artefact elimination, the margin of the artery became clear, so that the arteries became thicker. With subsequent correlation analysis, the increasement of artery volume was positively related with image quality change significantly, that further confirmed the motion artefact affected artery geometry and margin ambiguity, finally increase the hardness for VNET to segment the artery.

For PCAT, the volume didn't change significantly, but the volume change was positively correlated with image quality changes. That might be because of the confound effects of the artery volume change and the limited PCAT volume. The FAI values were not affected by the MC reconstruction significantly, that means the FAI as an averaged CT value was not sensitive to motion artefact.

The radiomics features contains more information about the adipose tissue than only FAI. They have been proved associated with adipose tissue fibrosis and microvascular remodelling[5], and with AI assisted, they could predict the cardiac risk more precisely. In our study, we found lots of radiomics features were affected by MC reconstruction, especially the texture and high-level radiomics features. And their change was significantly with image quality change. The results suggested when we need do PCAT radiomics analysis, the high-quality image is needed.

We investigated the MC reconstruction in affecting the PCAT quantification and proved the MC reconstruction would affect the quantitative feature value. But there were a few limitations, firstly, the sample size was small, only 40 patients and 80 CCTA images were included due to AI-based motion correction was a new technology. Secondly, we only analyzed the peri-RCA adipose tissue, omitted the LAD and LCX. That's because the PCAT in previous studies generally focused on peri-RCA. Besides, we didn't investigate whether MC would improve the diagnostic accuracy of radiomics. That would be studied in further.

Conclusion

Reconstruction with MC algorithm improved the CCTA image quality, and provided clearer artery boundary. The automatically segmented volumes of RCA and PCAT were changed due to MC, and the quantization of PCAT were also affected.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Shanghai Jiading Central Hospital. Ethics Committee of Shanghai Jiading Central Hospital waived the need for the informed consents. All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and material

The datasets generated and/or analysed during the current study are not publicly available due to the patient privacy policy of Shanghai Jiading Central Hospital, but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

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Authors’ contributions

Youbiao Guo and Kaiyi Liang conceived the study concept and design. Youbiao Guo, Hongchao Fu and Shengxiang Liang wrote the main manuscript text. Youbiao Guo, Xiaohua Yin and Dan Han performed the acquisition of data. Youbiao Guo, Hongchao Fu and Shengxiang Liang conducted data analysis and interpretation. All authors reviewed the manscript.

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References

1. Antonopoulos AS, Sanna F, Sabharwal N, et al. Detecting human coronary inflammation by imaging perivascular fat. 2017;2658(July).
2. Li Q, Li P, Su Z, et al. Effect of a novel motion correction algorithm (SSF) on the image quality of coronary CTA with intermediate heart rates: Segment-based and vessel-based analyses. Eur J Radiol. 2014;83(11):2024–2032. doi:10.1016/j.ejrad.2014.08.002
3. Yan C, Zhou G, Yang X, Lu X, Zeng M, Ji M. Image quality of automatic coronary CT angiography reconstruction for patients with HR ≥ 75 bpm using an AI-assisted 16-cm z-coverage CT scanner. BMC Med Imaging. 2021;21(1):1–8. doi:10.1186/s12880-021-00559-7
4. Oikonomou EK, Marwan M, Desai MY, et al. Non-invasive detection of coronary inflammation using computed tomography and prediction of residual cardiovascular risk (the CRISP CT study): a post-hoc analysis of prospective outcome data. Lancet. 2018;392(10151):929–939. doi:10.1016/S0140-6736(18)31114-0
5. Oikonomou EK, Williams MC, Kotanidis CP, et al. A novel machine learning-derived radiotranscriptomic signature of perivascular fat improves cardiac risk prediction using coronary CTangiography. 2019;2019:1–15. doi:10.1093/eurheartj/ehz592
6. Wang Y, Wu X, Quan G. An automatic dynamic optimal phase reconstruction for coronary CT. In: Schmidt TG, Chen G-H, Bosmans H, eds. *Medical Imaging 2019: Physics of Medical Imaging*. Vol 10948. SPIE; 2019:686–691. https://doi.org/10.1117/12.2512647.
7. Milletari F, Navab N, Ahmadi S. V-Net: Fully Convolutional Neural Networks for Volumetric Medical Image Segmentation. In: 2016 *Fourth International Conference on 3D Vision (3DV)*.; 2016:565–571. doi:10.1109/3DV.2016.79
8. Gibson E, Li W, Sudre C, et al. Computer Methods and Programs in Biomedicine NiftyNet: a deep-learning platform for medical imaging. Comput Methods Programs Biomed. 2018;158:113–122. doi:10.1016/j.cmpb.2018.01.025
9. Fedorov A, Parmar C, Hosny A, Narayan V. Computational Radiomics System to Decode the Radiographic Phenotype. 2018;77(21):1–8. doi:10.1158/0008-5472.CAN-17-0339.Computational
10. The image biomarker standardisation initiative. 2019;0(December).
11. Phenotyping I. The Image Biomarker Standardization Initiative: Standardized Quantitative Radiomics for High-Throughput. 2020;(5).

Figures

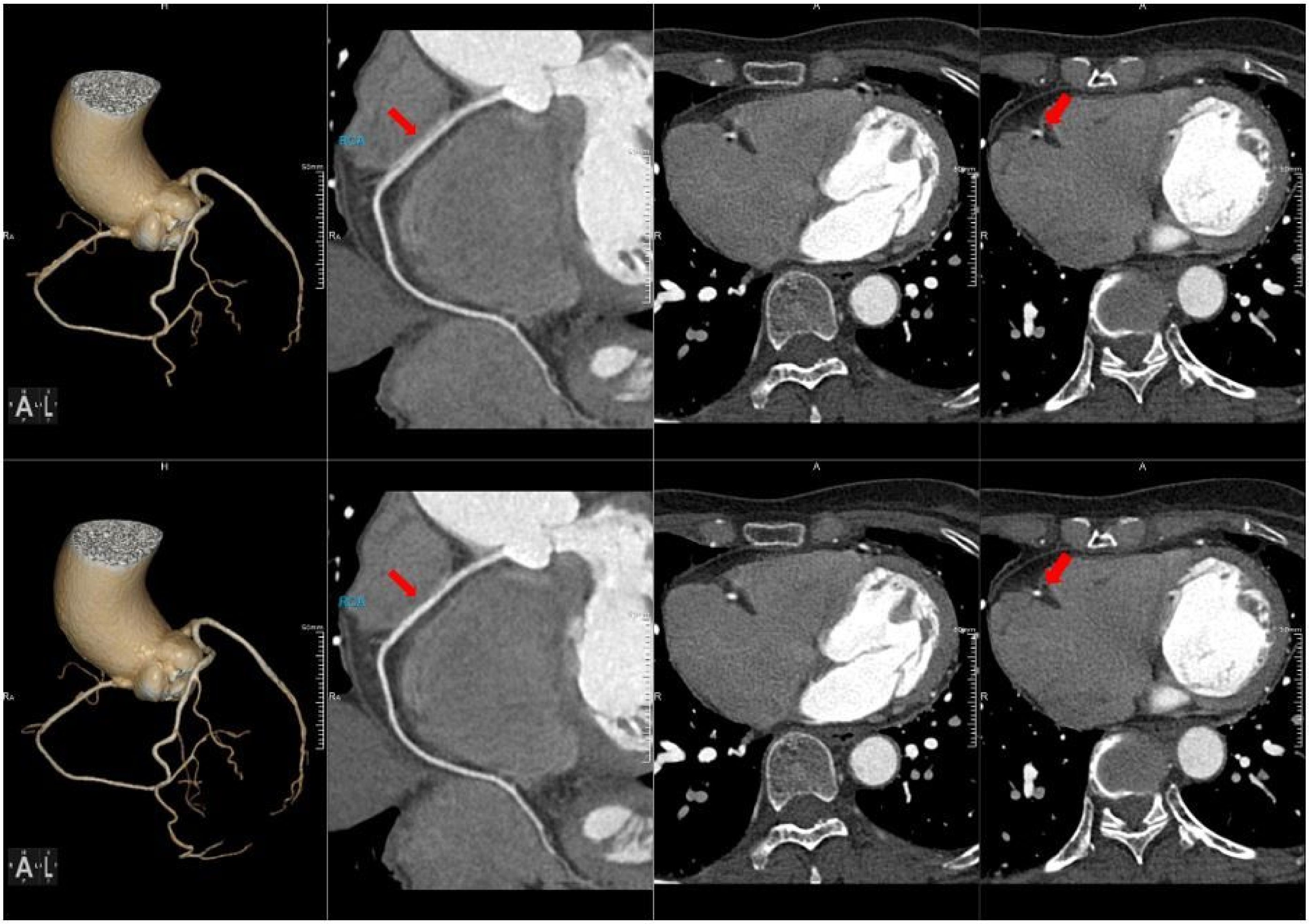

Figure 1

The CCTA images of a patient, the image quality was 2, and rise to 4 after MC reconstruction. The first row was the CCTA without MC, and the second row was CCTA images with MC. The red arrow indicated the RCA.

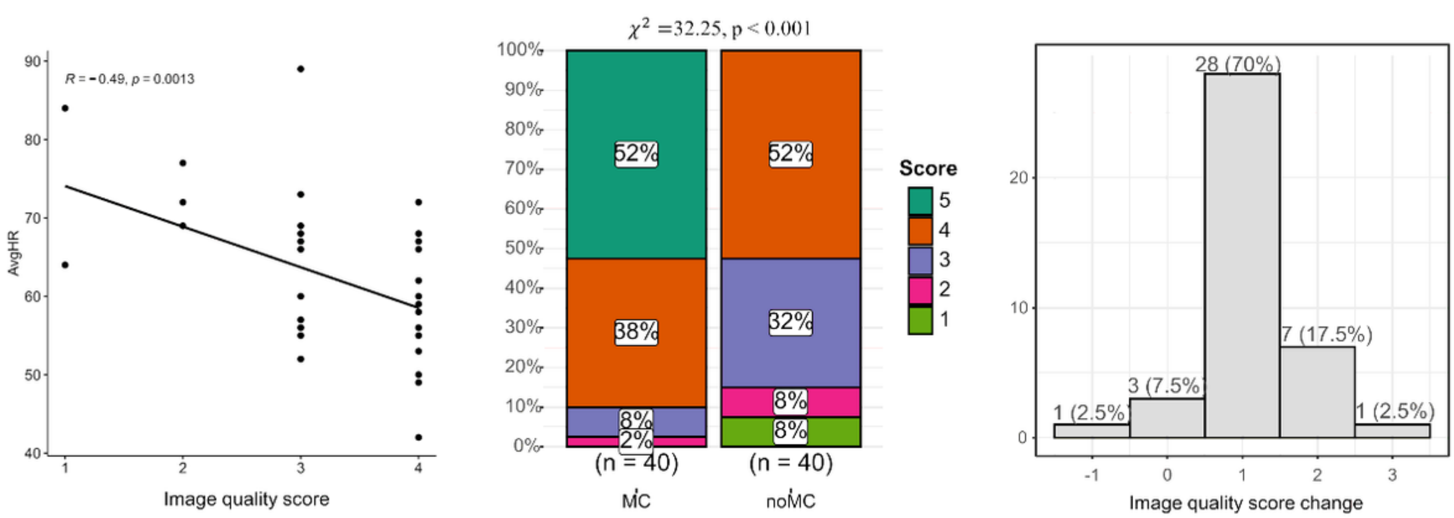

Figure 2

The results of image qualities analyses. The left image reflects the correlation of heart rate and the quality of CCTA image without MC (noMC). The middle image shows the image quality score distribution percentages in two different CCTA image series. The right image describes the distribution of the change of image quality score.

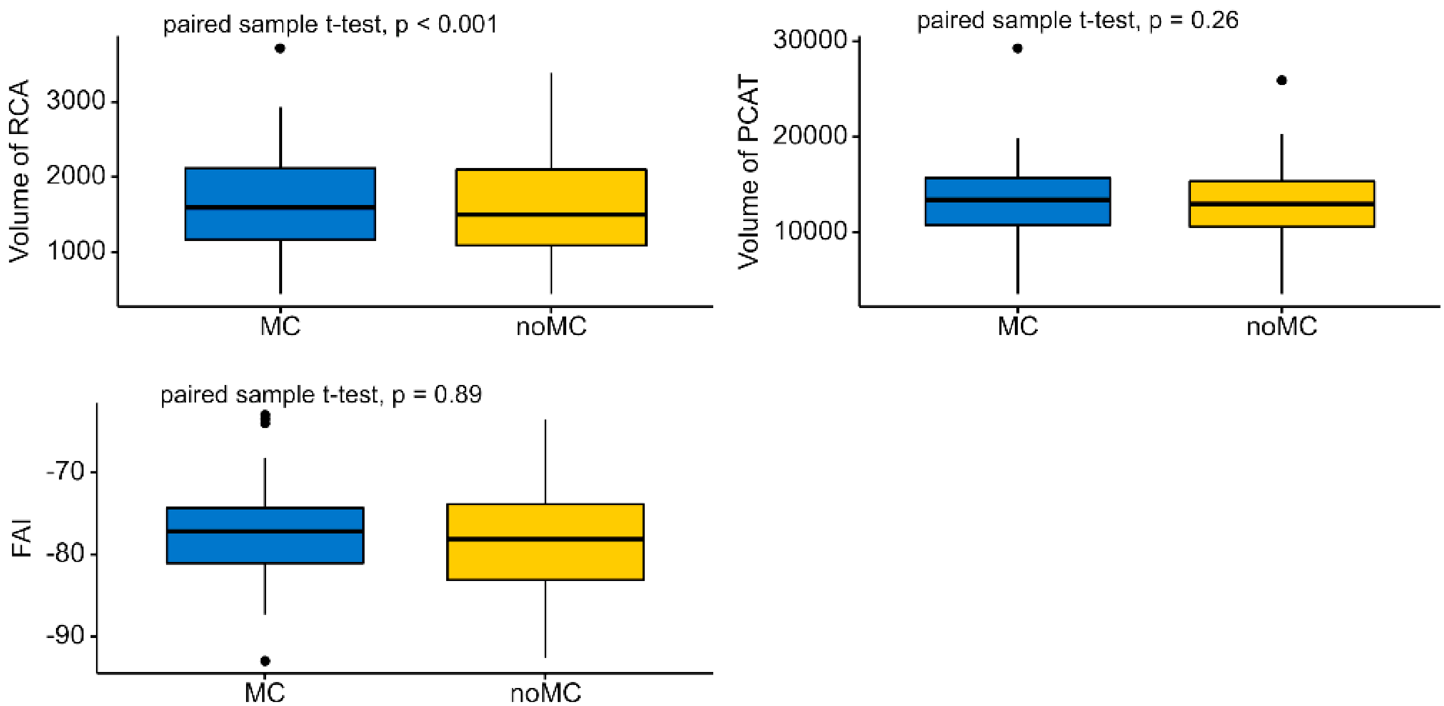

Figure 3

The boxplot of 3 classical parameters comparison between CCTA with (MC) and without MC (noMC). The topleft plot is the RCA volume, topright is the PCAT volume and the bottomleft is the FAI. The comparison using paired sample t test, and RCA volume was significantly different, while the others were not.

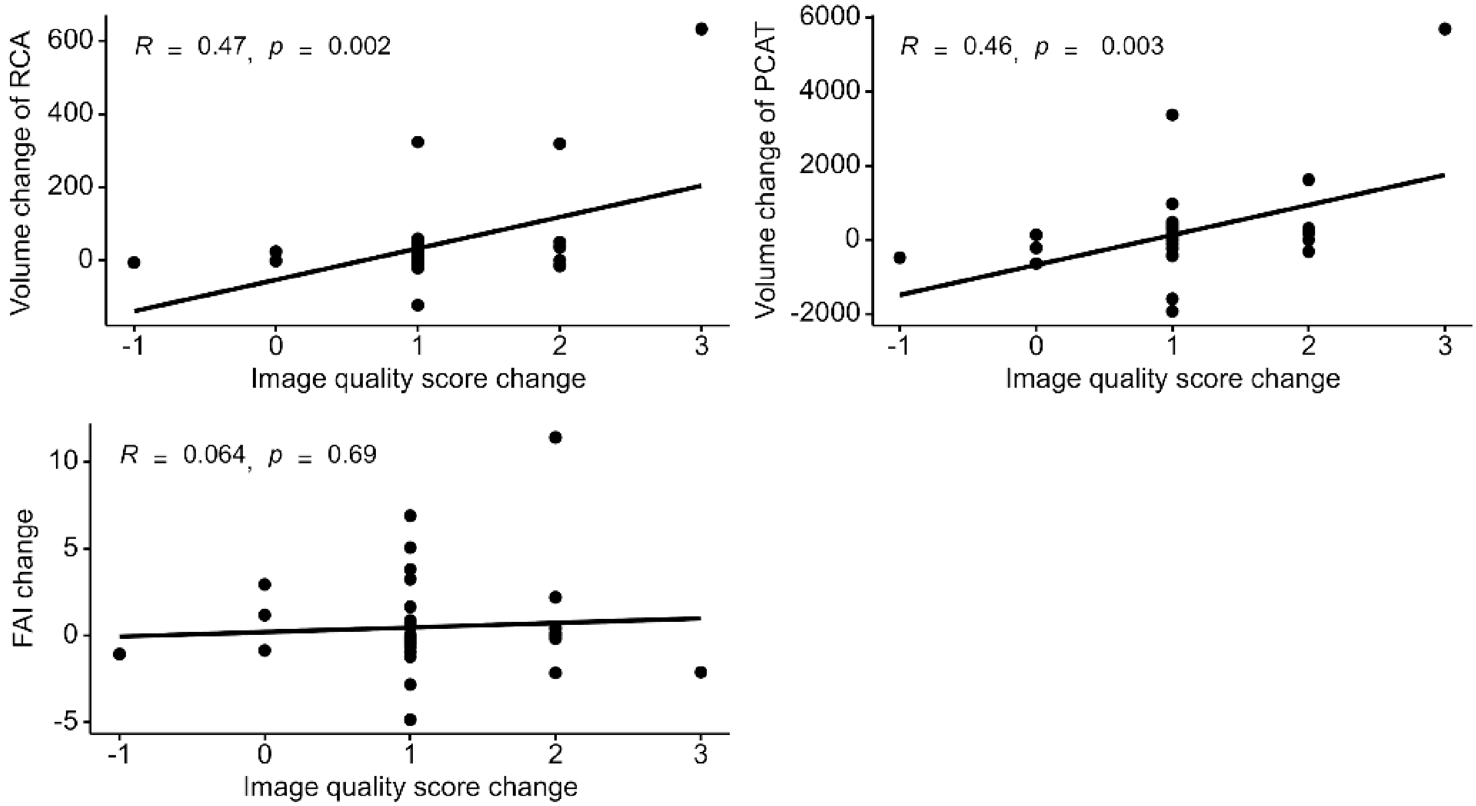

Figure 4

The correlation plots of image quality score change and RCA volume (topleft), PCAT volume (topright) and FAI (bottomleft). The RCA volume and PCAT volume changes were positively correlated with image quality score change.

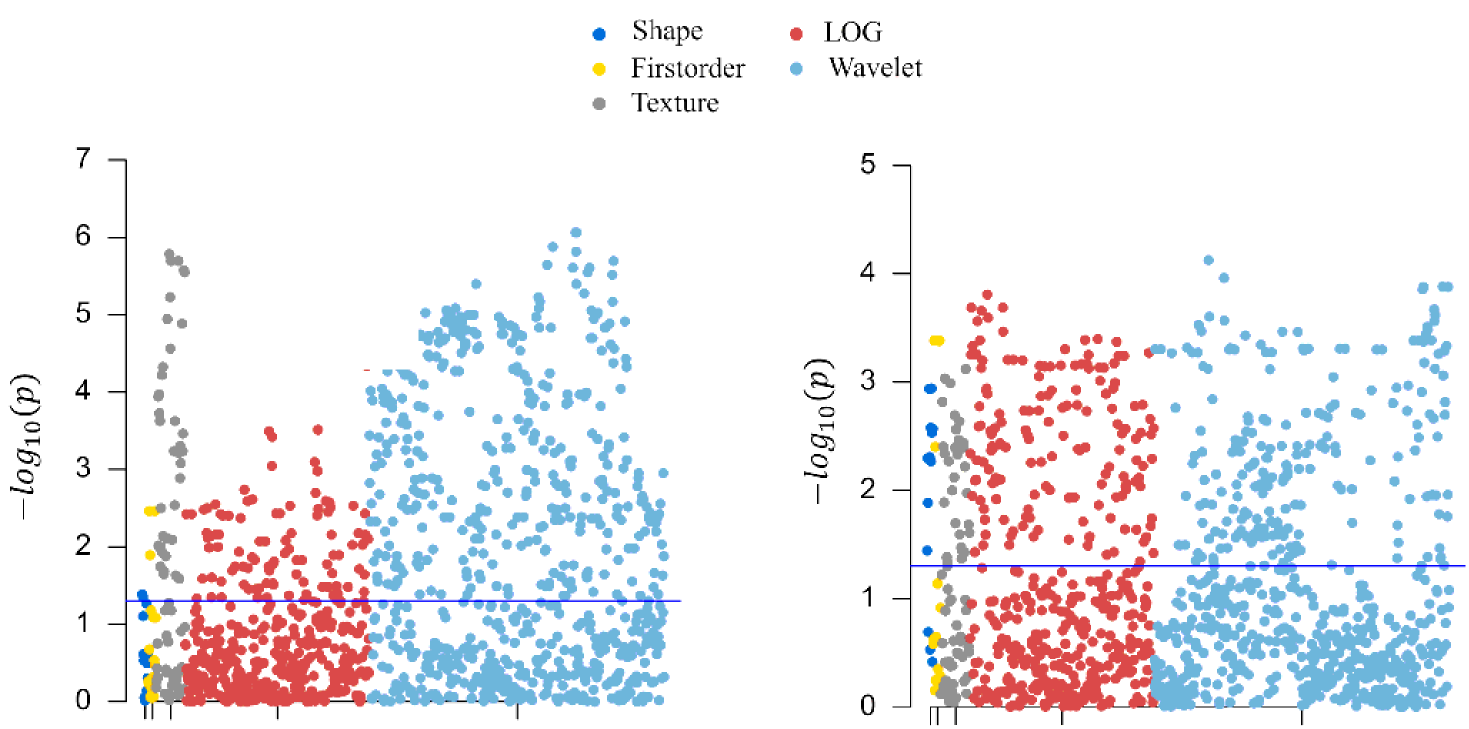

Figure 5

The Manhattan plot of p-values of paired sample t test between two CCTA with and without MC(Left), and correlation analysis for radiomics features change and image quality score change (Right). The blue line represents.