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Improved spillover correction model to quantify myocardial blood flow by ^{11}C-acetate PET: comparison with ^{15}O-H_2O PET

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Abstract

Objective ^{11}C-acetate has been applied for evaluation of myocardial oxidative metabolism and can simultaneously estimate myocardial blood flow (MBF). We developed a new method using two-parameter spillover correction to estimate regional MBF (rMBF) with ^{11}C-acetate PET in reference to MBF derived from ^{15}O-H_2O PET. The usefulness of our new approach was evaluated compared to the conventional method using one-parameter spillover correction.

Methods Sixty-three subjects were examined with ^{11}C-acetate and ^{15}O-H_2O dynamic PET at rest. Inflow rate of ^{11}C-acetate (K1) was compared with MBF derived from ^{15}O-H_2O PET. For the derivation, the relationship between K1 and MBF from ^{15}O-H_2O was linked by the Renkin-Crone model in 20 subjects as a pilot group. One-parameter and two-parameter corrections were applied to suppress the spillover between left ventricular (LV) wall and LV cavity. Validation was set using the other 43 subjects' data. Finally, rMBFs were calculated using relational expression derived from the pilot-group data .

Results The relationship between K1 and MBF derived from ^{15}O-H_2O PET was approximated as K1 = (1 - 0.764 * exp(- 1.001 / MBF)) MBF from the pilot data using the two-parameter method. In the validation set, the correlation coefficient between rMBF from ^{11}C-acetate and ^{15}O-H_2O demonstrated a significantly higher relationship with the two-parameter spillover correction method than the one-parameter spillover correction method ($r = 0.730$, 0.592, respectively, $p < 0.05$).

Conclusion In ^{11}C-acetate PET study, the new two-parameter spillover correction method dedicated more accurate and robust myocardial blood flow than the conventional one-parameter method.

Keywords

^{11}C-acetate, ^{15}O-H_2O, PET, regional myocardial blood flow, spillover correction

Introduction

^{11}C-acetate is a known PET tracer that is taken up by the heart, rapidly converted to acetylCoA, and readily metabolized to CO_2 through the TCA cycle with oxidative phosphorylation [1]. K1 inflow rate of ^{11}C-acetate is largely dependent on myocardial blood flow (MBF) [2]. One-parameter spillover correction is one of the commonly used techniques for estimating MBF [2, 3]. The method uses one coefficient value to eliminate the effect of spillover from the left ventricle (LV) cavity to the LV tissue. However, the regions of interest (ROIs) of the LV cavity and tissue potentially include a significant spillover from burring, and vice versa for the ROI of LV tissue and cavity. Therefore, multiple spillover corrections are needed. Here, we propose a two-parameter spillover correction model, with 2 independent coefficient values—one for the LV cavity within ROI, and one for the LV tissue of ROI. We assumed that the new two-parameter spillover correction would be more useful than conventional one-parameter spillover correction [4]. Thus, the first goal of this study was to develop a new two-parameter spillover correction method to estimate regional and global MBF with ^{11}C-acetate PET in reference to MBF derived from ^{15}O-H_2O PET [5]. The second goal was to compare MBF measured with our new two-parameter model with that from the conventional one-parameter spillover correction model.

Materials and Methods

Subjects

Sixty-three subjects who underwent ^{11}C-acetate PET and ^{15}O-H_2O PET within a 2-week period from August 2006 to August 2012 were retrospectively included in this study. The Ethics Committee of Hokkaido University Hospital approved the study protocol.

Study Protocol

The Renkin-Crone model was used to obtain the extraction fraction using the inflow rate of ^{11}C-acetate (K1) and the MBF from ^{15}O-H_2O PET from the first 20 subjects, who served as a pilot group. To validate the formula developed from the pilot group data, MBF assessed by ^{11}C-acetate PET was computed using the remaining 43 subjects. MBF from ^{11}C-acetate was estimated by both one-parameter and two-parameter spillover correction, and was subsequently compared with MBF derived from ^{15}O-H_2O PET.

PET Imaging Acquisition

PET data acquisition was performed using a whole-body scanner (ECAT/EXACT HR+; Siemens/CTI, Asahi-Siemens Medical Technologies Ltd., Tokyo, Japan). All emissions and transmissions were acquired in the 2-dimensional mode, and attenuation-corrected radioactivity images were reconstructed using filtered back-projection with a Hann filter of 4-mm full-width at half-maximum. Transmission scan was obtained with an external ^{68}Ge / ^{68}Ga source. ^{11}C-acetate tracer (740 MBq) was administered intravenously for 60 s under resting conditions, and dynamic PET acquisition was performed (10×10 s, 1×60 s, 5×100 s, 3×180 s, 2×300 s) [6]. ^{15}O-H_2O (1,500 MB) was infused into an antecubital vein as a slow (2-min) infusion. A 20-frame dynamic PET scan, consisting of 6×5 s, 6×15 s, and 8×30 s frames, was acquired for 6 min [7].

Analysis of ^{15}O-H_2O and ^{11}C-acetate

MBF of ^{15}O-H_2O was measured using a previously described method with the dedicated software [7]. Briefly, ROIs were drawn over the whole LV myocardium and within the LV cavity.(Fig 1) The ROIs were projected onto the dynamic ^{15}O-H_2O images. Arterial and myocardial tissue activity curves were derived with spillover correction, and were fitted to a single-tissue-compartment tracer kinetic model to calculate MBF at rest.

K1 from ^{11}C-acetate PET was measured using the same image-analysis method. A cylindrical ROI was positioned manually in the LV to obtain the time activity curve, LV(t), from the short axis images in the early phase. A whole myocardial ROI, R, was set semi-automatically to obtain the time activity curves from the myocardium, R(t), using the last frame images of the dynamic ^{11}C-acetate data. Time activity curve in the arterial blood, Ca(t), and in the myocardial tissue, Ct(t), were estimated with consideration of these spillovers, modeled as a partial-volume mixture of arterial blood and tissue activity concentrations [4]. For the analysis of ^{11}C-acetate, an averaged metabolite correction of the input function was also contained using the result of Buck et al.; $Ca(t) = 0.91\exp(t/T_{1/2})*LV(t)$, T1/2 = 5.3min [8-10]. We used two methods of spillover correction to estimate K1 for the one-parameter and two-parameter methods. The K1 was estimated as described in the Appendix. The parameter, "a" meant the contaminated ratio of the blood radioactivity into the myocardial ROI, and "(1-a)" yielded the mixed ratio of the myocardial radioactipavity into the LV ROI in the conventional method. This was based on the ideal assumption that the total ratio of the distribution of blood and myocardium within the ROI is just 1.0. Our method enabled to calculate the parameter "va" which was free from the parameter "a". K1 was then converted into MBF using the Renkin-Crone model [4, 11, 12]. Global LV and 3-coronary-regional MBFs (rMBFs) were calculated and validated [13].

Statistical Analysis

Data are expressed as mean ± SD. The correlation between MBF from ^{11}C-acetate and ^{15}O-H_2O were assessed using linear regression analyses and Bland-Altman plots. Pearson's correlation coefficients were used to evaluate the concordance between the conventional one-parameter method and our two-parameter method. For both analyses, p-values < 0.05 were considered significant.

Results

Hemodynamic data at the scan

The hemodynamic data of 8 participants in the pilot group, and 4 participants in the validation group were lost. The hemodynamic data of the remaining subjects are presented in Table 2. There were no significant differences in any of the hemodynamic data, including heart rate (HR), systolic blood pressure (sBP), diastolic blood pressure (dBP), and rate pressure product (RPP).

Pilot Group

The Renkin-Crone's formula yielded the relationship between K1 from ^{11}C-acetate and MBF from ^{15}O-H_2O PET in the whole myocardium from the pilot group. Eq. 1 and 2 represent the Renkin-Crone’s formula from the one- and two-parameter spillover models, respectively (Fig 2).

$$K1_{\text{1-parameter}} = (1 - 0.816 * \exp(0.998/MBF)) * MBF \qquad (1)$$

$$K1_{\text{2-parameter}} = (1 - 0.764 * \exp(1.001/MBF)) * MBF \qquad (2)$$

Validation Group

Using Eqs. 1 and 2, MBFs were calculated from the ^{11}C-acetate data of the validation group. Calculated global MBFs from the one- and two-parameter models were 0.67 ± 0.28 and 0.68 ± 0.23, respectively ($p = 0.39$). Calculated rMBFs from the one- and two-parameter models were 0.69 ± 0.35 and 0.74 ± 0.27 mL/g/min for regional, respectively ($p = 0.008$). In both the global and regional MBF values, significant relationships were seen between the MBFs from ^{11}C-acetate and $^{15}O\text{-}H_2O$. In the validation set, the two-parameter model dedicated a significantly better correlation coefficient than the one-parameter method ($r = 0.730$ vs. 0.592, $p < 0.05$) (Fig 3). Bland-Altman plots also presented more stable regional MBFs from the two-parameter spillover model than from the conventional one-parameter model (Fig 4).

Discussion

We developed a new, two-parameter spillover correction model to estimate global and regional MBF at the early phase of ^{11}C-acetate PET (0-5 min). The model demonstrated a better relationship between the MBF derived from both the ^{11}C-acetate and the ^{15}O-H_2O PET than the previous one-parameter spillover model, suggesting that our model is a reliable equation for estimating MBF from ^{11}C -acetate PET scans.

Our method demonstrated a good relationship between K1 from ^{11}C-acetate and MBF from ^{15}O-H_2O PET using the Renkin-Crone model, as well as other PET tracers such as ^{82}Rb [4]. This new two-parameter spillover correction method could suppress the spillover into the myocardium. Therefore, it might provide more precise MBF in the repeated measurement than the established method.

Some procedures were reported to measure the MBF using ^{11}C-acetate PET, such as net myocardial uptake of tracer [14], two tissue compartment model [2], and single tissue compartment model with one-parameter spillover collection [8]. And Timmer et al. recommended the method using a single tissue compartment model with one-parameter spillover method with standardized correction for recirculating metabolites and with corrections for partial volume and spillover [10]. Our model demonstrated a better relationship, suggesting that our model is a reliable equation for estimating MBF from ^{11}C -acetate PET scans. The one-parameter spillover correction model is one of the established techniques for estimating the MBF in a nonlinear least-squares method [2, 3]; in this model, the number of calculable variables is limited [15]. Our two-parameter model dedicated a significantly better coefficient value for linear correlation than the conventional one-parameter model. Therefore, the two-parameter spillover correction is more fitted to calculating MBF than the one-parameter method [7, 16]. In addition, our modified method is able to detect regional MBF reduction.

Klein et al. reported the usefulness of the ^{11}C-acetate dynamic PET for evaluating MVO_2 in a clinical research study that assessed ischemic heart disease, dilated cardiomyopathy, aortic stenosis, and recipient heart after transplantation [17]. The present study demonstrated that ^{11}C-acetate dynamic PET is reliably useful for estimating both MBF and MVO_2. Quantification of MBF offers a great advantage in the evaluation of the functional severity of vascular function in patients with coronary artery disease,[5, 13, 18-20] as well as information about morphological stenosis [21, 22]. In the present study, we used ^{15}O-H_2O as the ideal tracer to estimate MBF because, with an almost 100% extraction of water, it is a freely diffusible tracer [7]. The extraction fraction of ^{11}C-acetate was also thought to be high enough to calculate MBF [8, 14].

The present study had methodological limitations. The sample size was relatively small. However, smaller sample sizes used in previous physiological studies were found to have sufficient power to validate new methods [11, 23]. This study assessed MBF only at rest and not in a stress condition. Further studies are needed to evaluate MBF during stress tests. As we were focused on the utility of the two-parameter method for the estimation of MBF from ^{11}C-acetate PET, we didn't discuss the correlation between MBF and MVO_2. Finally, as this study was retrospective, some hemodynamic data, such as heart rate and blood pressure, were lost. Some patients showed certain amount differences MBF between ^{11}C-acetate PET and ^{15}O-H_2O. We have evaluated the background etiology of disease and the regional MBF in subjects who showed more than 40% difference between MBF from ^{11}C-acetate PET and that from ^{15}O-H_2O PET. Fifteen regions showed the large variation among MBFs including 8 LCX regions, 4 LAD regions, and 3 RCA regions. Seven regions were from PH patients, 3 regions were from ICM patients, 3 regions were from volunteers, 1region was from DCM patient, and 1 region was from valvular disorder patient. Not only a particular patient, but also healthy volunteers were included. Therefore, the patient characteristics might be little cause of the wide variation. The LCX region tended to show the large variation of MBF between ^{11}C-acetate and ^{15}O-H_2O. Respiratory motion might lead to the error of the attenuation correction between the myocardium and lung, since the LCX region widely faced the lung field.

Conclusions

We developed a new method for estimating regional myocardial blood flow using dynamic PET with ^{11}C-acetate, which yielded a good correlation with MBF from ^{15}O-H_2O PET. Our new, two-parameter spillover correction method produced a more robust estimation of regional MBF than the conventional one-parameter method.

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Appendix

1-parameter and 2-parameter spillover method

Relational expression among R(t), Ct(t), and Ca(t) was represented as Eq. 3 for the conventional method and as Eq. 4 for the two-parameter method.

$$R(t) = \alpha * Ct(t) + (1-\alpha) * Ca(t) \qquad (3)$$

where α denoted myocardial tissue ratio in the ROI R, and (1-α) is spillover from blood into the ROI R.

$$R(t) = \alpha * Ct(t) + v\alpha * Ca(t) \qquad (4)$$

where vα is spillover from blood into the ROI R for the two-parameter method.

Activity concentration in the LV blood cavity was modeled as a partial-volume mixture of arterial blood and myocardial tissue as Eq. 5.

$$LV(t) = \beta * Ca(t) + (1-\beta) * m * Ct(t) \qquad (5)$$

where β denoted a recovery coefficient in the LV ROI , (1-β) is spillover from myocardium into blood pool, and m is the density of myocardial tissue (1.04 g/ml). Radioactivity in the LV blood pool was calculated using Eq. 5 with β = 85% [4].

The change in tissue activity concentration was modeled using the one-tissue compartment model as Eq. 6.

$$dCt(t) = K1 * Ca(t) - k2 * Ct(t) \qquad (6)$$

where K1 (mL/g/min) is the uptake rate from blood into the tissue and k2 (/minute) is the washout rate from myocardial tissue into the blood Ca(t) (Bq/mL). The parameters K1, k2, α and vα were estimated by the non-linear least-squares method using Eqs. 3, 5, and 6 for the one-parameter method and Eqs. 4, 5, and 6 for the two-parameter method. Estimated data and the curve R(t) dedicated the spillover-corrected pure blood curve Ca(t).

References

1. Brown MA, Myears DW, Bergmann SR: **Validity of estimates of myocardial oxidative metabolism with carbon-11 acetate and positron emission tomography despite altered patterns of substrate utilization.** *Journal of nuclear medicine : official publication, Society of Nuclear Medicine* 1989, **30**:187-193.
2. Sun KT, Yeatman LA, Buxton DB, Chen K, Johnson JA, Huang SC, Kofoed KF, Weismueller S, Czernin J, Phelps ME, Schelbert HR: **Simultaneous measurement of myocardial oxygen consumption and blood flow using [1-carbon-11]acetate.** *Journal of nuclear medicine : official publication, Society of Nuclear Medicine* 1998, **39**:272-280.
3. Herrero P, Kim J, Sharp TL, Engelbach JA, Lewis JS, Gropler RJ, Welch MJ: **Assessment of myocardial blood flow using 15O-water and 1-11C-acetate in rats with small-animal PET.** *Journal of nuclear medicine : official publication, Society of Nuclear Medicine* 2006, **47**:477-485.
4. Katoh C, Yoshinaga K, Klein R, Kasai K, Tomiyama Y, Manabe O, Naya M, Sakakibara M, Tsutsui H, deKemp RA, Tamaki N: **Quantification of regional myocardial blood flow estimation with three-dimensional dynamic rubidium-82 PET and modified spillover correction model.** *Journal of nuclear cardiology : official publication of the American Society of Nuclear Cardiology* 2012, **19**:763-774.
5. Yoshinaga K, Tomiyama Y, Suzuki E, Tamaki N: **Myocardial blood flow quantification using positron-emission tomography.** *Circulation journal : official journal of the Japanese Circulation Society* 2013, **77**:1662-1671.
6. Wu YW, Naya M, Tsukamoto T, Komatsu H, Morita K, Yoshinaga K, Kuge Y, Tsutsui H, Tamaki N: **Heterogeneous reduction of myocardial oxidative metabolism in patients with ischemic and dilated cardiomyopathy using C-11 acetate PET.** *Circulation journal : official journal of the Japanese Circulation Society* 2008, **72**:786-792.
7. Katoh C, Morita K, Shiga T, Kubo N, Nakada K, Tamaki N: **Improvement of algorithm for quantification of regional myocardial blood flow using 15O-water with PET.** *Journal of nuclear medicine : official publication, Society of Nuclear Medicine* 2004, **45**:1908-1916.
8. van den Hoff J, Burchert W, Borner AR, Fricke H, Kuhnel G, Meyer GJ, Otto D, Weckesser E, Wolpers HG, Knapp WH: **[1-(11)C]Acetate as a quantitative perfusion tracer in myocardial PET.** *Journal of nuclear medicine : official publication, Society of Nuclear Medicine* 2001, **42**:1174-1182.
9. Buck A, Wolpers HG, Hutchins GD, Savas V, Mangner TJ, Nguyen N, Schwaiger M:

Effect of carbon-11-acetate recirculation on estimates of myocardial oxygen consumption by PET. *Journal of nuclear medicine : official publication, Society of Nuclear Medicine* 1991, **32**:1950-1957.

10. Timmer SA, Lubberink M, Germans T, Gotte MJ, ten Berg JM, ten Cate FJ, van Rossum AC, Lammertsma AA, Knaapen P: **Potential of [11C]acetate for measuring myocardial blood flow: Studies in normal subjects and patients with hypertrophic cardiomyopathy.** *Journal of nuclear cardiology : official publication of the American Society of Nuclear Cardiology* 2010, **17**:264-275.
11. Manabe O, Yoshinaga K, Katoh C, Naya M, deKemp RA, Tamaki N: **Repeatability of rest and hyperemic myocardial blood flow measurements with 82Rb dynamic PET.** *Journal of nuclear medicine : official publication, Society of Nuclear Medicine* 2009, **50**:68-71.
12. Herrero P, Markham J, Shelton ME, Bergmann SR: **Implementation and evaluation of a two-compartment model for quantification of myocardial perfusion with rubidium-82 and positron emission tomography.** *Circulation research* 1992, **70**:496-507.
13. Tsukamoto T, Morita K, Naya M, Katoh C, Inubushi M, Kuge Y, Tsutsui H, Tamaki N: **Myocardial flow reserve is influenced by both coronary artery stenosis severity and coronary risk factors in patients with suspected coronary artery disease.** *European journal of nuclear medicine and molecular imaging* 2006, **33**:1150-1156.
14. Chan SY, Brunken RC, Phelps ME, Schelbert HR: **Use of the metabolic tracer carbon-11-acetate for evaluation of regional myocardial perfusion.** *Journal of nuclear medicine : official publication, Society of Nuclear Medicine* 1991, **32**:665-672.
15. Sun KT, Chen K, Huang SC, Buxton DB, Hansen HW, Kim AS, Siegel S, Choi Y, Muller P, Phelps ME, Schelbert HR: **Compartment model for measuring myocardial oxygen consumption using [1-11C]acetate.** *Journal of nuclear medicine : official publication, Society of Nuclear Medicine* 1997, **38**:459-466.
16. Burger C, Buck A: **Requirements and implementation of a flexible kinetic modeling tool.** *Journal of nuclear medicine : official publication, Society of Nuclear Medicine* 1997, **38**:1818-1823.
17. Klein LJ, Visser FC, Knaapen P, Peters JH, Teule GJ, Visser CA, Lammertsma AA: **Carbon-11 acetate as a tracer of myocardial oxygen consumption.** *European journal of nuclear medicine* 2001, **28**:651-668.
18. Naya M, Murthy VL, Blankstein R, Sitek A, Hainer J, Foster C, Gaber M, Fantony JM, Dorbala S, Di Carli MF: **Quantitative relationship between the extent and morphology of coronary atherosclerotic plaque and downstream myocardial perfusion.** *Journal of the American College of Cardiology* 2011, **58**:1807-1816.

19. Goldstein RA, Kirkeeide RL, Demer LL, Merhige M, Nishikawa A, Smalling RW, Mullani NA, Gould KL: **Relation between geometric dimensions of coronary artery stenoses and myocardial perfusion reserve in man.** *The Journal of clinical investigation* 1987, **79**:1473-1478.

20. Yoshinaga K, Katoh C, Noriyasu K, Iwado Y, Furuyama H, Ito Y, Kuge Y, Kohya T, Kitabatake A, Tamaki N: **Reduction of coronary flow reserve in areas with and without ischemia on stress perfusion imaging in patients with coronary artery disease: a study using oxygen 15-labeled water PET.** *Journal of nuclear cardiology : official publication of the American Society of Nuclear Cardiology* 2003, **10**:275-283.

21. White CW, Wright CB, Doty DB, Hiratza LF, Eastham CL, Harrison DG, Marcus ML: **Does visual interpretation of the coronary arteriogram predict the physiologic importance of a coronary stenosis?** *The New England journal of medicine* 1984, **310**:819-824.

22. Naya M, Di Carli MF: **Myocardial perfusion PET/CT to evaluate known and suspected coronary artery disease.** *Q J Nucl Med Mol Imaging* 2010, **54**:145-156.

23. Siegrist PT, Gaemperli O, Koepfli P, Schepis T, Namdar M, Valenta I, Aiello F, Fleischmann S, Alkadhi H, Kaufmann PA: **Repeatability of cold pressor test-induced flow increase assessed with H(2)(15)O and PET.** *Journal of nuclear medicine : official publication, Society of Nuclear Medicine* 2006, **47**:1420-1426.

Figure legends

FIGURE 1.

(A)A cylindrical ROI was positioned manually in the left ventricle (LV) to obtain the time activity curves, LV(t), from the early phase images of the dynamic ^{11}C-acetate PET data. (B)A whole myocardial ROI was set semi-automatically to obtain the time activity curves from myocardium, R(t), using the last frame images of the dynamic ^{11}C-acetate data.

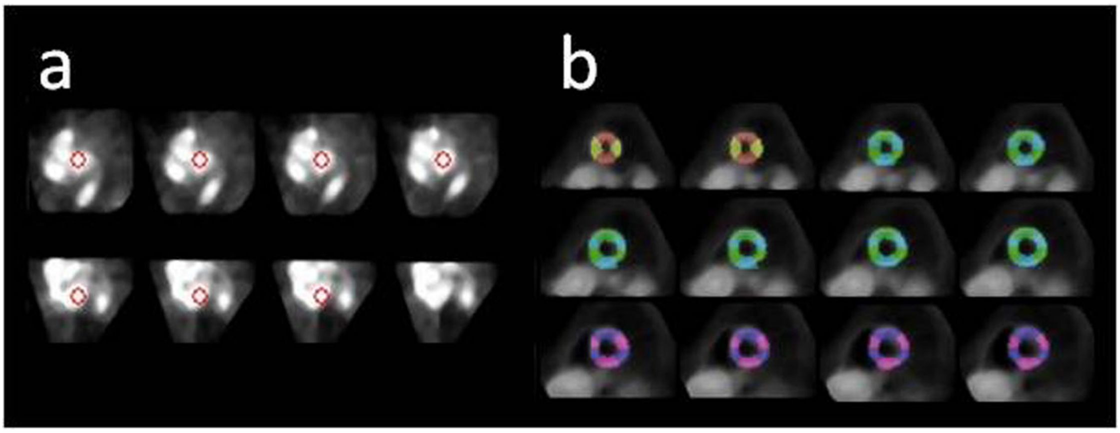

FIGURE 2. Relationship between K1 from ^{11}C-acetate and MBF from ^{15}O-H_2O PET

The relationship between K1 from ^{11}C-acetate and MBF from ^{15}O-H_2O PET using one-parameter method (A) and two-parameter method (B). Relational expression between K1 and MBF was developed from the Renkin-Crone model.

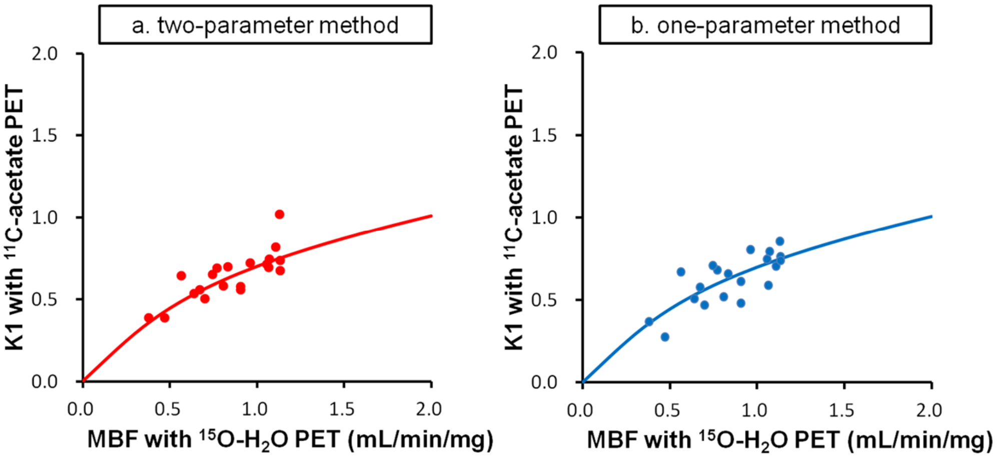

FIGURE 3. Relationship between regional MBFs from ^{11}C-acetate and ^{15}O-H$_2$O

Both one- and two-compartment models showed significant correction. The correlation using the two-compartment model (A) was significantly better than that using the one-compartment model (B).

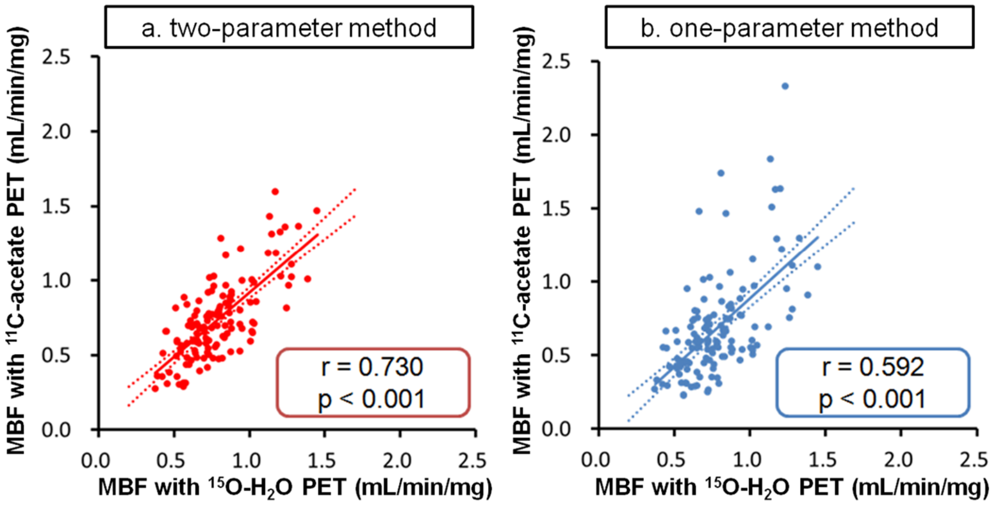

FIGURE 4. Bland-Altman plots

Bland-Altman plots presented more stable regional MBFs from the two-parameter spillover model (A) than from the conventional one-parameter model (B).

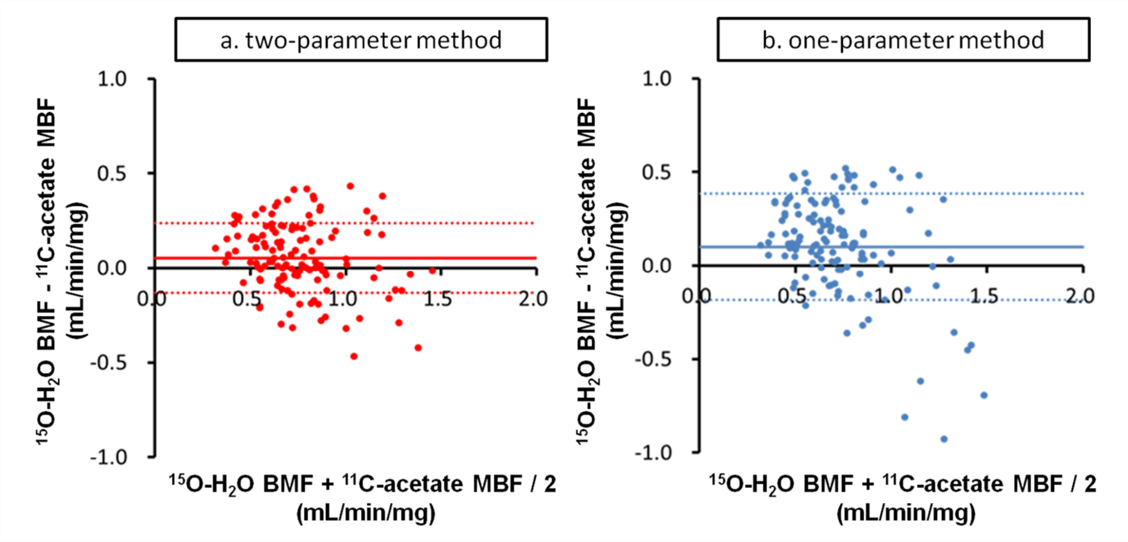

Table 1. Characteristics of participants

	Pilot Group (n=20)	Validation Group (n=43)	p value
Years old	50.9 ± 15.0	47.7 ± 14.5	0.58
Male / Female	6 / 14	14 / 29	0.84
Etiology			
Healthy volunteers	2	7	0.51
Dilated cardiomyopathy	2	4	0.93
Pulmonary hypertension	16	32	0.63

Table 2. Hemodynamic data at the scan

Pilot group (n =12)	^{11}C-acetate	^{15}O-H_2O	p value
HR	66.8 ± 13.2	65.2 ± 11.4	0.28
sBP	104.6 ± 10.4	106.9 ± 4.6	0.41
dBP	56.7 ± 6.7	60.0 ± 8.4	0.18
RPP	7004.9 ± 1692.9	6966.3 ± 1239.9	0.89

Validation group (n =39)	^{11}C-acetate	^{15}O-H_2O	p value
HR	64.6 ± 11.1	65.2 ± 10.7	0.56
sBP	99.9 ± 16.0	100.4 ± 18.1	0.68
dBP	56.6 ± 9.1	58.6 ± 11.0	0.14
RPP	6453.5 ± 1562.2	6546.4 ± 1581.9	0.46

HR, heart rate; sBP, systolic blood pressure; dBP, diastolic blood pressure; RPP, rate pressure product