

An Exploratory Study of Washout Rate Analysis for Thallium-201 Single-Photon Emission Computed Tomography Myocardial Perfusion Imaging Using Cadmium Zinc Telluride Detectors

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Abstract

The aim of this study was to assess the washout rate (WOR) for thallium-201-chloride single-photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI) using cadmium zinc telluride detectors for SPECT (CZT SPECT) versus conventional Anger-type SPECT (conventional SPECT). A total of 52 Japanese patients were examined using CZT SPECT and conventional SPECT, and the global WORs were compared. Additionally, the MPI WORs were compared for patients with a normal MPI versus those in whom MPI reflected the patients' multivessel disease (MVD) MPI. Washout rates were similar when approximated by CZT SPECT versus conventional SPECT $12.59 \pm 2.26\%/h$ vs $12.57 \pm 2.27\%/h$ ($P = .997$), respectively. The WOR values for CZT SPECT versus conventional SPECT were $13.42\%/h$ ($1.53\%/h$) vs $13.93\%/h$ ($1.24\%/h$) ($P = .337$), respectively, for 7 normal MPI patients, and $10.64 \pm 2.20\%/h$ vs $10.84 \pm 2.26\%/h$ ($P = .848$), respectively, for 7 MVD-MPI patients. The WOR values for normal MPI versus MVD-MPI patients for CZT SPECT were $13.42 \pm 1.53\%/h$ vs $10.64 \pm 2.20\%/h$ ($P = .025$), respectively. Thallium-201-chloride WOR values obtained with high-efficiency CZT SPECT, which enabled significantly reduced imaging times and use of a low-dose protocol, were similar to those obtained with conventional SPECT.

Keywords

washout rate, thallium-201-chloride, myocardial perfusion imaging, single-photon emission computed tomography, cadmium zinc telluride detectors

Introduction

Thallium-201-chloride (^{201}Tl) is widely used for single-photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI) in many Asian countries.¹⁻³ Thallium-201-chloride is a clinically important radiopharmaceutical for assessing both regional blood flow and the viability of the left ventricular myocardium. Thallium-201-chloride offers several advantages over technetium-99m, including lower extracardiac activity and higher first-pass myocardial extraction. Further, ^{201}Tl can be administered as a single injection for imaging during a stress/rest MPI protocol. The ^{201}Tl washout rate (WOR) is also a valuable tool for assisting MPI when diagnosing coronary artery disease (CAD).⁴⁻⁶

Dedicated cardiac exploratory systems with cadmium zinc telluride detectors for SPECT (CZT SPECT) offer a higher efficiency and resolution than conventional Anger-type SPECT

(conventional SPECT), thereby allowing low-dose imaging protocols and reduced acquisition times.⁷⁻⁹ The aim of this study was to assess the WOR for ^{201}Tl SPECT MPI using CZT SPECT versus conventional SPECT.

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Table 1. Patients' Characteristics.

Characteristic	Value
Age (years)	73.1 ± 8.5 (range 40-87)
Men sex, n (%)	36 (69.2)
BMI (kg/m ²)	21.8 ± 2.8 (range 16.0-28.7)
Prior myocardial infarction	10 (19.2)
Prior revascularization	26 (50.0)
Comorbidities	
Diabetes	18 (34.6)
Hypertension	30 (57.7)
Hypercholesterolemia	22 (42.3)
Chronic kidney disease	9 (17.3)
Smoking	14 (26.9)

Abbreviation: BMI, body mass index.

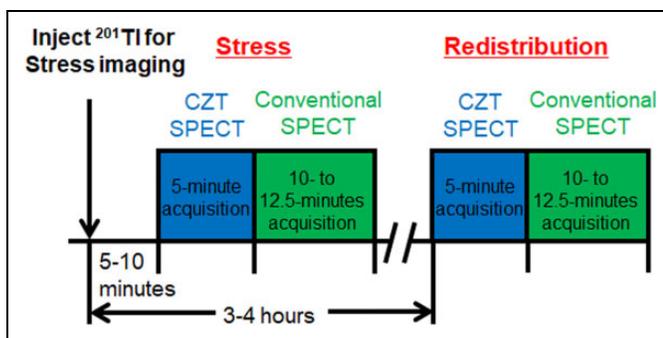


Figure 1. Study protocol for stress/redistribution myocardial perfusion imaging with thallium-201-chloride (²⁰¹Tl).

Materials and Methods

Patients

The final study population for this retrospective study comprised 52 Japanese patients (36 [69.2%] men; mean ± standard deviation [SD] age of 73.1 ± 8.5 years; standard body mass index 21.8 ± 2.8 kg/m² [16.0-28.7 kg/m²]) with suspected CAD (n = 26) or known CAD (n = 26). Each patient had undergone stress/redistribution testing during January and February 2015, which included a single injection of ²⁰¹Tl to assess myocardial ischemia, viability, and scarring of the left ventricle. The patients' clinical characteristics are shown in Table 1. The ethics committee of Hyogo Brain and Heart Center at Himeji (Himeji, Japan) approved this retrospective study.

Imaging Protocol

The imaging protocol is shown in Figure 1. In all cases, CZT SPECT and conventional SPECT were performed as consecutive acquisitions, with CZT SPECT acquisition performed prior to conventional SPECT to ensure that the interval between the 2 scans was short (to avoid stress and redistribution acquisition). Cadmium zinc telluride detectors for SPECT was performed with a 5-minute acquisition, while conventional SPECT was performed with a 10.0- to 12.5-minutes

acquisition. The injected activity was 111 MBq (3 mCi) for stress imaging. Exercise (13 patients) and adenosine (39 patients) stress testing were performed using the same protocol as previously reported.¹⁰ The CZT SPECT (D-SPECT Cardiac Scanner; Spectrum Dynamics, Caesarea, Israel) and conventional SPECT (BrightView; Philips Medical Systems, Cleveland, Ohio, USA) imaging systems were similar to those previously reported.¹⁰

Quantitative Analysis of WOR

All MPI scans were analyzed using WOR analysis software (CZT SPECT: D-SPECT WOR Software; Spectrum Dynamics; Conventional SPECT: AZE VirtualPlace HAYABUSA Heart Risk View-S; AZE Co., Ltd., Tokyo, Japan). Automated analysis compared the global WOR values for CZT SPECT versus conventional SPECT.

Additionally, WOR values were compared for 7 normal MPI patients and 7 multivessel disease (MVD) MPI patients (of 52 total patients) in each of the 2 SPECT devices. Washout rate values were also compared between 7 normal MPI patients and 7 MVD-MPI patients in the CZT SPECT. Patients with a normal MPI were diagnosed as normal MPI after an experienced nuclear cardiologist ascertained that they had not experienced cardiovascular events during a 1-year period after SPECT MPI. Multivessel disease MPI patients had undergone invasive coronary angiography within 90 days of MPI SPECT, with the angiography showing ≥75% stenosis in the presence of 2- or 3-vessel disease.

Results were calculated as percentage per hour (%/h). The formula for calculating the WOR is as follows:

$$\text{WOR (\%)} = \frac{(\text{mean stress counts}) - (\text{mean redistribution counts} \times \text{decay correction factor})}{(\text{mean stress counts}) \times 100}, \quad (1)$$

where the decay correction factor = 2 (stress and redistribution imaging time interval [hours]/72.97).¹¹

Statistics

Statistical analyses were performed with commercial statistical software (StatView version 5.0 and JMP version 11.2.0; SAS Institute, Inc., Cary, NC, USA). All continuous variables are expressed as mean (SD). Values of *P* < .05 were considered statistically significant. Cadmium zinc telluride SPECT and conventional SPECT results are depicted as both scatter plots and Bland-Altman plots. The degree of agreement was calculated according to Bland and Altman.¹² Bland-Altman limits were calculated as follows: mean of the difference ± 1.96 × SD of the difference. Pearson's correlation coefficients were also calculated. Mean WOR values were calculated from the patients' data. All differences between the 2 groups were assessed using the Mann-Whitney *U* test.

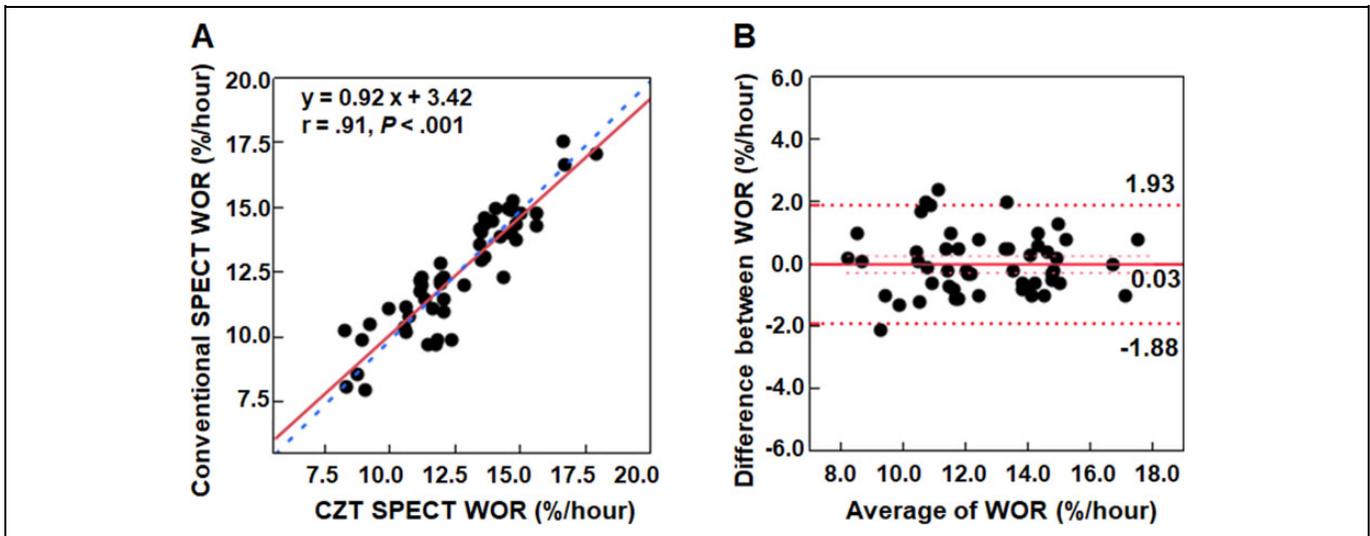


Figure 2. Linear regression analysis (A) and Bland-Altman plots (B) for cadmium zinc telluride single-photon emission computed tomography (CZT SPECT) and conventional SPECT.

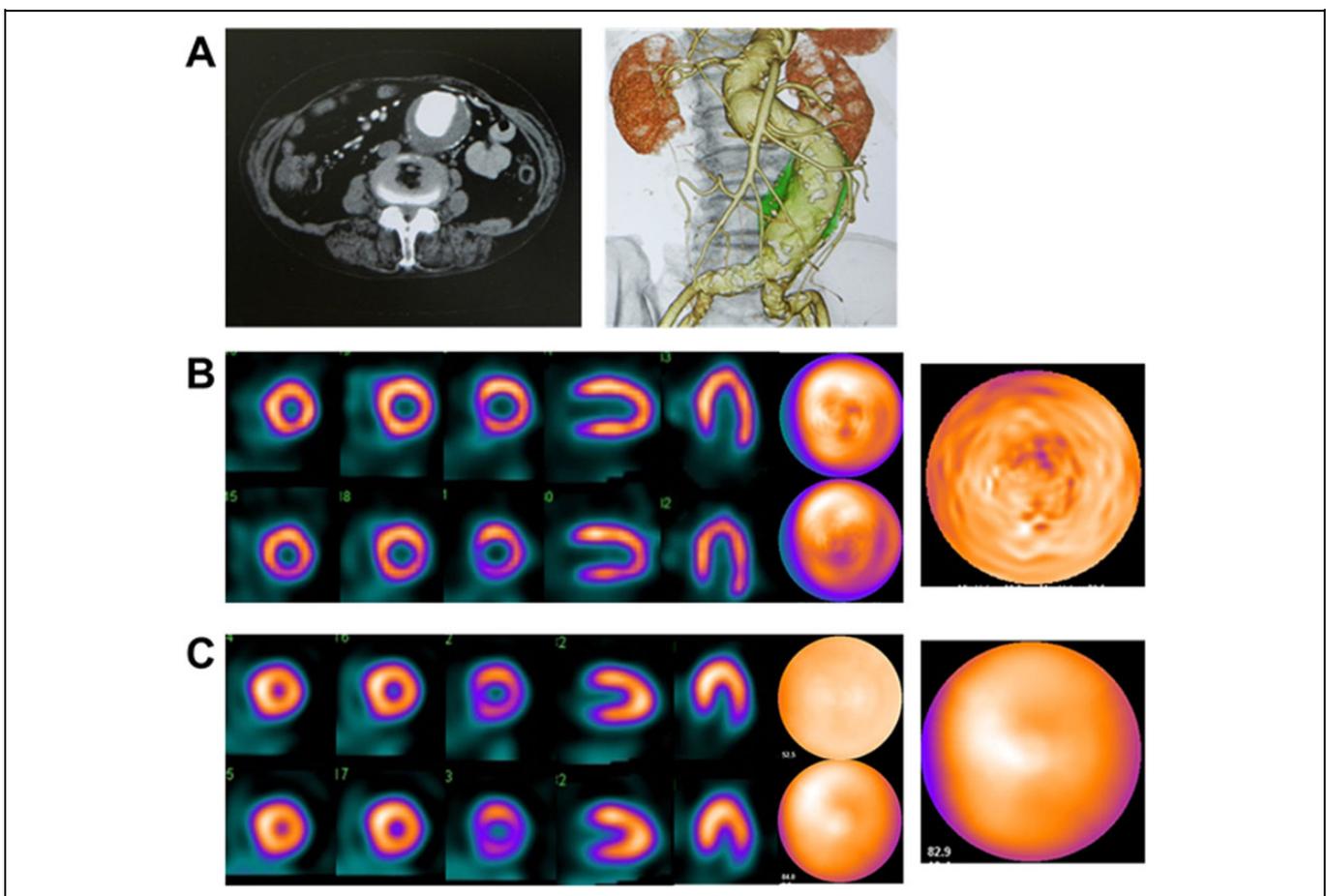


Figure 3. An 80-year-old woman was found to have an abdominal aortic aneurysm during a preoperative cardiac evaluation. A, Contrast-enhanced computed tomography shows an infrarenal abdominal aortic aneurysm. B, Cadmium zinc telluride (CZT) single-photon emission computed tomography (SPECT) stress images (top row), redistribution images (bottom row), and washout rate (WOR) (at 15.6%/h) image. C, Conventional SPECT stress images (top row), redistribution images (bottom row), and WOR (at 14.8%/h) image.

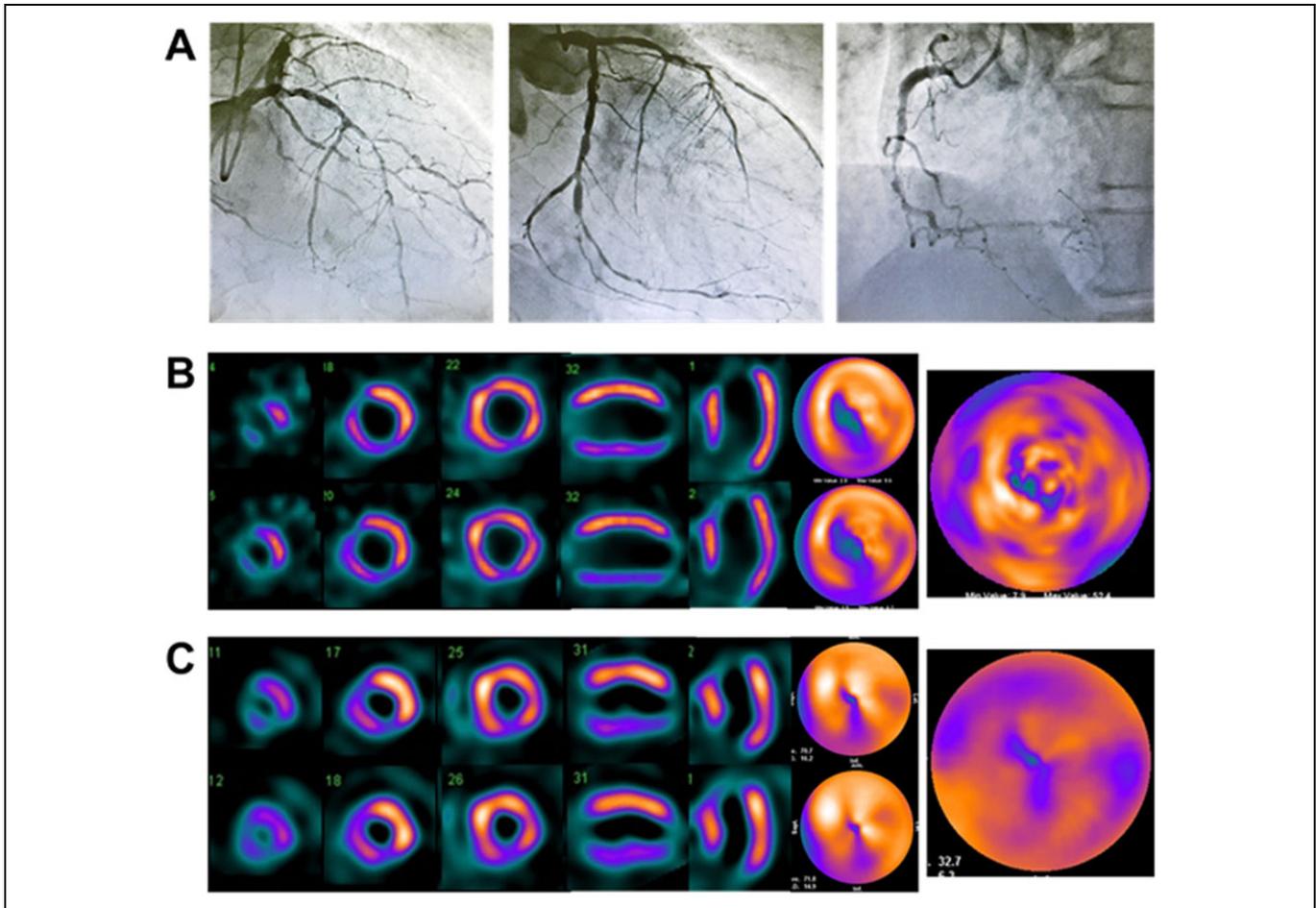


Figure 4. A 76-year-old man with effort angina pectoris. A, Invasive coronary angiography shows 3-vessel disease. B, Cadmium zinc telluride (CZT) single-photon emission computed tomography (SPECT) stress images (top row), redistribution images (bottom row), and washout rate (WOR) (at 8.7%/h) image. C, Conventional SPECT stress images (top row), redistribution images (bottom row), and WOR (at 8.6%/h) image.

Results

In all 52 patients, the global WOR values for CZT SPECT versus conventional SPECT were $12.59 \pm 2.26\%/h$ vs $12.57 \pm 2.27\%/h$ ($P = .997$), respectively. Cadmium zinc telluride SPECT and conventional SPECT results were compared using linear regression analysis (Figure 2A), with a positive correlation for the scores ($r = .91$, $P < .001$). The Bland-Altman comparison showed a mean difference score of 0.03 (Figure 2B). For factors affecting the ^{201}Tl WOR values (heart rate, ejection fraction, stress redistribution imaging time interval) for CZT SPECT versus conventional SPECT, the stress heart rates were 70.27 ± 13.03 beats per minute vs 66.63 ± 11.69 beats per minute ($P = .126$), respectively; the redistribution heart rates were 69.75 ± 12.87 beats per minute vs 66.06 ± 12.50 beats per minute ($P = .112$), respectively; the stress ejection fractions were $56.48 \pm 16.63\%$ vs $59.63 \pm 15.33\%$ ($P = .269$), respectively; the redistribution ejection fractions were $57.37 \pm 16.73\%$ vs $60.21 \pm 14.96\%$ ($P = .265$), respectively; and the stress redistribution imaging time intervals were

3.47 ± 0.23 hours vs 3.46 ± 0.22 hours ($P = .747$), respectively.

Washout rate values for CZT SPECT versus conventional SPECT were $13.42 \pm 1.53\%/h$ vs $13.93 \pm 1.24\%/h$ ($P = .337$), respectively, for the 7 normal MPI patients, and $10.64 \pm 2.20\%/h$ vs $10.84 \pm 2.26\%/h$ ($P = .848$), respectively, for the 7 MVD-MPI patients. The normal MPI versus MVD-MPI patients' WOR values for CZT SPECT were $13.42 \pm 1.53\%/h$ vs $10.64 \pm 2.20\%/h$ ($P = .025$), respectively. Representative cases are shown in Figures 3 and 4.

Discussion

Cadmium zinc telluride SPECT is a fast and efficient imaging technology that provides high-quality images and high diagnostic accuracy for the detection of CAD.^{8,13} Previous studies have shown that perfusion abnormalities detected with CZT SPECT are highly correlated with those using conventional SPECT.^{7,14} The CZT SPECT image quality with ^{201}Tl was reported to be superior to that achieved with conventional

SPECT, with significantly reduced imaging times and radioisotope doses but similar diagnostic accuracy.⁹ Thallium-201-chloride WOR is particularly useful for assisting MPI to diagnose CAD.⁴⁻⁶ In particular, in the presence of multivessel or diffuse CAD, ²⁰¹Tl WOR can help identify CAD in patients with apparently normal or slightly abnormal MPI. Cadmium zinc telluride SPECT provides better image quality and higher resolution than conventional SPECT, although there is potential for differences in the WORs. However, the use of ²⁰¹Tl WOR with CZT SPECT has not been reported. Thus, we compared WOR values using CZT SPECT and conventional SPECT in 52 patients with or without CAD, and between 7 normal MPI patients and 7 MVD-MPI patients. We found similar approximated global WOR values and a good correlation score between CZT SPECT and conventional SPECT. Further, WORs approximated by CZT SPECT and conventional SPECT were similar for normal MPI patients and MVD-MPI patients. This relates to the use of the same WOR calculation formula (using decay correction) for the 2 SPECT devices.

Cadmium zinc telluride SPECT and conventional SPECT were not subjected to attenuation correction in the current study as we used a CZT SPECT (D-SPECT cardiac scanner) and a conventional SPECT (BrightView), neither of which had attenuation correction (ie, neither SPECT system had gadolinium-153 transmission line sources or low-dose computed tomography).

A potential limitation of this study was the small sample size and the single-center study design. Further, this study was only based on a Japanese population using a D-SPECT camera. As the participants were Japanese, they had a lower overall body mass index. Thus, a study of Europeans and Americans with a larger body mass index may have produced different results. D-SPECT and other CZT camera system (eg, Discovery NM 530c camera; GE Healthcare, Haifa, Israel) also have different scanning methods and positioning, which may have produced different results. D-SPECT uses rotational wide-angle square-hole tungsten collimators and region of interest–centric scanning, with an upright position imaging used in all cases in the present study. In contrast, the Discovery NM 530c uses stationary multiple pinhole collimators and 19 detectors, usually imaging in a supine position.

Conclusion

Clinically, ²⁰¹Tl WOR values obtained with high-efficiency CZT SPECT, which enabled significantly reduced imaging times and use of a low-dose protocol, were similar to those obtained with conventional SPECT. Thallium-201-chloride WOR analysis using CZT SPECT may be useful for identifying MVD and diffuse CAD in patients with apparently normal or slightly abnormal MPI.

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Declaration of Conflicting Interests

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