Validation of Automated Quantification of Myocardial Perfusion Single-Photon Emission Computed Tomography Using Heart Score View in Patients With Known or Suspected Coronary Artery Disease

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SUMMARY

Heart Score View (HSV) is a free software package for automated quantification of myocardial single photon emission computed tomography (SPECT) imaging using a standard Windows computer. We compared scoring results of myocardial perfusion among visual analysis, Quantitative Perfusion SPECT (QPS), and HSV in patients with known or suspected coronary artery disease.

This study included 75 consecutive patients with known or suspected coronary artery disease who underwent adenosine stress-rest TI-201 SPECT. Analysis of myocardial perfusion SPECT was performed on a standard 17-segment model visually and using QPS and HSV.

There were 54 male and 21 female patients with a mean age of 70.5 ± 10.7 years. Thirteen patients (17%) had prior myocardial infarction. Summed stress score (SSS) and summed rest score (SRS) in the mid and basal areas were significantly higher on HSV than visual analysis or QPS. There was no significant difference in SDS in the whole area among the 3 methods. Similar results were found even in patients without prior myocardial infarction. Manual setting of the left ventricular cavity improved the correlations of SSS, SRS and SDS between HSV and the other methods.

Our data suggested that HSV was comparable with visual analysis or QPS in scoring myocardial perfusion when manual setting of the left ventricular cavity is applied. (Int Heart J 2014; 55: 350-356)

Key words: Myocardial ischemia, Scintigraphy

Myocardial perfusion single photon emission computed tomography (SPECT) with exercise or pharmacological stress is a noninvasive method to detect coronary artery disease.¹⁻³⁾ Although myocardial perfusion SPECT allows accurate diagnosis of coronary artery disease, visual analysis is subject to inter- and intraobserver variability even for experienced observers. To overcome these limitations, several software packages for automated quantification such as Quantitative Perfusion SPECT (QPS; version 7.2) (Cedars-Sinai Medical Center, USA) have been developed and commonly used to optimise reproducibility and improve accuracy.⁴⁻⁶⁾ Recently, a new software package called Heart Score View (HSV; version 1.5) (Nihon Medi-Physics, Japan) was developed in Japan.⁷⁻⁹⁾ In the current study, we compared the scoring results of myocardial perfusion among visual analysis, QPS and HSV in patients with known or suspected coronary artery disease.

METHODS

Patients: This study included 75 consecutive patients with known or suspected coronary artery disease who underwent adenosine stress-rest TI-201 SPECT at Hiroshima University Hospital. Patients with prior myocardial infarction or prior coronary intervention were included. Patients with significant valvular disease or congestive heart failure were excluded.

TI-201 SPECT: All patients fasted overnight, and underwent stress-rest TI-201 gated SPECT.¹⁰⁾ Adenosine was infused over 6 minutes ($120 \mu\text{g/kg/minute}$), and TI-201 (111 MBq [3.0 mCi]) was injected 3 minutes after the initiation of adenosine infusion. The stress TI-201 SPECT acquisition was started 5 minutes after the stress test. Four hours later, rest TI-201 SPECT images were also obtained. ECG-gated myocardial perfusion images were acquired with a dual-detector $90^\circ\gamma$ -camera (E.CAM; Siemens Medical Solutions). Images were acquired with the following parameters: 32 total projections; 180° from right anterior oblique to left posterior oblique and a noncircular orbit; 64×64 matrix; 0.6-cm pixel size; 8

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frames per cardiac cycle; low-energy, high-resolution collimation; and 40 seconds per stop. TI-201 SPECT images were acquired with a 10% symmetric window over the 80-keV TI-201 photopeak. Filtered backprojection with a Butterworth prefilter (order, 5; cutoff frequency, 0.65 cycles/pixel for rest and stress images) and decay correction were used for reconstruction. No scatter or attenuation correction was applied.

Visual analysis: Visual analysis of myocardial perfusion SPECT was performed on a standard 17-segment model.¹¹⁾ Each segment was graded by consensus by two nuclear medicine physicians (T.I. and S.K.) using a 5-point scale (0, normal uptake; 1, mildly reduced uptake; 2, moderately reduced uptake; 3, severely reduced uptake; 4, absence of detectable radiotracer in a segment) recommended by the Cardiac Imaging Committee of the American Heart Association and American Society of Nuclear Cardiology (ASNC).¹²⁾ The summed stress score (SSS) and the summed rest score (SRS) were obtained by adding the scores for the 17 segments. The summed difference score (SDS) was obtained by subtracting SRS from SSS.

Automated quantification: Automated quantification of myocardial perfusion was performed using QPS (version 7.2) and HSV (version 1.5). The HSV software generates a polar-map from myocardial perfusion SPECT images. Mean % uptake in each segment is automatically scored from normal (0) to absent (4) using a 5-point scale based on ASNC guidelines. The thresholds of % uptake for scoring were described in previous reports. Briefly, segments with a mean uptake of < 70% on images were defined as abnormal. Segments with 60 to 70%, 50 to 60%, and 40 to 50% uptake were scored as 1, 2, and 3, respectively. Segments with < 40% uptake were recognized as absent uptake, and scored as 4. Values of SSS, SRS and SDS on stress-rest TI-201 gated SPECT were automatically calculated with QPS and HSV using a normal database developed for Japanese patients.¹³⁾ Reverse redistribution on a rest TI-201 SPECT image was not reflected in the SDS, and it was considered to be zero. Regional SSS, SRS and SDS in apical, mid and basal areas were also calculated to evaluate the characteristics of each software.

Statistical analysis: All data are expressed as the mean $\pm$ SD. Analysis of variance was performed to test for differences of values among the 3 methods. Multiple comparisons were analyzed using the Bonferroni test. Correlations between the 2 methods were tested with Spearman's rank correlation coefficient (ρ). Bland-Altman plot analysis was applied to assess the agreement between the 2 methods. The regression of the mean and the difference between the 2 methods were analyzed. Differences were considered significant if the P value was < 0.05.

RESULTS

Patient characteristics: Patient characteristics are shown in Table I. There were 54 male and 21 female patients with a mean age of 70.5 ± 10.7 years. Forty-eight patients (64%) had hypertension and 26 (35%) had diabetes mellitus. Thirteen patients (17%) had prior myocardial infarction. The infarct-related artery was the left anterior descending artery in 8 patients, left circumflex artery in one patient, and right coronary artery in 4 patients. Thirteen patients (17%) had prior coronary intervention.

SSS, SRS and SDS: SSS, SRS and SDS assessed by visual

Table I. Patient Characteristics

Number of patients	75
Male gender	54 (72%)
Age (years)	70.5 ± 10.7
Hypertension	48 (64%)
Diabetes mellitus	26 (35%)
Dyslipidemia	39 (52%)
Prior myocardial infarction	13 (17%)
Prior coronary intervention	13 (17%)
Medications	
Angiotensin-converting enzyme inhibitors	7 (9%)
Angiotensin II type 1 receptor blockers	34 (45%)
Beta blockers	13 (17%)
Calcium channel blockers	7 (9%)
Statins	33 (44%)
Aspirin	28 (37%)

Table II. SSS, SRS and SDS Values Assessed by the 3 Methods

	Visual analysis	QPS	HSV	P
SSS	$5.9 \pm 7.2^*$	$5.8 \pm 5.9^*$	10.3 ± 7.3	< 0.01
SRS	$2.4 \pm 5.9^*$	$3.1 \pm 5.4^*$	7.2 ± 7.1	< 0.01
SDS	3.5 ± 4.0	2.8 ± 2.8	3.7 ± 3.9	NS

SSS indicates summed stress score; SRS, summed rest score; SDS, summed difference score; QPS, quantitative perfusion single photon emission computed tomography; and HSV, heart score view. P < 0.01 versus HSV.

analysis, QPS and HSV are shown in Table II. SSS and SRS were significantly higher on HSV than visual analysis or QPS (Figure 1). There was no significant difference in SDS among the 3 methods.

Regional SSS, SRS and SDS in all the patients are shown in Figure 2. SSS and SRS in the mid and basal areas were significantly higher on HSV than visual analysis or QPS. There was no significant difference in SDS in the whole area among the 3 methods. Similar results were found even in patients without prior myocardial infarction (Figure 3).

Correlations of SSS, SRS and SDS between the different methods: Correlations of SSS, SRS and SDS between the different methods are shown in Table III. In the overall patient population, the best correlations of their values were found between visual analysis and QPS. Correlations between HSV and the other methods were inferior to those between visual analysis and QPS. Similar results were found even in patients without prior myocardial infarction.

Effects of manual setting of HSV on SSS, SRS and SDS: Because SSS and SRS on HSV were higher in the basal area, manual setting of the left ventricular cavity was applied (semi-automated HSV). This manual setting improved the correlations of SSS, SRS and SDS between HSV and the other methods (Table III). There were good correlations of SSS (Figure 4), SRS (Figure 5) and SDS (Figure 6), and Bland-Altman plots showed good agreements of their values between semiautomated HSV and the other methods.

DISCUSSION

In the current study, we demonstrated the following: 1)

Figure 1. Automated quantification using QPS and HSV. In this case, SSS and SRS were markedly higher on HSV than QPS.

Figure 2. Regional SSS, SRS and SDS in overall patients. SSS indicates summed stress score; SRS, summed rest score; and SDS, summed difference score.

Figure 3. Regional SSS, SRS and SDS in patients without prior myocardial infarction. SSS indicates summed stress score; SRS, summed rest score; and SDS, summed difference score.

Table III. Correlations of SSS, SRS and SDS Values Between the 2 Different Methods

			SSS		SRS		SDS	
			ρ	P	ρ	P	ρ	P
Overall patients ($n = 75$)								
Visual analysis	versus	QPS	0.75	< 0.01	0.66	< 0.01	0.77	< 0.01
Visual analysis	versus	HSV	0.67	< 0.01	0.50	< 0.01	0.49	< 0.01
QPS	versus	HSV	0.65	< 0.01	0.43	< 0.01	0.43	< 0.01
Visual analysis	versus	semiautomated HSV	0.74	< 0.01	0.50	< 0.01	0.65	< 0.01
QPS	versus	semiautomated HSV	0.73	< 0.01	0.52	< 0.01	0.60	< 0.01
Patients without prior myocardial infarction ($n = 62$)								
Visual analysis	versus	QPS	0.68	< 0.01	0.56	< 0.01	0.77	< 0.01
Visual analysis	versus	HSV	0.54	< 0.01	0.30	< 0.05	0.53	< 0.01
QPS	versus	HSV	0.54	< 0.01	0.28	< 0.05	0.50	< 0.01
Visual analysis	versus	semiautomated HSV	0.63	< 0.01	0.31	< 0.05	0.66	< 0.01
QPS	versus	semiautomated HSV	0.64	< 0.01	0.40	< 0.01	0.62	< 0.01

SSS indicates summed stress score; SRS, summed rest score; SDS, summed difference score; QPS, quantitative perfusion single photon emission computed tomography; and HSV, heart score view.

Figure 4. Correlations and scatter plots of SSS between the different methods. SSS indicates summed stress score.

Figure 5. Correlations and scatter plots of SRS between the different methods. SRS indicates summed rest score.

SSS and SRS were significantly higher on HSV than visual analysis or QPS mainly due to different scoring results in the basal area; 2) SDS was similar among the 3 methods; and 3) manual setting of the left ventricular cavity improved the correlations of SSS, SRS and SDS between HSV and the other methods.

Visual analysis of myocardial perfusion SPECT remains to be the standard clinical practice, but is dependent on a subjective interpretation of the data and prone to possible bias related to observer experience. Several software packages for automated quantification such as QPS have been developed. Slomka, *et al* evaluated the diagnostic performance of QPS in patients with angiographically proven coronary artery disease, and reported that sensitivity, specificity, and accuracy were 92%, 79%, and 88%, respectively.²⁾ Nakajima, *et al* also showed its good diagnostic performance in Japanese patients with coronary artery disease.¹⁴⁾ As shown in the current study, SSS, SRS or SDS on QPS correlates well with that on visual analysis. QPS provides high diagnostic performance for the

detection of coronary artery disease, and its usefulness is well-established.

HSV is a free software package which was recently developed in Japan.⁷⁻⁹⁾ It is applicable to any type of myocardial SPECT imaging using a standard Windows computer. In addition, HSV has another advantage that SPECT data can be analyzed in any institution because HSV is a free software package not requiring a dedicated computer. Several studies have reported the usefulness of HSV in detecting coronary artery disease^{7,8)} or assessing risk stratification,⁹⁾ but its scoring performance remains to be investigated. In the current study, we showed that SSS and SRS were significantly higher on HSV than visual analysis or QPS mainly due to different scoring results in the basal area. Because HSV systematically produced higher values of SSS and SRS in the basal area, its algorithm appeared to be associated with this phenomenon. Manual setting of the left ventricular cavity resulted in good correlation and agreement of the SSS, SRS or SDS value between HSV and the other methods. Yoshinaga, *et al* previously evaluated

Figure 6. Correlations and scatter plots of SDS between the different methods. SDS indicates summed difference score.

the scoring results of HSV with manual setting in patients without prior myocardial infarction, and reported that there were good correlations of these values between visual analysis and HSV.⁷⁾ Nanasato, *et al* evaluated the diagnostic performance of HSV in patients with angiographically proven coronary artery disease, and reported that the sensitivity, specificity, and accuracy were 81%, 80%, and 80%, respectively.⁸⁾ According to our results and previous reports, HSV appeared to be comparable with visual analysis or QPS in diagnostic performance of coronary artery disease when manual setting of the left ventricular cavity was applied.

There are some limitations in this study. First, only half of our patients underwent coronary angiography, and we could not show the diagnostic accuracy of detecting the location of myocardial ischemia based on angiographic data. Second, HSV was validated on TI-201 SPECT. We did not evaluate the reliability of HSV on SPECT using a technetium-labeled tracer. Finally, the small sample size was a major limitation of this study.

In conclusion, HSV is comparable with visual analysis or QPS in scoring myocardial perfusion when manual setting of the left ventricular cavity is applied.

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