Semi-quantitative segmental perfusion scoring in myocardial perfusion SPECT: visual vs. automated analysis

Original Article

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ABSTRACT

Introduction: It is recommended that the physician apply at least a semi-quantitative segmental scoring system in myocardial perfusion SPECT. We aimed to assess the agreement between automated semi-quantitative analysis using QPS (quantitative Perfusion SPECT) software and visual approach for calculation of summed stress score (SSS), summed rest score (SRS) and summed difference score (SDS).

Methods: We retrospectively studied 1782 consecutive patients who had undergone two-day stress-rest Tc99m-MIBI myocardial perfusion SPECT. Based on 17-segment 5-scale scoring system, SSS, SRS and SDS were calculated visually and using QPS software.

Results: There was good correlation between visual analysis and QPS software in calculation of SSS and SRS and a fair correlation for SDS. However, there was statistically significant difference between two methods. By Bland-Altman analyses mean value of the differences (estimated bias) differs significantly from 0 on the basis of 1-sample t-test. Based on bias, Precision and 95% limits of agreement, discrepancies between measurements indicate no agreement equally through the range of measurements, so there is a proportional bias. Based on SSS, SRS and SDS ≤ 3 and SSS, SRS and SDS >3, there was fair concordance between the visual assessment and automated QPS calculation. Kappa statistics was 0.41 ($P<0.001$), 0.69 ($P<0.001$) and 0.25 ($P<0.001$) for SSS, SRS and SDS respectively.

Conclusion: Although semi-quantification sores by visual and automated analysis is correlated, the agreement assessed by Bland-Altman analysis is not high especially in more extensive perfusion defects. Semi-quantitative automated analysis should be used as a supplement to the visual assessment.

Key words: Myocardial perfusion SPECT; Semi-quantification; Visual analysis; Automated analysis; Scoring system

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INTRODUCTION

Perfusion assessment of myocardial perfusion SPECT (MPS) can be performed visual or by automated software [1]. Visual interpretation is subjective and is prone to intra-observer variability and to have lower repeatability than objective automated quantitative measurements [2, 3]. In addition to the qualitative evaluation of perfusion defects, it is recommended that the physician also apply at least a semi-quantitative segmental scoring system [4]. For this purpose, a semi-quantitative scoring system using a left ventricular-segmented model (17 or 20 segments) and scored with a five-point scale was introduced [3]. In order to facilitate consistency of nomenclature with other imaging modalities, the 17-segment model is preferred [4, 5].

Left ventricular myocardial walls in tomogram perfusion images are divided into a number of segments, e.g. 17 (Figure 1). Each segment is scored separately using a 5-point scoring system ranging from 0 (normal uptake) to 4 (uptake absent) [5-7]. The summed stress scores (SSS) equals the sum of the stress scores of all the segments and the summed rest score (SRS) equals the sum of the resting scores of all the segments. Difference between the SSS and SRS is summed difference score (SDS) and it is a measure of inducible ischemia [4]. This semi-quantitative scoring system provides a standard and reproducible assessment of perfusion defect severity and extent. SSS, SRS and SDS can provide valuable diagnostic and prognostic parameters [3]. In addition to visual calculation of the SSS, SRS and SDS, computer software packages were developed for automatic generation of semi-quantitative segmental scores [3, 8-9]. Agreement for the visual or automated semi quantitative systems is essential and understanding of the differences is necessary. QPS (Quantitative Perfusion SPECT) is one of the widely used and commercially available software packages.

In this study, we aimed to assess the agreement and concordance between automated semi-quantitative analysis using QPS software and visual approach for calculation of SSS, SRS and SDS.

METHODS

Study population

We retrospectively studied 1782 consecutive patients (732 male, 1050 female) with mean age 59.71±12.12 (25-94) who had underwent MPS in our nuclear medicine department. They were referred for clinically stress/rest Tc-99m Sestamibi MPS.

Myocardial perfusion SPECT

All patients underwent two-day stress-rest Tc99m-MIBI (methoxyisobutyl-isonitrile) myocardial perfusion SPECT (MPS). In a two-day protocol, after intravenous injection of 740-925 MBq Tc99m-MIBI SPECT acquisition was performed with a Dual-head SPECT system with the detectors oriented at 90 degrees ((Dual-Head Variable-Angle E.CAM; Siemens) equipped with a low-energy-high resolution collimator. A 20% window with 140 keV energy peak was used. A total of 32 projections (step-and-shoot mode, 25 s per view) were obtained over a 180° arc commencing from the right anterior oblique to left posterior oblique view. We used a zoom factor of 1.45. The images were stored in a 64×64 matrix in the computer and reconstructed by filtered backprojection using a Butterworth filter (cut-off value was 0.55 cycle/cm for ungated data, order =5). No attenuation or scatter correction was applied. All reconstructed tomographic images were interpreted by consensus of 2 experienced physicians. Based on 17-segment model and 5-point scale system (0, normal perfusion; 1, mildly reduced uptake; 2, moderately reduced uptake; 3, severely reduced uptake; and 4, absent uptake) visual semi-quantitative scores: SSS, SRS and SDS were calculated (Figure 1) [6].

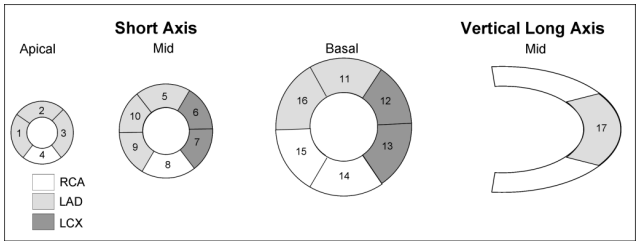

Fig 1. 17-segment 5-point scale for semi-quantitative assessment of myocardial perfusion.

Readers were blinded regarding clinical information, final diagnosis and results of automatic quantifications. Using QPS software, 17-segment automatic quantification of SSS, SRS and SDS was performed.

Statistical analysis

All continuous variables are reported as mean±SD. Univariate analyses of continuous variables were performed using the paired sample t test for the comparison of two studies and categorical variables were compared using the chi-squared test. Pearson correlation coefficients were calculated. Diagnostic concordance between the visual and quantitative methods was assessed with the kappa statistic. The Bland-Altman method was applied to determine the bias and agreement between quantitative and visual methods. $P<0.05$ was considered to represent a statistically significant difference.

Table 1: Calculated summed stress score (SSS), summed rest score (SRS) and summed difference score (SDS) visually and using QPS (Quantitative Perfusion SPECT) software.

Variable	Visual	QPS	t–test P value	Correlation: r (p value)
SSS	3.36±5.94	5.33±7.87	p<0.001	0.797 (p<0.001)
SRS	2.25±5.04	2.80±6.79	p<0.001	0.838 (p<0.001)
SDS	1.34±2.59	2.56±3.06	p<0.001	0.424 (p<0.001)

Table 2: Categorized summed stress score (SSS) calculated visually and using QPS (Quantitative Perfusion SPECT) software (P<0.001).

		QPS		Total
		SSS≤3	SSS>3	
Visual	SSS≤3	944(68.9%)	427(31.1%)	1371 (100%)
	SSS>3	53(13.9%)	328(86.1%)	381 (100%)
Total		997	755	1752

Table 3: Categorized summed rest score (SRS) calculated visually and using QPS (Quantitative Perfusion SPECT) software (P<0.001).

		QPS		Total
		SRS≤3	SRS>3	
Visual	SRS≤3	1302(92.6%)	104(7.4%)	1406 (100%)
	SRS>3	33(14.4%)	196(85.6%)	229 (100%)
Total		1335	300	1635

Table 4: Categorized summed difference score (SDS) calculated visually and using QPS (Quantitative Perfusion SPECT) software (P<0.001).

		QPS		Total
		SDS≤3	SDS>3	
Visual	SDS≤3	1119 (78.0%)	315 (22.0%)	1434 (100%)
	SDS>3	80 (40%)	120 (60%)	200 (100%)
Total		1999	435	1634

RESULTS

According to the perfusion patterns stress/rest tomograms, 1203(66.1%) had normal myocardial perfusion SPECT, 310(17.4%) patients had reversible defects, 72(4.0%) had fixed defects and 197(11.1%) patients had partially reversible perfusion defects. Table 1 showed SSS, SRS and SDS calculated visually as well as using QPS software in all patients. There was good correlation between visual analysis and QPS software in calculation of SSS and SRS and a fair correlation in calculation of SDS. However, there was statistically significant difference between two methods.

The differences of visual and automated QPS assessments by Bland-Altman analyses are shown in Figure 2. Mean value of the differences (estimated bias) differs significantly from 0 on the basis of 1-sample t-test. Bias (mean difference), Precision (SD) and 95% limits of agreement (mean ±1.96SD) for SSS were -1.97, 4.77, and -11.31 to 7.37 respectively. Bias (mean difference), Precision (SD) and 95% limits of agreement (mean ±1.96SD) for SRS were -.54, 3.76, and -7.91 to 6.82 respectively. Bias (mean difference), Precision (SD) and 95% limits of agreement (mean ±1.96SD) for SDS were -1.22, 3.06 and -7.21 to 4.78 respectively. Discrepancies between measurements indicate no equal agreement through the range of measurements, so there is a proportional bias.

Based on SSS, SRS and SDS ≤3 and SSS, SRS and SDS >3, there was fair concordance between the visual assessment and automated QPS calculation (Table 2, 3 and 4). Kappa statistics was 0.41 (P<0.001), 0.69 (P<0.001) and 0.25 (P<0.001) for SSS, SRS and SDS respectively. These values suggest moderate to good agreement for SRS but weak agreement for SSS and SDS specially SDS.

DISCUSSION

Semi-quantitative analysis of myocardial perfusion adds useful information, including prognostic information, and improves reproducibility as well as reliability of interpretations [10]. A variety of automated semi-quantitative scores and polar maps have been developed. Abnormalities are defined by comparison with a gender-matched normal database [3, 11].

In scoring systems such as semi-quantitative 17-segment system, it is possible to determine perfusion scores (SSS, SRS and SDS) based on visual assessment or using automated software programs. A number of programs for semi-quantitative analysis have been validated [8]. QPS is one of the most validated and common software used in this setting.

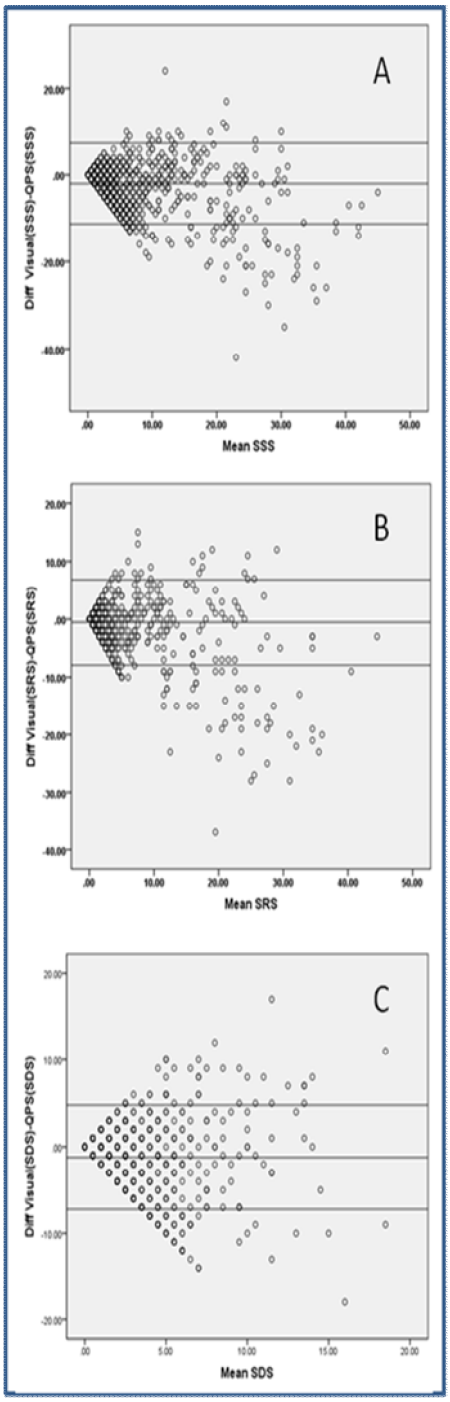

Fig 2. Bland-Altman analysis of calculated perfusion scores visually and using QPS (Quantitative Perfusion SPECT) software. A: Summed stress score (SSS), B: Summed rest score (SRS) and C: Summed difference score (SDS) visually and using QPS (Quantitative Perfusion SPECT) software.

We observed not high but weak to modest level of diagnostic agreement between the visual assessment of myocardial perfusion with 99mTc sestamibi SPECT and the computer derived automated SSS, SRS and SDS (weighted Kappa: 0.41, 0.69 and 0.25

respectively). Based on κ statistics, bias and precision in Bland-Altman analysis, SRS calculation had better values of agreement between visual and automated assessment.

Based on Bland-Altman analysis, we observed two remarkable points: first the agreement between two methods is not high and second the relationship is proportional: in low scores, agreement is higher than high scores indeed when there are multiple perfusion defects, agreement is lower.

Our findings are less compatible with the report from the group that developed the commercial software [9]. Leslie et al. [12] reported good concordance between the original visual interpretation and the automated SSS. In their study, they considered the automated derived SSS≤3 as normal comparing with the visual findings.

Of the 388 patients having visually normal scans, 305 (79%) had SSS≤3 and of the 330 patients were visually abnormal, 268 (81%) with SSS>3. The kappa statistic was 0.60 (P<0.0001) [12].

Hsu et al. reported that diagnostic performance of automated semi-quantitative analysis with 4D-MSPECT was comparable with the visual approach [3]. However, they reported moderate agreement for stress and rest images (weighted κ=0.55, weighted κ=0.50 respectively) between visual and automated 4D-MSPECT segmental scores (based on scores 0, 1, 2, 3, 4).

In practice, nuclear medicine physicians integrate the patients' clinical data and review image quality and attenuation artifacts and put all findings into consideration for calculation of perfusion scores [3]. Semi-quantitative automated analysis should be used as a supplement to the visual assessment and should not be reported in isolation from the review of the images [10]. Despite the advantages of quantitative analysis, visual analysis is still an integral part of myocardial perfusion SPECT interpretation, since the quantitative analyses have not yet been refined to recognize a variety of artifactual patterns [11]. It is recommended that semi-quantitative visual analysis and automated analysis be assessed simultaneously [11]. Physicians should be aware of the variability that exists between visual analysis and software packages as well as different interpreting physicians and software factors [3]. Concordant quantitative findings with the clinical impression can result more confidence in the interpretation, however, in presence of discordant findings, more careful review of the scan is necessary [12].

The result of our study including discrepancy with previous reports and lack of expected agreement between visual and automated calculation of SSS, SRS and SDS raises questions which need explanations:

- In presence of multiple defects and high scores, variability between measurements would be high.
- Our incorporated normal data base in the computer software program may be not a good reference population.
- Software cannot recognize some of the artifactual patterns easily recognized by visual inspection.
- On the other hand, in automated programs the patient's data was compared with normal data base. So for calculation of perfusion scores in different segments (for example in the inferior and anteroapical segments), the software may consider zero score based on diaphragmatic or breast attenuations which are existing in normal data pool. On the other hand, in visual scoring we may consider no zero scores for these segments.

In our retrospective study, we didn't have the data related to segment-by-segment scores as a limitation of study. So we recommend performing a prospective study with a large population to compare the visual and automated analysis based on a segment-by-segment protocol to be able to define the regions with most variability.

CONCLUSION

The present study demonstrates that although semi-quantification sores by visual and automated analysis more or less are in agreement but this correlation as assessed by Bland-Altman analysis is not high especially in more extensive perfusion defects. Semi-quantitative automated analysis should be used as a supplement to the visual assessment and should not be reported in isolation from the review of the images.

REFERENCES

1. Xu Y, Hayes S, Ali I, Ruddy TD, Wells RG, Berman DS, Germano G, Slomka PJ. Automatic and visual reproducibility of perfusion and function measures for myocardial perfusion SPECT. J Nucl Cardiol. 2010 Dec;17(6):1050-7.
2. Berman DS, Kang X, Gransar H, Gerlach J, Friedman JD, Hayes SW, Thomson LE, Hachamovitch R, Shaw LJ, Slomka PJ, Yang LD, Germano G. Quantitative assessment of myocardial perfusion abnormality on SPECT myocardial perfusion imaging is more reproducible than expert visual analysis. J Nucl Cardiol. 2009 Jan-Feb;16(1):45-53.
3. Hsu CC, Chen YW, Hao CL, Chong JT, Lee CI, Tan HT, Wu MS, Wu JC. Comparison of automated 4D-MSPECT and visual analysis for evaluating myocardial perfusion in coronary artery disease. Kaohsiung J Med Sci. 2008 Sep;24(9):445-52.

4. Holly TA, Abbott BG, Al-Mallah M, Calnon DA, Cohen MC, DiFilippo FP, Ficaro EP, Freeman MR, Hendel RC, Jain D, Leonard SM, Nichols KJ, Polk DM, Soman P; American Society of Nuclear Cardiology. Single photon-emission computed tomography. J Nucl Cardiol. 2010 Oct;17(5):941-73.

5. Dabbagh Kakhki VR. Gated myocardial perfusion SPECT in patients with kidney transplantation: Semi-quantification. Iran J Nucl Med. 2013;21(2):44-45.

6. Dabbagh Kakhki VR, Zakavi SR, Sadeghi R, Emadzadeh MR, Vejdani A. Normal values of left ventricular functional indices in gated 99mTc-MIBI myocardial perfusion SPECT. Iran J Nucl Med. 2008;16(1):14-19.

7. Dabbagh Kakhki VR, Jabari H. Dipyridamole stress and rest gated 99mTc-sestamibi myocardial perfusion SPECT: left ventricular function indices and myocardial perfusion findings. Iran J Nucl Med. 2007;15(1):1-7.

8. Kakhki VR, Zakavi SR, Sadeghi R. Comparison of two software in gated myocardial perfusion single photon emission tomography, for the measurement of left ventricular volumes and ejection fraction, in patients with and without perfusion defects. Hell J Nucl Med. 2007 Jan-Apr;10(1):19-23.

9. Sharir T, Germano G, Waechter PB, Kavanagh PB, Areeda JS, Gerlach J, Kang X, Lewin HC, Berman DS. A new algorithm for the quantitation of myocardial perfusion SPECT. II: validation and diagnostic yield. J Nucl Med. 2000 Apr;41(4):720-7.

10. Hesse B, Tägil K, Cuocolo A, Anagnostopoulos C, Bardiés M, Bax J, Bengel F, Busemann Sokole E, Davies G, Dondi M, Edenbrandt L, Franken P, Kjaer A, Knuuti J, Lassmann M, Ljungberg M, Marcassa C, Marie PY, McKiddie F, O'Connor M, Prvulovich E, Underwood R, van Eck-Smit B; EANM/ESC Group. EANM/ESC procedural guidelines for myocardial perfusion imaging in nuclear cardiology. Eur J Nucl Med Mol Imaging. 2005 Jul;32(7):855-97.

11. A guide to the interpretation and reporting of myocardial perfusion and gated SPECT. http://www.medical.siemens.com/siemens/en_GB/gg_nm_FBAs/files/UK_Content/Quantitative7.pdf

12. Leslie WD, Tully SA, Yogendran MS, Ward LM, Nour KA, Metge CJ. Automated quantification of 99mTc sestamibi myocardial perfusion compared with visual analysis. Nucl Med Commun. 2004 Aug;25(8):833-8.