Original Article

^{201}Tl을 이용한 심근관류 SPECT에서 재구성 방법에 따른 작은 용적 심장의 정량 지표 변화

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Quantitative Indices of Small Heart According to Reconstruction Method of Myocardial Perfusion SPECT Using the ^{201}Tl

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Purpose: Myocardial perfusion SPECT using ^{201}Tl is an important method for viability of left ventricle and quantitative evaluation of cardiac function and now various reconstruction methods are used to improve the image quality. But in case of small sized heart, you should always be careful because of the Partial Volume Effect which may cause errors of quantitative indices at the reconstruction step. So, In this study, we compared those quantitative indices of left ventricle according to the reconstruction method of myocardial perfusion SPECT with the Echocardiography and verified the degree of the differences between them. **Materials and Methods:** Based on ESV 30 mL of Echocardiography, we divided 278 patients (male;98, female;188, Mean age;65.5±11.1) who visited the Asan medical center from February to September, 2012 into two categories; below the criteria to small sized heart, otherwise, normal or large sized heart. Filtered and output each case, we applied the method of FBP and OSEM to each of them, and calculated EDV, ESV and LVEF, and we conducted statistical processing through Repeated Measures ANOVA with indices that measured in Echocardiography. **Results:** In case of men and women, there were no significant difference in EDV between FBP and OSEM (p=0.053, p=0.098), but in case of Echocardiography, there were meaningful differences (p<0.001). The change of ESV especially women in small sized heard, significant differences has occurred among FBP, OSEM and Echocardiography. Also, in LVEF, there were no difference in men and women who have normal sized heart among FBP, OSEM and Echocardiography (p=0.375, p=0.969), but the women with small sized heart have showed significant differences (p<0.001). **Conclusion:** The change in quantitative indices of left ventricle between Nuclear cardiology image reconstruction, no difference has occurred in the patients with normal sized heart but based on ESV, under 30 mL of small sized heart, especially in female, there were significant differences in FBP, OSEM and Echocardiography. We found out that overestimated LVEF caused by PVE can be reduced in average by applying OSEM to all kinds of gamma camera, which are used in analyzing the differences. **(Korean J Nucl Med Technol 2013;17(1):18-24)**

Key Words : Filtered Back Projection, Ordered-Subset Expectation Maximization, Echocardiography

INTRODUCTION

Myocardial perfusion SPECT offers the possibility of simultaneous measurement of heart perfusion and myocardial function. Values of the left ventricular ejection fraction

(*LVEF*), heart wall thickening, and heart wall motion are important factors in the diagnosis of coronary artery disease and the prognosis of patient recovery.[1)]

Filtered back projection (FBP) has been the standard method for reconstructing SPECT MPI.[2)] FBP has the ad-

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vantage of being fast reconstruction time and computationally non-intensive.[3] But It has problem with low-count SPECT images due to the inevitable amplification of image noise, and mandates higher radiation doses or longer acquisition times.It is unable to correct for photon attenuation and scatter.[4-7] Also it has a generation of artifacts, which mainly consist of streaking and negative counts near the borders of hot objects.[8-10]

Iterative reconstruction (IR), especially in OSEM, refers to a broad category of SPECT and PET reconstruction techniques that estimate the distribution of the radioactivity being imaged by mathematically generating projections that such a distribution would produce.[6,7] The generated projections are compared to the actual acquired projections and the difference is used to improve the estimate of the estimated distribution. Using IR allows the injection of a lower radiation dose and correction for the Poisson nature of the noise as well as attenuation and scatter.[5] And it has advantage of higher visual quality, especially in low count area, and eliminate the count loss artifact.[11-20]

Through these reconstruction steps, cardiac functions are calculated by each method. But all the cardiac functions are not exactly correct. Patient who has small heart has the possibility of error in LVEF caused by partial volume effect and low spatial resolution of gamma camera. In our study, we want to know about the difference of quantitative indices between FBP and OSEM, so we found out the degree of difference compared with Echocardiography.

MATERIALS AND METHODS

1. Clinical application & SPECT acquisition

We analyzed the 278 patients (male;90, female;188, Mean age;65.6±11.1) who were examined by ^{201}Tl gated myocardial perfusion SPECT and Echocardiography at Asan Medical Center in Feb. 2012 to Sep. 2012. Patients were excluded if they had frequent arrhythmias, an acute cardiac event, or hemodynamic instability. Depending upon their end-systolic volume (ESV) calculated on a echocardiography, the patients were classified as having either a normal-sized or large heard (ESV>30 mL, group Ⅰ) or small heart (ESV<30 mL, group Ⅱ).[21] There's no standard of small sized heart, [22-25] the ESV value of 30 mL was chosen on the basis of data from Ford et al. showing that the difference between measured and true LVEF in a cardiac phantom becomes pronounced when the end-diastolic volume (EDV) is <70 mL and the true LVEF is >40%.[22,24]

Pharmacological stress test was performed. At stress test, ^{201}Tl injections (111 MBq) were performed during intravenous pharmacological coronary vasodilatation with adenosine (140 μg/kg per minute infused over 6 min). And then, we performed rest test after 3 hours later. We can't compare the quantitative indices objectively at the stress test. Because of adenosine, heart rate will increase at that time. So we compared the quantitative indices at rest test.

Equipment for diagnosis of coronary artery disease were E-cam (Siemens Medical Systems, Inc. USA), Ventri (General Electric Healthcare, Waukeshau, WI), INFINIA (General Electric Healthcare, Waukeshau, WI) 90° angled dual-head gamma camera equipped with low-energy general purpose collimators. Imaging was performed over 180°, with a total imaging time of 15 min. Data were stored in a 64 x 64 matrix. Acquisitions were gated for eight frames per cardiac cycle with a beat acceptance window set at 20% of the average R-R interval, calculated prior to image acquisition.

2. Filtered backProjection Reconstruction

When we used the equipment of Infinia and Ventri, images were filtered using a butterworth with an power of 10.0 and a cut-off of 0.37.[27,28] Also quantitative ramp filter was applied. Attenuation correction was not performed. The resulting trans-axial image sets were re-oriented into short-axis sets to which the automatic QGS (Cedars - Sinai) algorithm was applied. LV chamber volumes are automated detected by computer program.

3. Ordered-Subset Expectation Maximization Reconstruction

When we reconstructed the image using Infinia and

Ventri, the number of subsets and number of iterations were 10 and 2, respectively.[3,27] The datasets were filtered after reconstruction using a Butterworth filter (order 10; cutoff frequency; 0.32 cycle per pixel). In case of equipment of E-cam, Gaussian filter was used. The reason why we didn't set the parameters equally, gaussian filter was applied only or none on flash 3D.

4. Echocardiography acquisition & Reconstruction

The two-dimensional echocardiograms were acquired at rest with standard short axis, apical 2-chamber and 4-chamber views by IE33 echocardiography system (Philips, Netherlands) (Fig. 1). The cinematic frames corresponding to end-diastole and end-systole were selected from the 2-chamber and 4-chamber views. Left ventricular end-diastolic volume, end-systolic volume and ejection fraction were derived via the previously validated modified Simpson's biplane disc method.[29]

Fig. 1. IE33 echocardiography system (Philips Healthcare, Netherlands).

5. Statistical analysis

Results are expressed in absolute EF units for LVEF and in millilitres for the volumes. All statistical analyses were performed using the SPSS statistical program package (SPSS, Inc., Chicago, USA).

First of all, quantitative indices (EDV, ESV and LVEF) of group I, Ⅱ which were separated by the heart size were calculated by FBP and OSEM. Calculated quantitative indices were compared with Echocardiography.

Second, we divided patients into two groups; Korean's standard Body Surface Area above or below (standard of male : 1.68 mm^2, standard of Female : 1.49 mm^2). And then we calculated the quantitative indices. Calculated quantitative indices were compared among FBP, OSEM and Echocardiography.

Inter-method variability was expressed as mean. Paired data among three method (Echocardiography, FBP and OSEM) were compared using repeated measurements analysis of variance (ANOVA). A p value of 0.05 or less was

Table 1. Quantitative indices of group I (ESV>30 mL)

		FBP	OSEM	Echo
Male	EDV	78.1385	75.8000	108.3538
	ESV	29.4923	27.7231	41.9077
	LVEF	64.0308	64.8000	61.4308
Female	EDV	68.1688	66.5455	42.7909
	ESV	22.9091	22.3766	39.8831
	LVEF	67.1688	67.1169	60.3247

Table 2. Quantitative indices of group Ⅱ (ESV<30 mL)

		FBP	OSEM	Echo
Male	EDV	48.6538	48.8462	69.0000
	ESV	11.4615	12.3462	23.9231
	LVEF	78.8077	75.9615	65.2692
Female	EDV	42.7909	42.9273	65.4000
	ESV	9.1455	10.2818	23.2364
	LVEF	81.9182	78.5727	64.3091

considered significant.

RESULTS

Classifications according to heart size and Korean's standard BSA are below. FBP tended to calculated LV volume largely than OSEM for normal sized heart, but it didn't apply to small sized heart. In case of small sized heart, OSEM tend to calculated LV volume comparative largely than FBP (Table 1, 2).

Echocardiography compared with FBP and OSEM, always showed the difference of quantitative indices.

1. Classifications according to heart size

Group I (ESV > 30 mL)

There were no differences of EDV for male and female between FBP and OSEM (p= 0.053, p=0.098). However both FBP and OSEM had difference of EDV compared with Echocardiography (p<0.000, p<0.000). In case of ESV, it showed difference in male between FBP and OSEM, but not in female (p=0.007, p=0.404).

And there was no difference of LVEF in male and female between FBP and OSEM (p=0.375, p=0.969) (Fig. 2).

Group Ⅱ (ESV < 30 mL)

There were no differences of male and female's EDV who had small heart between FBP and OSEM (p=0.914, p=0.932). However both FBP and OSEM had difference of EDV compared with Echocardiography (p<0.000, p<0.000). In case of ESV, significant difference for female was existed in female (p<0.000). Also, LVEF showed the difference in female with small heart (p<0.000) (Fig. 3).

2. Classifications according to Korean's average BSA

Group I (Above more than standard BSA)

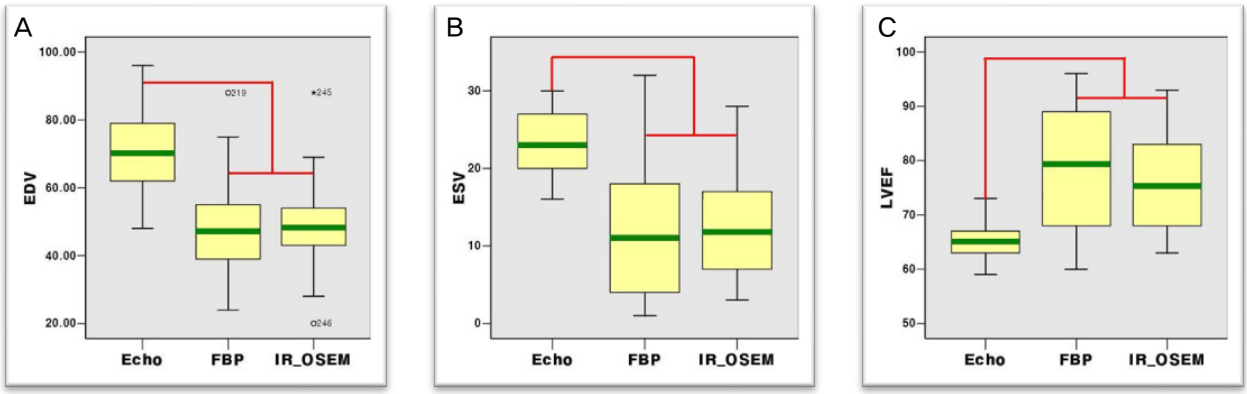

Fig. 2. Box plot of group I (ESV>30 mL). A, B and C show the distribution of quantitative indices among FBP, OSEM and Echocardiography.

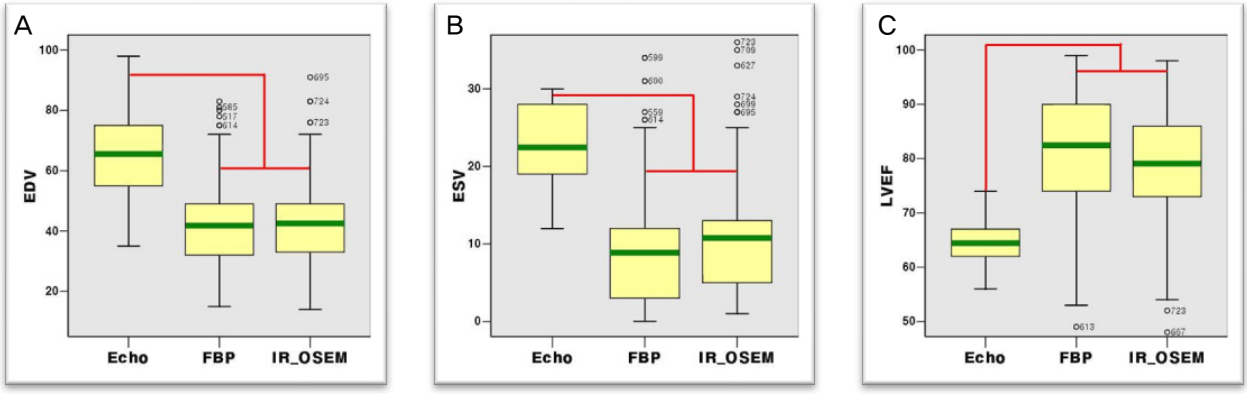

Fig. 3. Box plot of groupⅡ (ESV<30 mL). A, B and C show the distribution of quantitative indices among FBP, OSEM and Echocardiography.

Male didn't show any difference between FBP and OSEM (p=0.889), but there were significant differences of female's LVEF (p=0.002) (Fig. 4).

Group Ⅱ (Below less than standard BSA)

Like the group I, it showed the difference between FBP and OSEM, especially in female who had BSA less than Korean's average (p<0.000) (Fig. 4).

DISCUSSION

During the past 20 years, the use of ECG gating in conjunction with perfusion SPECT has been accepted as a routine procedure and a reliable method.[30-32] The quantitative analysis of gated SPECT in routine use has, in particular, contributed to the improvement of perfusion image sensitivity, permitting better evaluation of coronary artery diseases.[33] To enhance and the image quality for exact diagnosis, a variety of reconstruction method have been developed. That is the FBP and OSEM. In case of OSEM, It has the advantage of higher accuracy, especially in low count emission area. Take this fact into consideration, when we used the ^{201}Tl, low count emission radioisotope less than ^{99m}Tc-MIBI, we thought that the overestimated LVEF can be reduced caused by partial volume effect and low spatial resolution of gamma camera. Through the result of our study, using the OSEM can reduce the overestimated LVEF rather than using the FBP, so we can make less deviated LVEF with Echocardiography.

According to classification of heart size, however, our study showed that using OSEM resulted in only minor underestimation of LVEF compared with FBP. There are a lot of factors that can affect these results. One is that automatic cardiac wall detection method. If we used manual cardiac wall detection by operator, the gap among FBP, OSEM and Echocardiography can be reduced. Another is the absence of standard OSEM parameters. It is affects the result of quantitative indices. For example, iteration number can control the noise level[34], so cutoff frequency be controlled actively. The last one is no standard of small heart.

According to classification of Korean's standard BSA, female has the more possibility of overestimated LVEF than male. It means that gender may be related to the low spatial resolution of nuclear cardiology images, which causes the apparent shrinkage of the left ventricular cavity in patients with small ventricles; i.e., in women or patients with a smaller body surface area. Female may have a low myocardial count density or contrast because of breast attenuation, a low coronary flow reserve, and a high washout of ^{201}Tl after vasodilator stress.[25,26,35,36]

CONCLUSIONS

Both FBP and OSEM didn't show the difference of EDV by the classification of heart size. Besides, we knew that patient who has small heart or smaller body surface area, especially in female, calculated overestimated LVEF caused by wrong ROI of endocardial edge in ESV.

In conclusion, both FBP and OSEM didn't eliminate the partial volume effect completely, but if we consider the gender and body surface area, applying of OSEM for reconstructing of nuclear cardiology image can reduce the

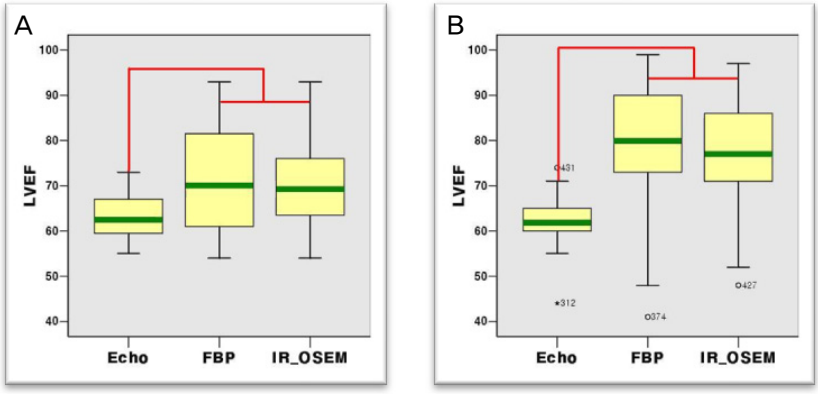

Fig. 4. Box plot of groupⅡ (Below less than standard BSA). A and B show the distribution of LVEF among FBP, OSEM and Echocardiography.

overestimated LVEF.

요 약

^{201}Tl을 이용한 심근관류 SPECT 검사는 좌심실의 생존능 및 심장 기능의 정량적 평가를 함에 있어 중요한 방법으로서 현재 영상의 질을 향상시키기 위해 다양한 재구성 방법들이 이용 되고 있다. 하지만 작은 용적 심장에서는 부분용적효과로 인해 재구성 단계에서 정량 지표 값의 오류를 야기 할 수 있으므로 항상 주의 해야 한다.

이에 본 연구는 심근관류 SPECT 검사의 재구성 방법에 따른 좌심실의 정량적 지표 값을 심장 초음파와 서로 비교함으로써 그 차이의 정도를 확인 한다. 2012년 2월부터 9월까지 본원에 내원하여 심근관류 SPECT 및 심장 초음파 검사를 실시한 278명의 환자(남자 90명, 여자 188명, 평균 65.5±11.1세)를 심장 초음파의 ESV 30 mL를 기준으로 삼아 그 이하를 작은 용적 심장, 그 이상을 보통 또는 큰 용적 심장으로 구분하였다. 각각 여과 후 FBP 및 OSEM의 방법을 적용하여 EDV, ESV 그리고 LVEF를 산출하였으며, 이를 심장 초음파에서 측정된 지표들과 함께 반복측정 분산분석 방법(Repeated Measures ANOVA)으로 분석하였다. 남녀 간의 EDV는 FBP, OSEM 간 유의한 차이가 없었으나 (p=0.053, p=0.098), 심장 초음파와의 비교에서는 유의한 차이를 보였다(p<0.001). ESV의 변화는 특히 작은 용적 심장을 가진 여성에서 FBP, OSEM, 심장 초음파 모두 유의한 차이(p<0.001)를 보였다. 또한 LVEF에서도 보통 용적 심장을 가진 남녀 모두 FBP, OSEM, 심장 초음파 간 유의한 차이는 보이지 않았으나(p=0.375, p=0.969), 작은 용적 심장을 가진 여성에서 모두 유의한 차이(p<0.001)를 보였다. 핵의학 영상 재구성 방법 간 좌심실의 정량적 지표 값의 변화는 보통 용적 심장을 가진 환자에서는 유의한 차이를 발견 할 수 없었으나, ESV를 기준으로 30 mL 이하의 작은 용적 심장, 특히 여성에서는 FBP, IR_OSEM, 심장 초음파 간 유사한 차이를 확인 할 수 있었다. 하지만 이러한 차이는 분석에 사용된 3종류의 모든 감마 카메라에서 OSEM 적용 시 FBP 보다 평균적으로 심장 초음파와의 오차가 적은 LVEF 값이 산출됨을 확인 할 수 있었다.

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