Original Article

Tl-201 심근관류 SPECT 검사에서 광대역 재구성(Wide Beam Reconstruction: WBR) 방법과 여과 후 역투영법에 따른 영상의 질 및 정량적 지표 값 비교

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The Comparison of Image Quality and Quantitative Indices by Wide Beam Reconstruction Method and Filtered Back Projection Method in Tl-201 Myocardial Perfusion SPECT

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Purpose: The Xpress3.cardiac™ which is a kind of wide beam reconstruction (WBR) method developed by UltraSPECT (Haifa, Israel) enables the acquisition of at quarter time while maintaining image quality. The purpose of this study is to investigate the usefulness of WBR method for decreasing scan times and to compare to it with filtered back projection (FBP), which is the method routinely used. **Materials and Methods:** Phantom and clinical studies were performed. The anthropomorphic torso phantom was made on an equality with counts from patient's body. The Tl-201 concentrations in the compartments were 74 kBq (2 μCi)/cc in myocardium, 11.1 kBq (0.3 μCi)/cc in soft tissue, and 2.59 kBq (0.07 μCi)/cc in lung. The non-gated Tl-201 myocardial perfusion SPECT data were acquired with the phantom. The former study was scanned for 50 seconds per frame with FBP method, and the latter study was acquired for 13 seconds per frame with WBR method. Using the Xeleris ver. 2.0551, full width at half maximum (FWHM) and average image contrast were compared. In clinical studies, we analyzed the 30 patients who were examined by Tl-201 gated myocardial perfusion SPECT in department of nuclear medicine at Asan Medical Center from January to April 2010. The patients were imaged at full time (50 second per frame) with FBP algorithm and again quarter-time (13 second per frame) with the WBR algorithm. Using the 4D MSPECT (4DM), Quantitative Perfusion SPECT (QPS), and Quantitative Gated SPECT (QGS) software, the summed stress score (SSS), summed rest score (SRS), summed difference score, end-diastolic volume (EDV), end-systolic volume (ESV) and ejection fraction (EF) were analyzed for their correlations and statistical comparison by paired *t*-test. **Results:** As a result of the phantom study, the WBR method improved FWHM more than about 30% compared with FBP method (WBR data 5.47 mm, FBP data 7.07 mm). And the WBR method's average image contrast was also higher than FBP method's. However, in result of quantitative indices, SSS, SDS, SRS, EDV, ESV, EF, there were statistically significant differences from WBR and FBP(p<0.01). In the correlation of SSS, SDS, SRS, there were significant differences for WBR and FBP (0.18, 0.34, 0.08). But EDV, ESV, EF showed good correlation with WBR and FBP (0.88, 0.89, 0.71). **Conclusion:** From phantom study results, we confirmed that the WBR method reduces an acquisition time while improving an image quality compared with FBP method. However, we should consider significant differences in quantitative indices. And it needs to take an evaluation test to apply clinical study to find a cause of differences out between phantom and clinical results. **(Korean J Nucl Med Technol 2010;14(2):122-127)**

Key Words : Wide beam reconstruction (WBR), Filtered back projection (FBP), Xpress3.cardiac™

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Purpose

The resolution and sensitivity trade-off problem in gamma

camera is systemic. So, the image resolution and the image sensitivity of collimator system are inversely related. The wall between holes of collimator is called septa. Almost all photons are absorbed by septa. So, few photons reach the detector crystal to the ones that nearly perpendicular to it.[1] This results in lower image sensitivity. The more limiting the collimators are, the higher the image resolution that can be obtained. However, as resolution is improved, sensitivity is compromised. Thus, there is a clear trade-off between the sensitivity and resolution of the system. Reduced sensitivity is generally compensated for by long acquisition times and / or high radiopharmaceutical doses typical of Nuclear Imaging.

SPECT is based on the reconstruction of tomographic images from projection images. Tomographic reconstruction theory states that a 3-dimensional images can be backprojected and reconstructed from a series of 2-dimensional projection images acquired at many angles around the patient's body.[2] As data from each angle overlap the data from other angles, a summation occurs that results in a blurred image, with a loss of resolution and contrast. A mathematic filter applied to this information before it is backprojected onto the reconstructed image matrix will recover image contrast and resolution. This reconstruction process is commonly known as filtered back projection (FBP).[3] This process inherently improves contrast by removing underlying and overlying activity but, as with planar imaging, improvements in the resolution characteristics of a SPECT image are made to the detriment of the sensitivity characteristics.[4]

Newly developed imaging reconstruction algorithms have now enabled us to acquire images at half or quarter of the scan time, avoiding motion artifacts while maintaining or even improving imaging quality.[5] According to several publications, Wide Beam Reconstruction (WBR), Ultra SPECT (Haifa, Israel)'s reconstruction algorithms technology resolves the sensitivity and resolution trade-off problem that is inherent to the gamma camera, and which is critical in SPECT imaging. WBR is an reconstruction is an iterative reconstruction method which simultaneously addresses resolution recovery and noise reduction for low count density data.[6] The Xpress3.cardiac™ which is a kind of WBR method enables the acquisition of at quarter time while maintaining image quality. WBR is an iterative reconstruction method which simultaneously addresses resolution recovery and noise reduction for low count density. The purpose of this study is to investigate the usefulness of WBR method for decreasing scan times and to compare to it with FBP, which is the method routinely used.

Materials and Methods

Phantom and clinical studies were performed.

1. Phantom study

We compared image quality by using anthropomorphic phantom (Fig. 1, Table 1). We made a phantom on an equality with counts from patient's body. The Tl-201 concentrations in the compartments were 74 kBq (2 μCi)/cc in myocardium, 11.1 kBq (0.3 μCi)/cc in soft tissue, and 2.59 kBq (0.07 μCi)/cc in lung. The non-gated Tl-201 myocardial perfusion SPECT data were acquired with the phantom. The former study was scanned for 50 seconds per frame with FBP method, and the latter study was acquired for 13 seconds per frame with WBR method. Using the Xeleris ver. 2.0551, full width at half maximum (FWHM) and average image contrast were compared (Fig. 2, 3). To get the FWHM, first, set frame. Second. Profile ROI. And lastly, using Xeleris software, we obtained the FWHM. The average image contrast was calculated by this formula.

Contrast=A-B/A+B (A=region, B=background)

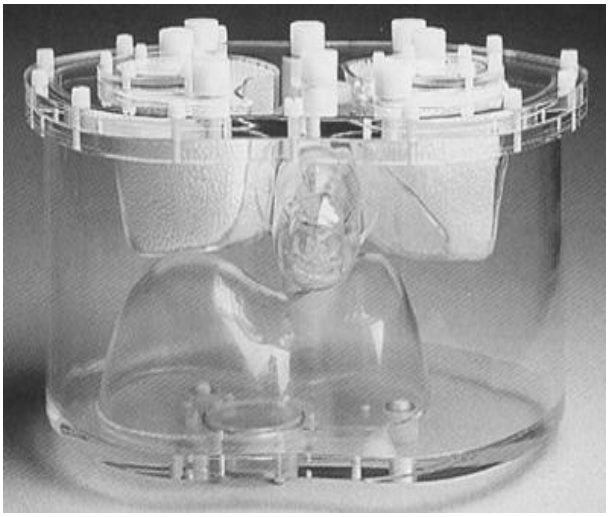

Fig. 1. Anthropomorphic torso phantom.

2. Clinical Study

In clinical studies, 30 patients who had no coronary artery disease were examined by Tl-201 gated myocardial perfusion SPECT in department of nuclear medicine at Asan Medical Center from January to April 2010 and compared by WBR method and FBP method. The age range was 37-79 years (mean = 62.0±10.9). All patients were examined two times, Stress and Rest test. And the patients were imaged at full time (50 second per frame) for 15 minutes with FBP algorithm and again quarter-time (13 second per frame) for 5 minutes with the WBR algorithm. Using the 4D MSPECT (4DM), Quantitative Perfusion SPECT (QPS) and Quantitative Gated SPECT (QGS) software, the SSS (summed stress score), SRS (summed rest score), summed difference score, end-diastolic volume (EDV), end-systolic volume (ESV) and ejection fraction (EF) were analyzed for their correlations and statistical comparison by paired *t*-test. And we used SPSS program (ver.12.0).

3. Study protocol and image processing

For this study, a General Electric (GE healthcare, Waukeshau, WI) Infinia 90°-angled dual-headed scintillation camera equipped with general-purpose collimators was used for all SPECT imaging. To acquire Thallium SPECT images, we used dual energy window. A ±15% and a ±10% window were centered over the 70 keV and 167 keV Tl-201 photopeaks. An angular step of degree is 6. A matrix size was 64X64 and we used FBP reconstruction method with a Butterworth filter. "Full time" SPECT: 180° arc, 15 stops (30 views), and 50 second-per-stop, step-and-shoot mode. 8 frame per cardiac cycle gating, 100±50% irregular beat acceptance window. "Quarter time" SPECT: 180° arc, 15 stops (30 views), and 13 second-per-stop, step-and-shoot mode. 8 frame per cardiac cycle gating, 100±50% irregular beat acceptance window.

To acquire reconstructed WBR data, there are several steps. First we should send patient data to Xpress3.cardiac™. Upon receiving patient data parameters and the corresponding 2D projections, it utilizes the unique WBR algorithm, optimized for the specific application, to accurately calculate the 3D reconstructed image of the SPECT data. After reconstructing WBR data, Xpress3.cardiac™ send the reconstructed data to Xeleris workstation automatically (Fig. 4).

Table 1. Specifications of anthropomorphic torso phantom

Lateral outside dimension : 38 cm
Lateral inside dimension : 36 cm
Anterior-posterior outside dimension : 26 cm
Anterior-posterior inside dimension : 24 cm
Wall thickness : 9.5 mm
Liver volume : 1.2 liters
Background : 10.3 liters

Results

In the phantom result, WBR method improved image quality

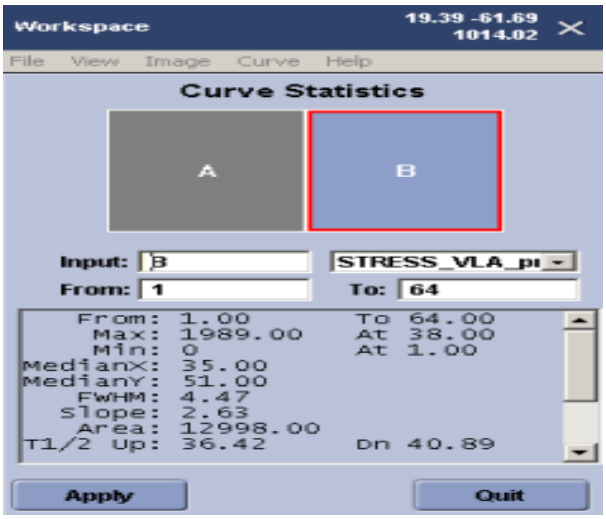

Fig. 2. Full Width at Half Maximum in Xeleris software program.

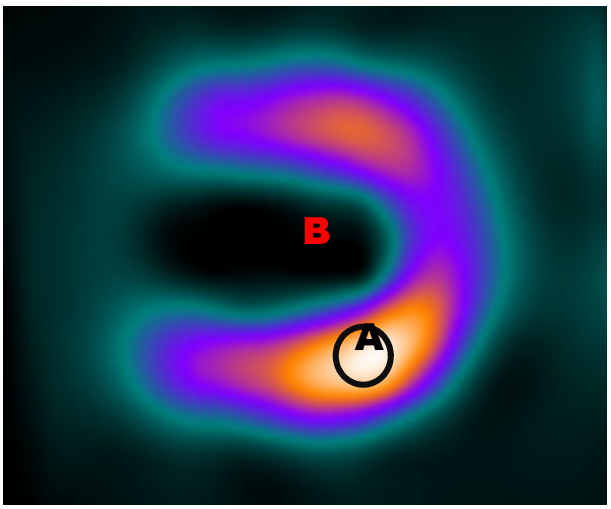

Fig. 3. Positioning of region and background area ROI.

compared to FBP method. In clinical result, we found that there were significant differences for quantitative indices. And we could know that correlation is not good in quantitative indices except EDV, ESV and EF.

1. Phantom study

We tested the phantom three times. As a result of the phantom study, the WBR method improved FWHM more than about 30% compared with FBP method (WBR data 5.47 mm, FBP data 7.07 mm) (Fig. 5, Table 2). And the WBR method's average image contrast was also higher than FBP method's (Fig. 6, Table 3).

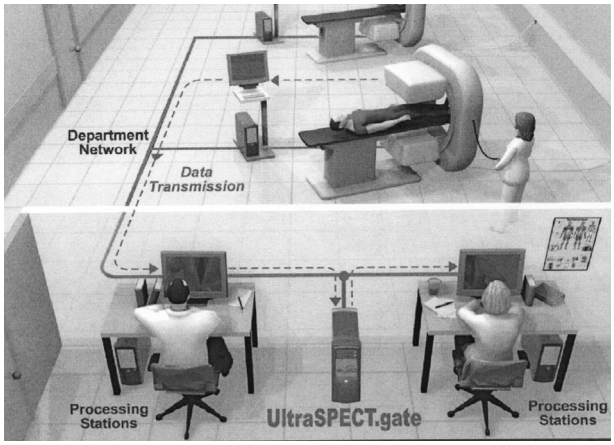

Fig. 4. UltraSPECT. gate computer is connected to the NM camera and workstation network intended of reconstruction or enhancing data acquired by a NM gamma camera. The reconstructed data is sent to a NM workstation for final processing and physician review.

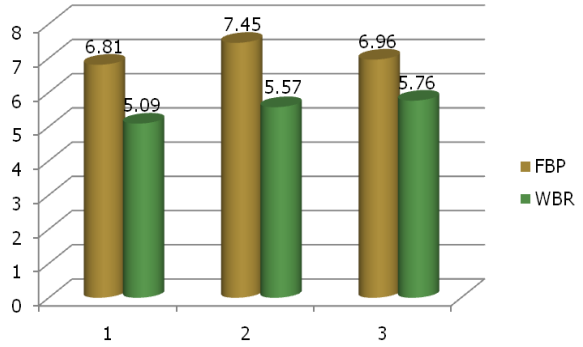

Fig. 5. FWHM between two methods.

Table 2. FWHM (mm) between two methods

	FBP	WBR
1	6.81	5.09
2	7.45	5.57
3	6.96	5.76

2. Clinical study

30 patients were compared with two methods. In result of quantitative indices, SSS, SDS,SRS, EDV, ESV, EF, there were statistically significant differences from WBR and FBP (p<0.01) (Table 4, 5). In the correlation of SSS, SDS, SRS, there were significant differences for WBR and FBP (0.18, 0.34, 0.08) (Fig. 7). But EDV, ESV, EF showed good correlation with WBR and FBP (0.88, 0.89, 0.71) (Fig. 8).

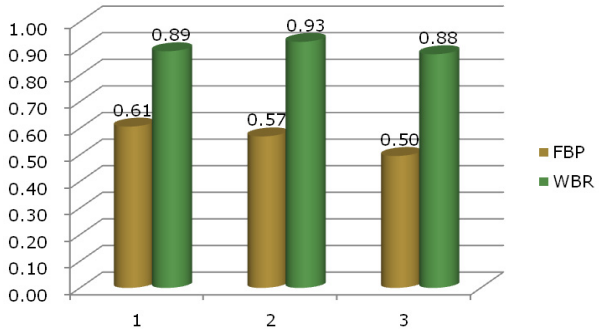

Fig. 6. Contrast between two methods.

Table 3. Contrast between two methods

	FBP	WBR
1	0.61	0.89
2	0.57	0.93
3	0.50	0.88

Table 4. Differences between WBR and FBP method in QPS

Quantitative indices	Reconstruction	Mean±SD	t
SSS	FBP	2.17±2.75	-3.96
	WBR	5.93±4.93	
SRS	FBP	4.10±4.18	-4.17
	WBR	9.43±7.22	
SDS	FBP	1.46±2.35	-3.20
	WBR	4.10±4.02	

Table 5. Differences between WBR and FBP method in QGS

Quantitative indices	Reconstruction	Mean±SD	t
EDV	FBP	67.83±18.27	-5.73
	WBR	77.20±18.54	
ESV	FBP	24.67±12.12	-5.56
	WBR	30.83±13.32	
EF	FBP	67.83±18.27	-2.86
	WBR	77.20±18.54	

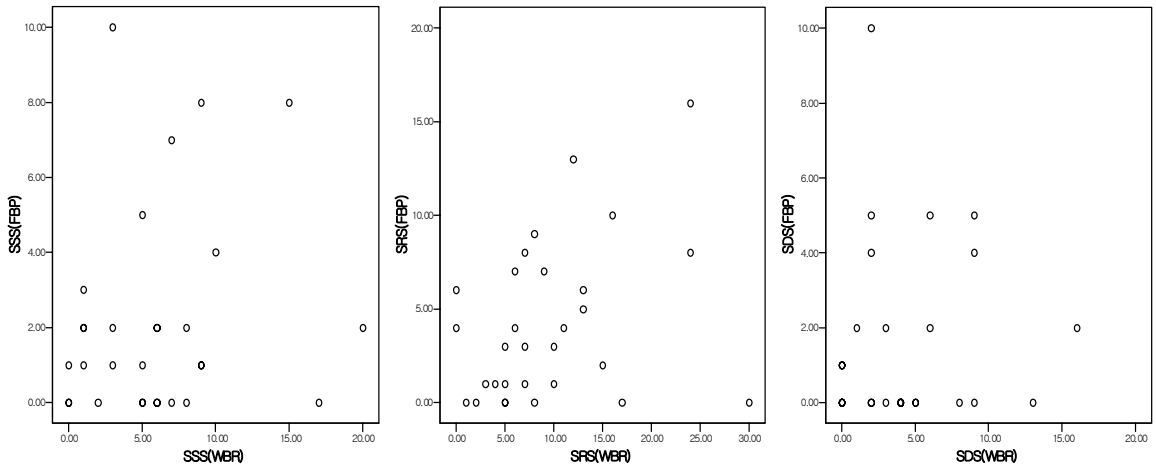

Fig. 7. Correlations of SSS, SRS, SDS between WBR and FBP method in QPS.

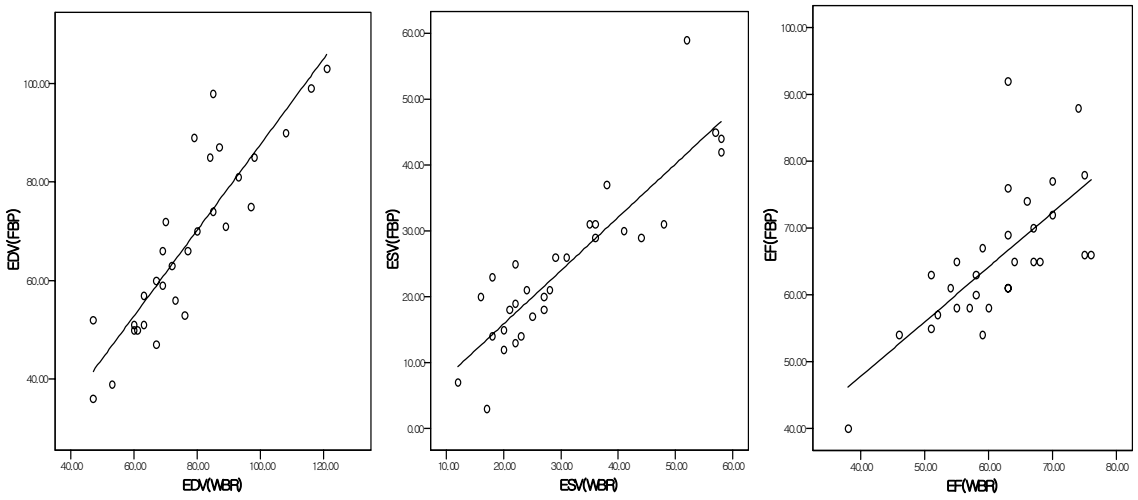

Fig. 8. Correlations of EDV, ESV, EF between WBR and FBP method in QGS.

Conclusions

From phantom study results, we confirmed that the WBR method reduces an acquisition time while improving an image quality compared with FBP method. However, we should consider significant differences in quantitative indices. And it needs to take an evaluation test to apply clinical study to find a cause of differences out between phantom and clinical results.

요 약

광대역 재구성 기법(Wide Beam Reconstruction : WBR)은 잡음을 감소시켜 신호 대 잡음 비를 증가시키고, 또 광속 확산 함수 효과(Beam spread function effect)를 저하시킴으로써 기존의 여과 후 역투영법(Filtered Back Projection : FBP)와 비교하였을 때 영상의 질은 동등하고 영상획득 시간을 줄일 수 있는 장점이 있다고 보고 있다. 본 연구는 UltraSPECT (Haifa,Israel)사 광대역 재구성 기법 인 Xpress3.cardiac™를 이용하여 기존의 FBP기법에 대한 WBR기법의 유용성을 알아보고자 한다. 1. Phantom 실험 : Anthropomorphic torso phantom을 사용하여 심근과 연부조직 그리고 폐 영역에 ^{201}Tl을 각각 74 kBq(2 μCi)/cc, 11.1 kBq (0.3 μCi)/cc, 2.59 kBq (0.07 μCi)/cc의 비율로 투여하여 검사 시 실제 환자의 count와 유사하게 phantom을 제작하였다. 영상획득은 게이트법 적용 없이 Tl-201 심근관류 SPECT를 시행하였다. FBP로 재구성 한 영상은 투사영상 당 50초로 영상을 획득하였고, WBR으로 재구성 한 영상은 시간을 1/4로 단축하여 투사영상 당 13초로 영상을 획득하였다. 두 가지 기법으로 재구성

한 영상을 Xeleris ver. 2.0551을 이용하여 반치폭(Full Width at Half Maximum : FWHM)과 평균 영상 대조도를 비교하였다. 2. 환자 정량분석 값 비교 : 2010년 1월 ~ 4월까지 본원에서 Tl-201 심근관류 SPECT 시행한30명의 환자를 대상으로 분석하였다. 먼저 아데노신 부하 후 stress 촬영 시 투사영상 당 50초로 약 15분 동안 영상을 획득한 후 곧바로 투사영상 당 13초로 약 4분 동안 영상을 다시 획득하였다. 또 rest 촬영 시에도 동일하게 획득하였다. 투사영상 당 50초로 획득한 데이터는 FBP기법으로, 투사영상 당 13초로 획득한 데이터는 WBR기법으로 재구성하여 SSS, SDS, SRS, EDV, ESV, EF 값을 산출하여 비교 하였다. Phantom 실험 후 분해능 측정 결과, WBR기법으로 재구성한 경우 FBP기법에 비하여 FWHM은 29.46% 향상되었다(WBR data: 5.47 mm, FBP data: 7.07 mm). 또 평균 영상 대조도 증가하는 것으로 나타났다(WBR data: 0.90, FBP data: 0.56). 반면 환자 데이터를 분석한 결과, SSS, SDS, SRS, EDV, ESV, EF 등 정량분석 값들은 상호간에 유의한 차이를 보였다(p<0.01). 상관계수는 SSS, SDS, SRS에서 각각 0.18, 0.34, 0.08로 통계적으로 유의한 차이를 보였지만 EDV, ESV, EF에서는 각각 0.88, 0.89, 0.71로 좋은 상관관계를 보였다. Phantom 실험 결과 WBR기법은 FBP에 비해 분해능이 향상된 결과를 보였고, 평균 영상 대조도 역시 증가하는 것으로 나타났다. 환자 데이터를 분석하였을 때, WBR기법과 FBP기법 간의 정량분석 값들은 유의한 차이를 보였고, 상관계수 또한 SSS, SRS, SDS에서 유의한 차이가 보였으나, EDV, ESV, EF값에서는 높은 상관관계를 나타났다. 본 연구를 통하여 phantom 실험에서는 영상 획득 시간의 단축 및 영상의 질 향상을 확인할 수 있었다. 단, 환자 데이터에 대한 정량분석에서는 기존의 FBP기법에 비하여 많은 차이가 있어 임상에 적용 시 이에 대한 고려 및 추가적인 연구가 필요할 것이라고 사료된다.

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