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**<원저>**

# Correlation Between High-Sensitive Collimator and Quantitave Analysis in Lung Ventilation SPECT

## -폐 환기 SPECT에서 고감도 Collimator와 정량분석의 상관관계-

Department of Radiological Technology, Dongnam Health University
[1)]Department of Diagnostic Radiology, Seoul National University Hospital

Jung-Soo Kim·Sang-Hyun Kim[1)]

— Abstract —

This study investigated the correlation between the characteristics of collimator in accordance with the efficiency of detecting photon signals and the quantitative analysis of the lung function, thereby assessing the possibility of clinically applying high sensitivity lung ventilation SPECT.

From March to May, 2014, 10 subjects in normal volunteers underwent an ultra high resolution, high resolution and high sensitivity collimator planar scan and SPECT. The experiment showed that compared with the collimator scan, the quantitative analysis results were significant (p=0.89), and compared to the high resolution collimator SPECT, the time was reduced by 4.9 fold.

Therefore, the lung ventilation SPECT that had not been used due to an undermined effectiveness can offer usefulness when clinically applied if a high sensitivity collimator is used since the quality and quantity of information and the duration of scan time all offer an improvement.

**Key Words :** Pulmonary embolism, ventilation, SPECT, collimator, quantitave analysis

## Ⅰ. Introduction

Nuclear medicine scans in lung diseases are used for diagnosing pulmonary embolism that causes a disorder in the pulmonary artery when a substance in the vein moves to the lungs. When diagnosing pulmonary embolism, angiography is the most standard exam method but it has constraints when limiting embolism in the distal portion and also because it is also an invasive exam[1)]. Because lung scan that uses radioactive isotope has less radiation exposure and side effects like aggravation of renal failure through contrast medium, compared with CT (computed tomography) and pulmonary angiography, it is an exam whose usefulness was proved through years of clinical practice and currently, it is widely used to lung disease patients[2-4)]. This lung scan can be classified as perfusion, ventilation scan and it is selected and implemented according to the patient's diagnostic purpose. Lung ventilation scan is implemented in order to identify that reasons of perfusion defect which is examined in lung perfusion scan are embolism. Therefore, it is used in increasing the specificity of

교신저자: 김상현 (110-744) 서울특별시 종로구 대학로 101
서울대학교병원 영상의학과. Tel : 02-2072-2247 / E-mail: snuhkim1@naver.com
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perfusion scans by evaluating the degree of ventilation in the lung. Like this, ventilation scan has the advantage of comprehensive analysis to compare the local lung disease as well as analysis of quality[5,6].

Lung scan can be implemented by two methods, the planar scan and SPECT (single photon emission computed tomography). Collimators used in nuclear medicine imaging can be categorized into UHR (ultra high resolution), HR (high resolution) and AP (all purpose; high sensitivity) depending on the physical and geometrical characteristics, such as the thickness of the isolation wall forming the collimator, the number and area of the holes. These are used for different exam purposes[7]. For example, the UHR collimator is good at identifying small lesion due to its high resolution, but the sensitivity is low and therefore the exam takes longer, making it unrecommendable for children or emergency patients. In contrast, the AP collimator has a high detection efficiency of the photon signal which allows the exam time to be reduced but because of its low resolution has a hard time identifying the size and location of the lesion. Therefore, in nuclear medicine imaging, making the most of the characteristics of the collimator for a given scan purpose is important (Figure. 1)[8].

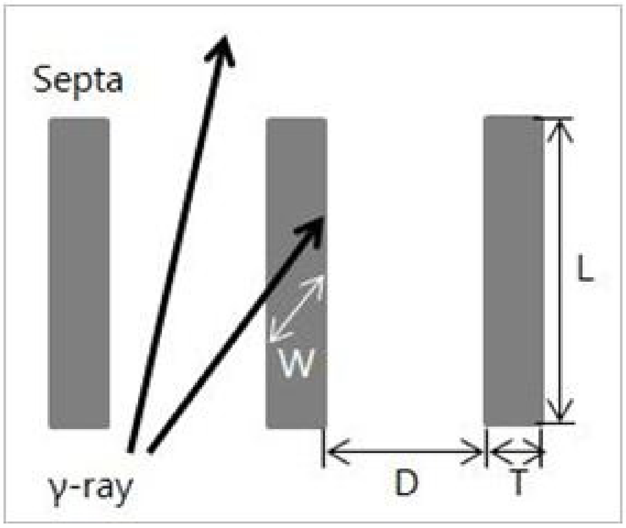


**Figure 1** The diagram shows a $\gamma$-ray following the shorexam path (W) through the septa. (L; septal length, T; septal wall thickness, D; septal width)

Lung SPECT offers more information on the depth of the lesion, which is hard to acquire with regular lung scans. By overlapping the photon signals that occur in all depths, the contrast and resolution of the image is of higher quality than regular images. Therefore, according to related research, the sensitivity and speificity of the lung planar scan is 64% and 72% respectively, while for the lung SPECT, they are 100% and 87% respectively[9,10]. In principle, compared to lung planar scan, SPECT has an excellent resolution and allows for quantitative analysis of the function of small site ventilation. It also has the advantage of allowing the identification of relation between different anatomical structures of the lesion through tomographic images. A massive amount of information can be gained on the size, shape of the lung, the distribution of the blood flow, the lung disease and also a quantitative analysis of the radioactive drug that is concentrated in the lung volume can also be preformed. However, given the traits of tomography where a 360° rotation is needed to gain the information, it takes a significantly longer time. The change in the patient's body position and difficulty in breathing can also undermine the quality of the image acquired. Due to the errors in the data collected, inaccurate results can come about as well as errors in quantitative analysis, limiting its clinical application[11]. Ventilation SPECT inhales the radiopharmaceutical through breath SPECT which inject the tracer in to the vein. In case of the patient who cannot breathe well, uptaking rate of tracer to target organ is decreasing and consequently the appropriate count rate which is effective for exams is also decreasing. This eventually extending examination time could bring many problems and therefore, it is difficult to apply in clinical scans physically. Because of this, considering the convenience, costs and relation with other exams done by different departments, long scans are more commonly used despite the many benefits of lung SPECT[12,13]. Accordingly, applicability of lung ventilation SPECT; LV-SPECT to clinical exams and its usefulness was evaluated by shortening the examination time of low count rate patient through AP collimator which has high sensitivity characteristics in this study.

# Ⅱ. Materials and Methods

## 1. Subjects

Using 10 normal adults who volunteered for the study (7 males, 3 females), the study was conducted from March, 1st to May, 31th, 2014. Average age was 26.23±2.47 years and average height was 169.2±5.12 ㎝, with average weight being 63.6±6.24 ㎏. Given the characteristics of the experiment, those with a history of lung diseases including asthma or respiratory inflammation as well as women who have a likelihood of getting pregnant were excluded from the subjects. The glucose level of all participants were lower than 140 ㎎/㎗ and blood pressure lower than 120/80 ㎜Hg. The samples with diabetes were excluded from the experiment and only those who were in the range of BST (blood sugar exam) 80–120 ㎎/㎗ and BMI (body mass index) 18.5–23.5 were selected. Before the experiment, subjects were banned from drinking alcohol or smoking at least 48 hours and sufficient rest was recommended to maintain a stable level of breathing.

## 2. Equipments

A highly specific activity $^{99m}TcO4^{-}$ 37 MBq was injected into the generator to create a gas form with very small particles of 0.0005 ㎛ or smaller, which were then administered to the subjects (Figure. 2).

**Figure 2** Technegas generator (Technegas-Plus), Cyclomedica, Australia

Subjects blocked their nose while breathing in the radioactive drugs through the mouthpiece in order to allow the drug to reach the alveolus, and then was instructed to hold their breath for 3–5 seconds. During the course of inhaling, cautionary instructions were given in order to prevent any radioactivity from occurring in the mouth or trachea due to the secretion of the esophagus[14]. Using a dual head gamma camera, the 2 detectors rotated while taking the LV-SPECT and confirming that the count rate of each subject at every angle was maintained at 3 kcounts/second or more. UHR, HR and AP collimators were used for comparison (Figure. 3, 4).

**Figure 3** Dual head SPECT (E.cam signature), Siemens, USA

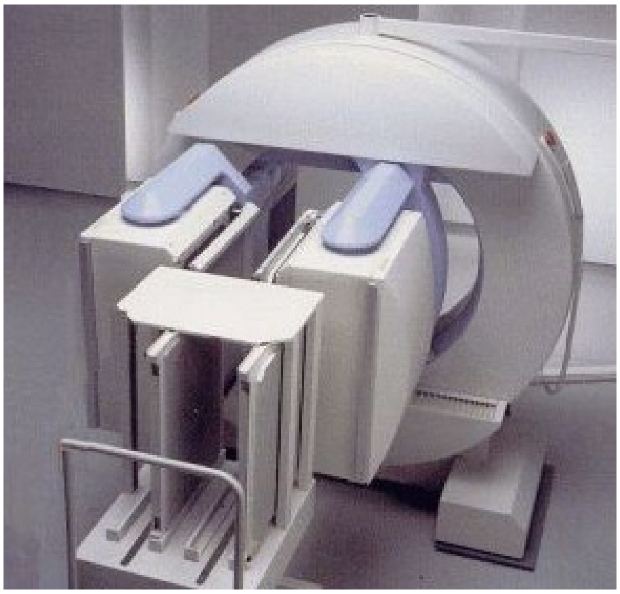

**Figure 4** Exchange for 3 type of collimator, UHR, HR and AP

## 3. Methods

The principle of the SPECT is to rotate the object and add all the signals acquired at all angles for a certain duration of time. Then through a calculation, the image is recomposed in order to offer information on depth. The total exam duration can be modified by adjusting the time acquired at each angle. In accordance with the counts measured at the minimum acquisition time of the equipment used, it was set at low counts mode to conduct the experiment for a minimum amount of time. The existing SPECT duration, which is in accordance with the guideline recommended by EANM (european association of nuclear medicine), was categorized as high counts mode[15,16].

Make exam subjects inhale technegas 370 MBq sufficiently for 10 minutes and measure the count rate by using dual head SPECT. Exam subjects install UHR, HR, AP collimator with supine position and have a total of 6 views of lung ventilation planar scan; LVPS which are ANT (anterior), POST (posterior), LPO (left posterior oblique), RPO (right posterior oblique), both-LAT (lateral) with the condition of 300 kcounts acquisition, 256×256 matrix and 1.0 magnification.

Same exam subjects have high counts mode LV-SPECT by applying the existing protocol with the condition of 128×128 matrix, step and shoot mode, non circular orbit, 180° / detector (total 360°) rotation, counterclockwise direction, body contour and 70 kcounts/view acquisition. And make 7 kcounts/view acquisitions with the same method and make low counts mode LV-SPECT for a comparative exam. Compare and analyze the exams results. After acquiring the LV-SPECT image, the raw data were recomposed into an OSEM (ordered-subsets expectation maximization) type with a number of iteration 6 and maximum number of subset 8. The post-filter used at this stage was butterworth and the critical frequency was 0.48, with a power of 9.82. Additionally, a scatter correction was applied (Figure. 5)[17,18].

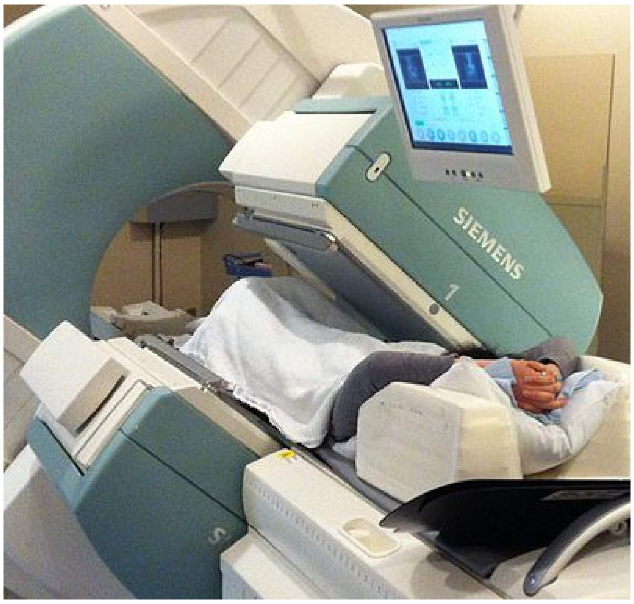


**Figure 5** Lung ventilation SPECT were performed with 3 collimators, HR, UHR, and AP, in low (7 kcpv) and high (70 kcpv) counting modes

## 4. Quantitative Analysis

E-soft workstation, syngo MI application 2007A (Siemens, Germany) was used for quantitative analysis of experimental results. All results which were acquired by LVPS according to the kinds of collimator were set in ANT and POST images so that Rt. (right) and Lt. (left) lung can have the same ROI (region of interest) and subsequently, geometric mean of coefficient values were calculated and the lung segmentation; upper, middle, lower ratio was acquired. The reason a geometric mean is used and not a arithmetic mean is because anatomically, due to the heart, the lower base of the left-side lung can show damage and the site of damage is more prominent from the front. Moreover, the sternum and the spine can cause attenuation in the middle line by a slight degree[19,20].

In LV-SPECT results which were acquired from two modes of low counts and high counts which is according to the kinds of collimators, all coronal planes of each lung were summed up and the acquired coefficient was established to have the same ROI with the LVPS and the study results were calculated (Figure. 6).

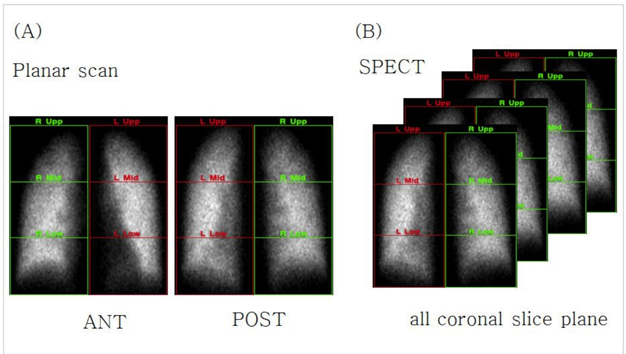


**Figure 6** Analyze each data acquired from two different methods. In case of lung ventilation planar scan, left-right lung segmentation ratio result was calculated from ANT and POST image with geometric average (A), For lung ventilation SPECT was with two each mode collimator attached, all coronal slice plane was summed and lung segmentation ratio result was calculated with same method (B)

### 5. Statistical Analysis

To objectify the correlation between the experimental data, descriptive statistic analysis was carried out using arithmetic, geometric mean and standard deviation. Parametric paired $t$-test, which is one of inferential statistics, was applied and significant difference was confirmed ($\alpha$=0.05; significance level of 95%, $p$>0.05). SPSS ver. 20 (IBM Inc. USA) program was used for all the experimental data. Statistical analysis was verified by the physical research team in Department of Nuclear Medicine, College of Medicine, Seoul National University.

## Ⅲ. Results

All experiments of LVPS led to an acquisition of 300 kcounts for each scan of six views for ANT, POST, LPO, RPO and Both-LAT, making the total of 1,800 kcounts regardless of the three types of collimators used. On the other hand, low counts mode LV-SPECT which was acquired by 7 kcounts/view acquired from minimum 705 kcounts to maximum 1,217 kcounts according to the kinds of collimators and high counts mode LV-SPECT which was acquired by 70 kcounts/view acquired from minimum 8,003 kcounts to maximum 10,475 kcounts according to the kinds of collimators (Table 1).

Since LV-SPECT follows the principle of collecting signals at every angle of the object then recomposing the acquired data, essentially it has more counts than a simple 2-dimensional planar scan. As for the low counts mode LV-SPECT, the average count for all experiments was 959.5 kcounts, making it 1.87 times lower than LVPS and as for high counts mode LV-SPECT, it was an average of 9273.9 kcounts, making it 5.15 times higher than LVPS. The count in nuclear medicine imaging refers to the

**Table 1** Total acquisition counts of all experiments

(kcounts)

| | LVPS | Low cts. mode LV-SPECT | | | High cts. mode LV-SPECT | | |
|---|---|---|---|---|---|---|---|
| Vol. | All | UHR | HR | AP | UHR | HR | AP |
| 1 | 1,800 | 1,217 | 938 | 987 | 10,333 | 10,250 | 9,424 |
| 2 | | 870 | 1,095 | 850 | 8,003 | 8,446 | 8,427 |
| 3 | | 846 | 822 | 829 | 8,273 | 8,498 | 8,288 |
| 4 | | 1,096 | 1,013 | 1,043 | 9,730 | 9,932 | 9,422 |
| 5 | | 975 | 705 | 751 | 9,452 | 9,358 | 9,236 |
| 6 | | 962 | 1,198 | 949 | 8,768 | 9,012 | 9,142 |
| 7 | | 1,041 | 954 | 997 | 10,123 | 10,024 | 9,587 |
| 8 | | 886 | 847 | 864 | 8,345 | 8,129 | 8,098 |
| 9 | | 1,121 | 989 | 1,002 | 10,475 | 10,236 | 10,019 |
| 10 | | 982 | 989 | 968 | 9,752 | 9,685 | 9,751 |
| mean | 1,800 | 1,000 | 955 | 924 | 9,325 | 9,357 | 9,139 |
| *SD* | - | 119.5 | 140.0 | 94.3 | 910.6 | 792.1 | 652.7 |

material that can be realized into an image. The more materials there are, the more important components there are that can determine the quality of the image. Having fewer counts under the same conditions means that it took less time to conduct the scan while a higher count means it took longer (Figure. 7)[21].

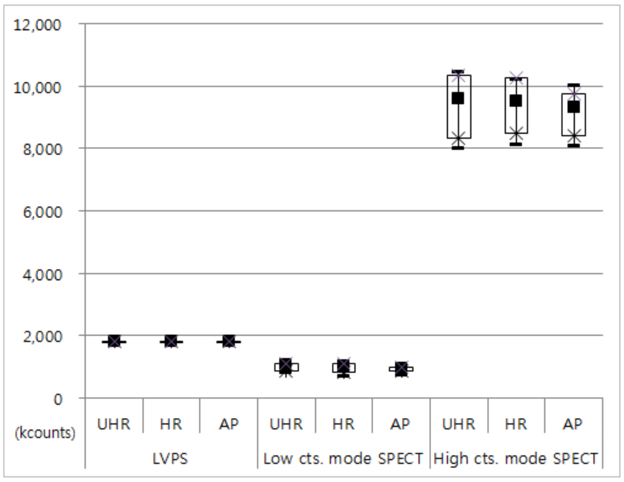


**Figure 7** Low counts mode LV-SPECT has 9.66 times less counts than high counts mode LV-SPECT

For normal adults, the lung that consists of 3 right side lobes and 2 left side lobes shows a uniform distribution of radioactivity. This means that the same concentration of breathing is occurring in each segment of the lung. If it is not uniform and radioactivity is found in only specific parts, it indicates that the breathing is disrupted and therefore a damage has occurred in the ventilation passage. If the distribution of radioactivity in the right and left side of the lungs is quantified, it can then be used as a determining factor in diagnosing the lung function[22]. In all experiments using the participants, the statistical significance of the results of quantitative analysis in the right and left side lungs was taken to analyze the correlation with collimators used. After calculating 10 lung segmentation ratios through all experiment results of various counts and subsequent mean values and standard deviations, Lt.:Rt. lung ratio showed the following values with the orders of 45.3:54.7 (±0.29), 45.5:54.5 (±0.23), 50.1:49.9 (±0.24), 49.1:50.9 (±0.42), 48.2:51.8 (±0.21), 51.5:48.5 (±0.21), 50.0:50.0 (±0.24), 49.3:50.7 (±0.40), 52.2:47.8 (±0.43) and 46.7:53.3 (±0.34) respectively (Table 2).

At this moment, standard deviations are all the same because lung ratios calculate the results as relative functions. The reason why exam results are significant is that LVPS is the calculation of arithmetic mean of ANT and POST image 2 view even though it has many total counts and also that low counts mode LV−SPECT, which is a comparative exam is the sum up of all coronal slice planes, and therefore total counts are thought be sufficient to analyze the results even if the counts of individual slice planes are small. The reason a geometric mean is used and not a arithmetic mean is because anatomically, due to the heart, the lower base of the left−side lung can show damage and the site of damage

**Table 2** Segmentation results of Lt.:Rt. lung ratio

(%)

| | LVPS | Low cts mode LV-SPECT | | | High cts mode LV-SPECT | | | |
|---|---|---|---|---|---|---|---|---|
| Vol. | HR | UHR | HR | AP | UHR | HR | AP | *SD* |
| 1 | 45.6:54.4 | 45.1:54.9 | 44.9:55.1 | 45.8:54.2 | 45.3:54.7 | 45.4:54.6 | 45.3:54.7 | ±0.29 |
| 2 | 45.3:54.7 | 45.7:54.3 | 45.9:54.1 | 45.6:54.4 | 45.5:54.5 | 45.2:54.8 | 45.6:54.4 | ±0.23 |
| 3 | 49.8:50.2 | 49.9:50.1 | 50.2:49.8 | 50.0:50.0 | 50.5:49.5 | 50.1:49.9 | 50.3:49.7 | ±0.24 |
| 4 | 48.3:51.7 | 49.6:50.4 | 49.2:50.8 | 48.8:51.2 | 49.2:50.8 | 49.4:50.6 | 49.2:50.8 | ±0.42 |
| 5 | 47.9:52.1 | 48.4:51.6 | 48.2:51.8 | 48.0:52.0 | 48.2:51.8 | 48.5:51.5 | 48.1:51.9 | ±0.21 |
| 6 | 51.2:48.8 | 51.5:48.5 | 51.5:48.5 | 51.3:48.7 | 51.7:48.3 | 51.8:48.2 | 51.6:48.4 | ±0.21 |
| 7 | 49.6:50.4 | 50.1:49.9 | 50.3:49.7 | 50.2:49.8 | 50.3:49.7 | 50.1:49.9 | 49.9:50.1 | ±0.24 |
| 8 | 49.8:50.2 | 49.1:50.9 | 48.8:51.2 | 49.5:50.5 | 49.4:50.6 | 49.8:50.2 | 48.9:51.1 | ±0.40 |
| 9 | 52.7:47.3 | 51.8:48.2 | 52.3:47.7 | 52.1:47.9 | 51.6:48.4 | 52.1:47.9 | 52.8:47.2 | ±0.43 |
| 10 | 46.1:53.9 | 46.9:53.1 | 47.1:52.9 | 46.4:53.6 | 46.8:53.2 | 46.8:53.2 | 46.9:53.1 | ±0.34 |

is more prominent from the front. Moreover, the sternum and the spine can cause attenuation in the middle line by a slight degree. Accordingly, the quantitative analysis results showed that lung segmentation ratios which are related with LVPS and low and high counts mode LV-SPECT according to the kinds of collimator have the statistically significant levels because all the values are located within the range of errors. After analyzing the LVPS which installs existing HR collimator, and low counts mode LV-SPECT that installs AP collimator, which is a comparative exam by statistics program, analysis results showed 0.89 of $p$-value which means that results of 2 experiments are both statistically significant (Table 3).

When diagnosing pulmonary embolism using nuclear medicine, the guidelines by PIOPED (Prospective Investigation of Pulmonary Embolism Diagnosis) are often used [23,24]. When there is no damage, it is ruled to be normal. If there is a damage, it is categorized as abnormal and depending on the number or size of the damage and comparing with the results of other exams, embolism can be diagnosed. In order to diagnose lung diseases, the accurate images for the lung function are important. A normal adult's right-side lung is wider and shorter than the left side and accounts for 55% of the total lung function while the left side lung accounts for 45%. Therefore it is advisable that the function of the right and left lungs are diagnosed by using a quantitative analysis method.

Analysis results of examination times of LVPS showed 1924.9±262.1 sec, 997.8±214.9 sec and 566.2±142.2 sec with the orders of UHR, HR, AP collimator respectively. Low counts mode LV-SPECT which is a comparative exam showed 1176.9±177.5 sec, 943.9±121.9 sec and 740±0 sec and high counts mode LV-SPECT which is an existing protocol 5961.1±1085.0 sec, 3698.2±433.6 sec and 2126.7±155.5 sec (Table 4).

LVPS is the aggregate time of all durations for the 6 times of 2 dimensional scans, while for the LV-SPECT it is the time it took to rotate 360°. According to the characteristics of each collimator, the time for acquiring an imaging signal at each angle were input in advance. In low counts mode LV-SPECT, when a high sensitivity collimator is attached, all experiments showed 740 sec. This is because given the characteristics of the equipment, the same minimum signal acquisition time was applied. The difference in time for all experiments shows the physical characteristics of each collimator. It is observed that the time decreases from UHR to HR to AP collimator. Under conditions that exclude resolution, an AP collimator has a higher likelihood of acquiring geometrical signals and therefore has the advantage of being able to reduce time compared to UHR collimator. In high counts mode LV-SPECT, when a UHR collimator was used, the average was 5,961 sec, which means it takes approximately 8 times longer. The

**Table 3** Lt.:Rt. lung ratio of LVPS (HR) and low counts mode LV-SPECT (AP)

(%)

| | Rt. lung | | Lt. lung | |
|---|---|---|---|---|
| Vol. | HR | AP | HR | AP |
| 1 | 45.6 | 45.8 | 54.4 | 54.2 |
| 2 | 45.3 | 45.6 | 54.7 | 54.4 |
| 3 | 49.8 | 50.0 | 50.2 | 50.0 |
| 4 | 48.3 | 48.8 | 51.7 | 51.2 |
| 5 | 47.9 | 48.0 | 52.1 | 52.0 |
| 6 | 51.2 | 51.3 | 48.8 | 48.7 |
| 7 | 49.6 | 50.2 | 50.4 | 49.8 |
| 8 | 49.8 | 49.5 | 50.2 | 50.5 |
| 9 | 52.7 | 52.1 | 47.3 | 47.9 |
| 10 | 46.1 | 46.4 | 53.9 | 53.6 |

**Table 4** Acquisition time of all lung scan with different collimators

(sec)

| | LVPS | | | Low cts mode SPECT | | | High cts mode SPECT | | |
|---|---|---|---|---|---|---|---|---|---|
| Vol. | UHR | HR | AP | UHR | HR | AP | UHR | HR | AP |
| 1 | 1,896 | 897 | 412 | 1,261 | 871 | 740 | 7,240 | 3,956 | 2,108 |
| 2 | 2,174 | 1,136 | 671 | 1,132 | 1,002 | 740 | 5,745 | 4,084 | 2,156 |
| 3 | 1,754 | 952 | 598 | 1,004 | 893 | 740 | 4,772 | 3,215 | 2,068 |
| 4 | 1,545 | 759 | 408 | 1,142 | 883 | 740 | 5,755 | 3,449 | 1,912 |
| 5 | 1,694 | 784 | 568 | 893 | 852 | 740 | 4,531 | 3,108 | 1,996 |
| 6 | 1,923 | 901 | 456 | 1,382 | 903 | 740 | 6,982 | 4,012 | 2,253 |
| 7 | 2,241 | 1,305 | 753 | 1,256 | 1,104 | 740 | 5,924 | 4,257 | 2,321 |
| 8 | 1,856 | 884 | 408 | 1,245 | 845 | 740 | 6,987 | 3,878 | 2,007 |
| 9 | 2,378 | 1,402 | 785 | 1,456 | 1,207 | 740 | 7,119 | 3,912 | 2,401 |
| 10 | 1,788 | 958 | 603 | 998 | 879 | 740 | 4,556 | 3,111 | 2,045 |

AP-low counts mode LV-SPECT that is presented in this study can reduce the time for the exam by 1.3 times compared to HR-LVPS or the existing exam method and approximately 4.9 times compared to the HR-high counts mode LV-SPECT. Additionally and considering the comparison of 2 dimensional planar scan and 3 dimensional SPECT, reduction of examination times is judged to be significant (Figure. 7).

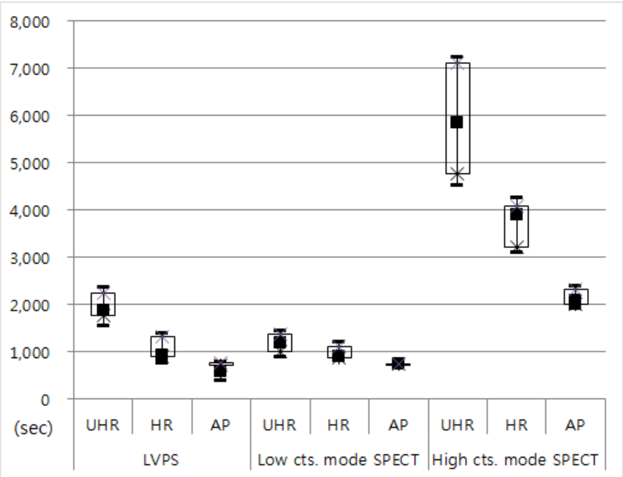


**Figure 7** All acquisition time of lung scan with various collimator. Consideration standard experiment is planar scan and comparative experiment is SPECT, the meaning of reduced time is significant

Finally, if the LV-SPECT is implemented after installing the high sensitivity AP collimator, clinically significant quantitative analysis results could be obtained which means the reduction of exam times could be effectively achieved.

## Ⅳ. Discussion

More clinical studies will be required to generalize the results because the experiment subjects were relatively small of 10 volunteers and they are not the serious patients who cannot breathe but the normal subjects and decay correction was not applied to the technique according to the time. In addition, the functions of SPECT equipments and collimators are different according to the manufacturers and dosage of radiopharmaceutical that patients inhale are also different in individual institutions. In order to reduce the difference between the upper and lower lobe of the lung, it is advisable that the patient is seated when undergoing the exam but taking into account the duration, the scan was conducted in a supine position. Therefore, the geometrical difference in the lung volume that occurs from the different position that might have caused a difference in quantitative analysis must also be taken into account. For patients with severe difficulty in breathing, the intake of radioactive tracer is severely low and therefore the minimum imaging data that is required to diagnose a lung disease may not be met, causing errors in quantitative analysis[25).

The experiment was conducted on normal subjects that had no difficulty of breathing and therefore, the overall counts in the lung due to the intake of the radiopharmaceutical, its correlation with quantitative analysis and the duration of the scan must be taken into account. According to the EANM guideline, there is a recommended minimum count for an optimal result of SPECT quantitative analysis and quality of the image that can tell the size and the location of the lesion. Since in this experiment, only the significance of quantitative analysis results were verified and the resolution of the image or SNR (signal to noise ratio) were excluded from analysis, correlation with such factors will need to be investigated.

In addition, Objective of this study was to identify the significance of LVPS results according to the characteristic of collimator and the correlations with time reduction, in the process of finding hardware methods in order to reduce examination times of LV-SPECT. If the software like image processing and half time methods (ex; onco.flash, astonish, evolution) can be provided by the manufacturer and additional tests are performed, interesting results are expected and therefore, additional studies are considered to be conducted in the future[26,27]. Recently technologies which enable consecutive capturing SPECT and CT images and subsequent fusion or registration provide the methods to compare and read the images more accurately and conveniently which are the current trends, and therefore, additional studies will be required[28].

## Ⅴ. Conclusion

This study analyzed the correlation of UHR, HR and AP collimators and their characteristics with the quality of the images acquired, especially compared to LVPS that are most commonly used in clinical settings. By doing so, it sheds light on the possible application of SPECT to clinical settings while the quantitative analysis figures of exam results are maintained at a significant level and the duration of the scan is reduced.

If the LV-SPECT is implemented by using high sensitivity AP collimator in cases that child, emergency and serious patients cannot have normal exams according to their breathing conditions and the exam should be implemented very shortly, it could compensate low count rate which is resulting from low eating rate of radiopharmaceutical and consequently increase the total counts of raw data. This could also have the same results compared with that of existing planar scan and could reduce the examination time as well. Accordingly, errors of exam results could be reduced which are resulting from the artifacts according to the patient's condition, patient's motion blurring due to long-time exam, and the advantages of SPECT could be implemented, which include detection of small lesion that cannot be implemented by planar scan or the location and size of the lesion. Additionally, for serious lung disease patients, conditions of anatomical structures are identified because CT image and relative comparison is easy by implementing additional exams like lung CT or tracer and patient's condition and functions of target organ are compensated through quantitative analysis results, more accurate diagnosis is possible, and therefore its sufficient usefulness of clinical exams are considered to be existing and further applications are expected.

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**•국문초록**

# 폐 환기 SPECT에서 고감도 Collimator와 정량분석의 상관관계

김정수·김상현[1)]

*동남보건대학교 방사선과*

*[1)]서울대학교병원 영상의학과*

본 연구는 광자 신호의 검출 효율에 따른 collimator의 특성과 폐기능 정량분석의 상관관계를 비교하여 고감도 collimator 폐 환기 SPECT의 임상적용 가능성을 평가하였다.

2014년 3월부터 5월까지 10명의 정상 성인을 대상으로 초고해상도, 고해상도, 고감도 3종류의 collimator를 이용하여 평면 스캔과 SPECT를 비교 실험하였다. 기존 검사방법인 고해상도 collimator 평면 스캔과 비교하여 정량분석 결과는 유의하였으며($p$=0.89), 고해상도 collimator SPECT보다 4.9배의 시간이 단축되었다.

따라서 효용성 저하로 제한적으로 시행하였던 폐 환기 SPECT는 고감도 collimator를 이용하면 진단 정보의 양과 질, 검사시간의 단축 측면에서 효과적이므로 추후 임상적용에 유용할 것으로 사료된다.

**중심 단어 :** 폐색전, 환기, SPECT, collimator, 정량분석