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Extravascular lung water measured with ^{99m}Tc-RBC and ^{99m}Tc-DTPA is increased in left-sided heart failure

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Extravascular lung water (EVLW) was quantitatively measured in 81 patients consisting of 10 subjects with normal cardiac function and 71 patients with left-sided heart diseases, using ^{99m}Tc-RBC as a non-diffusible indicator and ^{99m}Tc-DTPA as a diffusible indicator in the equilibrium phase. EVLW averaged 3.0±1.4 (ml/kg, mean±SD) in subjects with normal cardiac function (n=10), 4.3±1.7 in New York Heart Association functional class I patients (n=30), 4.8±2.4 in NYHA functional class II patients (n=33) and 9.4±5.4 in NYHA functional class III (n=8) patients. EVLW was greater in NYHA class III than in normal controls or NYHA classes I or II ($p<0.01$).

Lung thermal volume (LTV) was also measured in 31 of the 81 patients using a double indicator dilution technique with sodium and heat. LTV averaged 6.0±1.2 (ml/kg) in normal subjects (n=4), 8.6±2.0 in NYHA functional class I patients (n=11), 9.7±3.0 in NYHA functional class II patients (n=13), and 15.9±8.2 in NYHA functional class III patients (n=3). The correlation between EVLW and LTV was significant (EVLW=0.79×LTV-72.8, $r=0.80$, $p<0.01$). There were significant differences in EVLW/LTV ratio between NYHA class III (0.93±0.16) and NYHA class I (0.62±0.22) or class II (0.60±0.23). Thus, it was shown that EVLW was increased in left-sided heart failure and that LTV overestimated the EVLW.

Key words: extravascular lung water, lung thermal volume, RN-angiocardiography, ^{99m}Tc-RBC, ^{99m}Tc-DTPA

INTRODUCTION

THE CLINICAL EVALUATION of pulmonary edema routinely depends upon chest roentgenography. A double indicator dilution technique using heat (diffusible indicator) and sodium chloride (non-diffusible indicator, by definition) currently is used to obtain a quantitative parameter called the lung thermal volume (LTV).[1-9] This technique measures the total intra- and extra-cellular fluid quantitatively but tends to overestimate the extravascular fluid volume (EVFV) when it is in the normal range[3,5] and underestimates it in the presence of pulmonary edema.[10]

We performed first pass radionuclide (RN)-angiocardiography using ^{99m}Tc-RBC (technetium-99m labeled autologous red blood cells) to measure the pulmonary blood volume (PBV) by a method developed by our laboratory.[11] Simultaneously, extravascular lung water (EVLW) was determined using ^{99m}Tc-RBC and ^{99m}Tc-DTPA (diethylene triamine pentaacetate).[12,13] In principle, the PBV represents the sum of the red blood cell (RBC) volume and the plasma volume. Lung fluids measured by techniques based on the gravimetric theory[2,4] include not only

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the extravascular extracellular water, but the intracellular lung water as well. ^{99m}Tc-RBC can label intravascular RBCs and serves as a non-diffusible indicator and ^{99m}Tc-DTPA equilibrates between the plasma and interstitium and serves as a diffusible indicator. We were able to determine the EVLW from the ratio of RN counts of these two indicators (Fig. 1). We then compared the EVLW in subjects with normal cardiac function and patients with cardiac disease classified as class I, II, and III by the New York Heart Association (NYHA) system. The EVLW/LTV ratio and the relationship between EVLW and LTV (determined by heat and sodium) also were studied.

MATERIALS AND METHODS

Eighty-one patients, 50 with ischemic heart disease, 21 with valvular heart disease, and 10 with normal cardiac function (6 with neurocirculatory asthenia, 1 with arrhythmia and 2 with hypertension, 1 with idiopathic alveolar bleeding), constituted the subjects of the present study to determine EVLW. The average age was 59.6±9.4 years (mean±SD) and male to female ratio 63: 18.

A) Estimation of pulmonary blood volume

The pulmonary blood volume (PBV) was measured according to a method published previously by this laboratory.[11] The method is briefly as follows. RN-angiocardiography first pass method was performed with an Anger type gamma camera ZLC equipped with a 140 keV high resolution collimator (Siemens), taking a modified left anterior oblique view, after stannaous pyrophosphate was administered to patients intravenously through the right ante-cubital vein followed by a post-30 minute intravenous injection of $^{99m}TcO_4^-$ in a dose of 370 MBq. Data were processed with a Scintipac 2400 (Shimadzu Co.). Regions of interest (ROI) were externally set at the bifurcation of the pulmonary artery (PAB) and the left atrium (LA). Time activity curves were recorded at the two sites and the difference in mean transit time between the two sites (ΔMTT$_{PAB-LA}$) was calculated. From this difference and the cardiac output (CO), PBV was obtained as

$$PBV = CO \times \Delta MTT_{PAB-LA} \quad (1)$$

When the RN image of the LA was not separable from that of the left ventricle or the pulmonary artery, PBV was calculated from the peak to peak time (PPT) of the time activity curve, which was obtained from a large ROI covering almost the entire heart, according to equation (2) as previously reported[11]

$$PBV = CO \times PPT_{large\ ROI} \times 0.77 \quad (2)$$

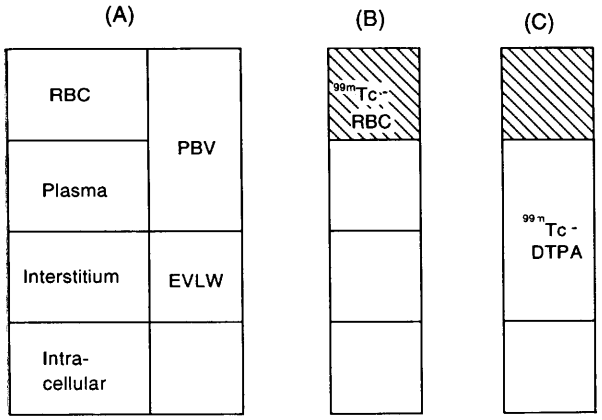

Fig. 1 Fraction of the lung volume consisting of intravascular and extravascular components and distribution of ^{99m}Tc-RBC and ^{99m}Tc-DTPA. (A) Fraction of lung volume. (B) Distribution of ^{99m}Tc after injection of ^{99m}Tc-RBC. (C) Distribution of ^{99m}Tc after injection of ^{99m}Tc-DTPA. RBC: red blood cells; PBV: pulmonary blood volume; EVLW: extravascular lung water (extracellular).

B) Estimation of extravascular lung water

Extravascular lung water was measured by the method described by Casaburi et al,[14] and Suzuki et al.[15] with modification.[12,13] At the equilibrium phase of ^{99m}Tc-RBC, the ROI was set on the right lung field away from the heart, liver and central vein and the data were collected from a 45° right anterior oblique view; the RN count was measured from the ROI. (Fig. 2A). Four hundred forty-four MBq of ^{99m}Tc-DTPA was administered intravenously through a peripheral vein about 35 minutes after the initiation of measurement. In the equilibrium phase attained about 10 minutes after the administration, the RN count of the ROI was monitored for 15 minutes. Assuming that the biological and physical decay of the RN count of the ROI in the equilibrium phase of ^{99m}Tc-RBC is almost linear, an approximate straight line was drawn from the RLr (Fig. 2 line a: R means radioactivity, L means lung, r means RBC). Assuming that the attenuation of blood counts caused by ^{99m}Tc-RBC (CBr) is linear, the blood counts caused by ^{99m}Tc-RBC after the intravenous injection of ^{99m}Tc-DTPA were calculated from an approximate line (Fig. 2, line b). Fifteen minutes after the initiation of measurement (sampling point 1), the RN counts for the ROI (RLr) were measured (Fig. 2, A). The RN counts ascribable to ^{99m}Tc-RBC of the ROI (R'Lr) at sampling point 4, which was the first sampling time after ^{99m}Tc-DTPA administration, were obtained by extrapolation (Fig. 2 line a). The RN counts of the ROI after the administration of ^{99m}Tc-DTPA (RLd) at sampling point 4 were also measured (RLd included R'Lr). Blood samples

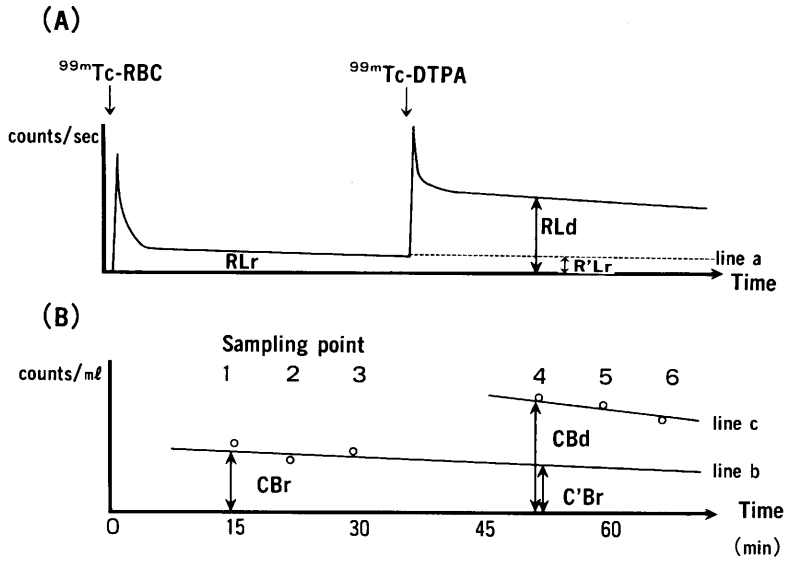

Fig. 2 Time courses of RN count at ROI over the chest and that of blood count. (A) Time activity curve of the RN counts of the ROI over the chest. (B) Time course of RN counts of blood. RLr: RN counts of the ROI over the chest due to RBC at the first sampling point, CBr: Blood counts due to RBC at the first sampling point, RLd: RN counts of the ROI over the chest at sampling point 4, CBd: Blood counts at sampling point 4, R'Lr: RN counts due to ^{99m}Tc-RBC at the ROI over the chest at sampling point 4, C'Br: Blood counts due to ^{99m}Tc-RBC at sampling point 4.

(3 m*l* each) were collected three times at intervals of 5 minutes in the equilibrium phase of ^{99m}Tc-RBC, and three times in the equilibrium phase of ^{99m}Tc-DTPA (Fig. 2, B). Three blood samples (1.0 m*l* each) were processed for counting in a well counter and the counts, with decay, were obtained. From the three blood counts in the equilibrium phase of ^{99m}Tc-RBC, an approximate straight line was drawn (Fig. 2, line b). From the blood counts (CBr) at the end of 15 minutes after the initiation of measurement (sampling point 1) and the approximate straight line (Fig. 2, line b) was drawn, and the blood counts (C'Br) at sampling 4 were calculated by extrapolation. C is for counts, B is for blood, and r is for RBC. Blood counts of the three samples collected in the equilibrium phase of ^{99m}Tc-DTPA gave a decay line (Fig. 2, line c) and the blood counts at sampling point 4 were CBd (Fig. 2, B) was calculated. CBd included C'Br. At the first sampling time after the intravenous administration of ^{99m}Tc-RBC, RN only existed in RBC. The RN counts for the ROI and the blood counts at this time were RLr and CBr, respectively. RLr represented the RN count of ^{99m}Tc combined with RBC in "pulmonary" blood externally measured at the ROI. CBr represented the RN counts of ^{99m}Tc combined with RBCs in 1 m*l* of blood. Assuming that the efficiency of proof of ^{99m}Tc is k, the following equation can be formulated.

$$RLr = k \times CBr \times PBV, \text{ from which it follows that}$$
$$PBV = RLr/(k \times CBr) \quad (3)$$

By the time of the fourth sampling after ^{99m}Tc-DTPA administration, the RN has been distributed in the interstitium, plasma and intravascular space. The RN counts for the ROI surveyed externally and that for the blood measured internally at this time were RLd and CBd, respectively (Fig. 2). At this time the RN counts for the ROI due to ^{99m}Tc-RBC and the blood counts due to ^{99m}Tc-RBC were R'Lr and C'Br, respectively. The plasma volume was Vp and the RN counts due to ^{99m}Tc-DTPA in the plasma measured at ROI externally at this time were Rpd. C'Br represents the RN counts of ^{99m}Tc combined with RBCs in 1 m*l* of blood, and CBd represents the blood RN counts after the administration of ^{99m}Tc-DTPA. CBd-C'Br represents the blood RN count due to ^{99m}Tc-DTPA (which exists in the plasma and interstitium) per 1 m*l* of blood. The following equation (4) can be obtained:

$$Rpd = k \times (CBd - C'Br) \times PBV \quad (4)$$

R'Lr represents the RN counts of ^{99m}Tc combined with RBC in "pulmonary" blood recorded externally at the ROI, and RLd represents the RN counts after the administration of ^{99m}Tc-DTPA at the ROI. RLd-R'Lr represents the RN counts due to ^{99m}Tc-DTPA

(which exists in EVLW and plasma) recorded externally at the ROI. And so equation (5) is obtained.

$$Rpd=(RLd-R'Lr)\times Vp/(EVLW+Vp) \quad (5)$$

The following equation can be derived from equations (4) and (5).

$$k\times(CBd-C'Br)\times PBV = (RLd-R'Lr)\times Vp/(EVLW+Vp) \quad (6)$$

Plasma volume (Vp) was calculated as follows

$$Vp=PBV\times(1-Ht) \quad (7)$$

where Ht is hematocrit.
With equations (7) and (6), Vp is eliminated and equation (8) results.

$$\frac{EVLW}{PBV}=\frac{(RLd-R'Lr)\times(1-Ht)}{k\times(CBd-C'Br)\times PBV}-(1-Ht) \quad (8)$$

From equation (3) and equation (8), it follows that

$$\frac{EVLW}{PBV}=\left\{\frac{CBr\times(RLd-R'Lr)}{RLr\times(CBd-C'Br)}-1\right\}\times(1-Ht) \quad (9)$$

This equation no longer contains k; thus calculation of the ratio EVLW/PBV is possible actual measurements alone. With the actual measurement of PBV, and from formula (9), EVLW can be calculated as an absolute value. The results thus obtained are corrected for the attenuation factor described in detail in the Appendix.

C) Measurement of LTV

Among 81 subjects whose EVLWs were determined, 31 patients (21 with valvular heart desease, 6 with coronary artery heart disease and 4 with neurocirculatory asthenia, average age 56.5±9.1), underwent cardiac catheterization within 1 week prior to or after the measurement of EVLW, and it was during this catheterization that the LTV was measured by the double indicator dilution technique using heat and sodium, employing two catheters, one positioned in the pulmonary artery trunk and the other positioned at the root of the aorta. For the evaluation of LTV, an MTV1100 (Nihon Koden) and a thermal dilution catheter (5 French, Elecath) were used to measure MTT at two sites, i.e., the pulmonary artery trunk and the root of the aorta.

Values are expressed as the mean±standard deviation. Variables were compared with one-way ANOVA. Correlation between variables was evaluated by simple linear regression analysis.

RESULTS

1) Measurements of EVLW

The EVLW and PBV recorded in the 81 subjects averaged at 4.8±2.9 ml/kg and 9.0±2.9 ml/kg, respectively. PBV and EVLW values in normal subjects (n=10), NYHA class I (n=30), class II (n=33) and class III (n=8) patients are shown in Table 1. EVLW was significantly greater in NYHA class III than in "normal" controls or NYHA classes I or II.

Table 1 PBV and EVLW in the normal group and in NYHA classes I, II, and III

	n	PBV (ml/kg)	EVLW ml/kg)
Normal	10	7.2±2.1	3.0±1.4
NYHA I	30	9.0±2.9	4.3±1.7
II	33	9.2±3.2	4.8±2.4
III	8	10.4±2.1	9.4±5.4*

*: significant difference ($p<0.01$) between NYHA class III and normal or NYHA class I or class II
mean±S.D.

2) Relationship between EVLW and LTV

In the 31 subjects studied, EVLW and LTV averaged 6.1±3.8 and 9.4±4.0 ml/kg, respectively. A positive correlation was observed between EVLW and LTV ($EVLW=0.79\times LTV-72.8$, $r=0.80$, $p<0.01$) (Fig. 3). The EVLW/LTV ratio was significantly higher in the NYHA class III patients (0.93±0.16; n=3) than in normal controls (0.60±0.16; n=4), NYHA class I (0.62±0.22; n=11) ($p<0.05$) or NYHA class II patients (0.60±0.23; n=13) ($p<0.05$) (Fig. 4).

DISCUSSION

(1) Validity of the measurement of EVLW

Quantitative determination of extravascular lung water has generally been carried out by the double indicator dilution technique.[1-9] Various indicators have been used for this purpose, including sodium chloride and heat, which have now become popular as non-diffusible and diffusible indicators, respectively. In the RN technique, the first pass method has been performed with iodinated albumin and tritiated water to estimate EVLW from the difference in MTT between these two substances.[16] However, this method is no longer employed because of concern about humans using tritiated water. A technique for estimating the ratio of the extravascular water volume to pulmonary blood volume in the equilibrium phase was recently reported.[15] As to ^{99m}Tc-RBC labelling, 95% or more of red blood cells were found to be in the form of ^{99m}Tc-RBC with high stability in the blood.[17] In the equilibrium phase, ^{99m}Tc-DTPA diffuses almost completely into the interstitium of the lung within 1 minute,[14] and most of it stays out of cells.[18,19] Based on these findings, using ^{99m}Tc-RBC and ^{99m}Tc-DTPA as non-diffusible and diffusible indicators, respectively, a non-invasive quantification of EVLW has become possible by

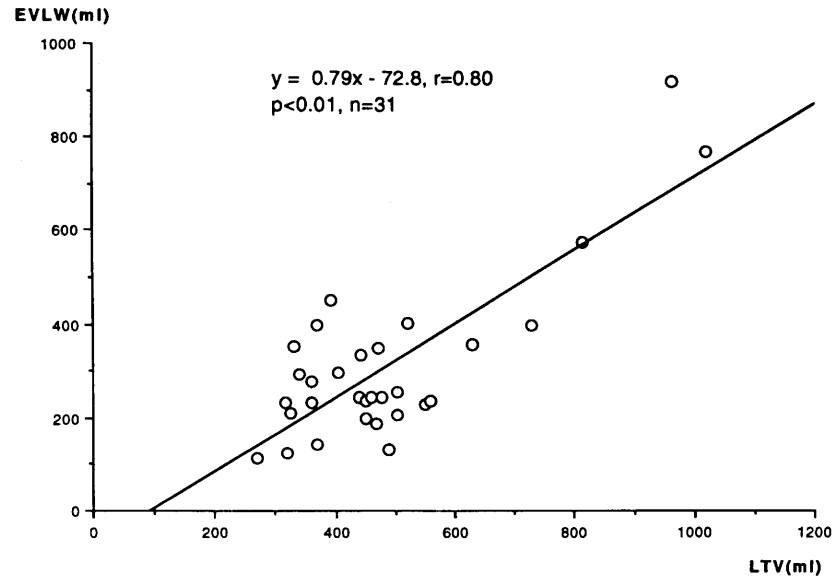

Fig. 3 Relationship between lung thermal volume (LTV) and extravascular lung water (EVLW).

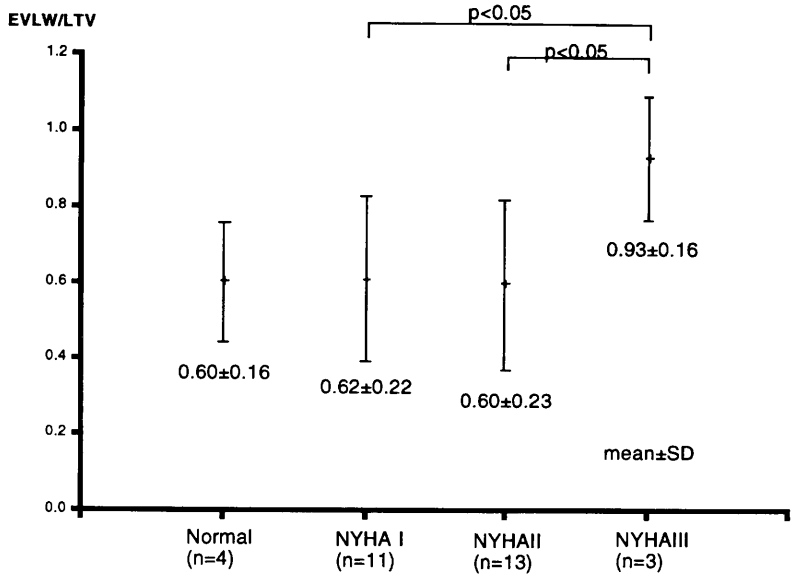

Fig. 4 EVLW/LTV in normal subjects and patients in NYHA classes I, II, and III.

employing the ratio of the counts to these two indicators in their respective equilibrium phases. Table 2 shows the values for EVLW and LTV previously determined in normal subjects by various methods. The values obtained in the present study were 73% of the value obtained by the gravimetric theory and 50 to 60% of the LTV. Lung fluid measured by the gravimetric theory contains intracellular water.[2] LTV tended to be higher than lung fluid measured by the gravimetric theory, because LTV includes the intracellular water and probably because heat also diffuses to the myocardial wall, mediastinum and chest wall.[1,2] A study was carried out by Vaughan and his coworkers[20] with human pulmonary tissue that had been removed by thoracotomy after the injection of ^{14}C sucrose 10 minutes before lung biopsy. This study revealed that the extravascular extracellular interstitial space was 0.60 ± 0.28 of the extravascular extracellular and intracellular spaces, suggesting that the level of EVLW measured in the present study represented the extravascular extracellular water. The present study employed ^{99m}Tc-DTPA, a compound almost incapable of entering the cell. It was therefore used as the diffusible indi-

Table 2 Extravascular lung fluids in normal human reported by various investigators

	(ml/kg)
Gravimetric	
Mihm[2]	4.1±1.0
Double indicator dilution method	
Thermal-dye (LTV)	
Lewis[6]	5.7±1.2
Sibbald[7]	5.6±1.8
Sivak[8]	5.5±1.7
Thermal-Na (LTV)	
Watanabe[9]	6.1±2.2
Arakawa[24]	5.7±1.4
EVLW (the present study)	3.0±1.4

mean±S.D.

cator, so that the measured EVLW represents the extravascular extracellular water. In an experimental study with laboratory animals, the LTV estimated by heat and sodium was 1.17–1.19 times as great as lung fluids measured by the gravimetric theory, but the two showed a good correlation.[3,5] There was a good positive correlation between LTV and EVLW ($r=0.80$) in the present study.

In NYHA functional class III, the EVLW/LTV ratio was higher than in other classes (Fig. 4). Because the first pass method was used to estimate LTV, when pulmonary edema was advanced, the perfused area was decreased, and the indicators of LTV were prevented from reaching the alveoli where perfusion was interrupted, thus underestimating the LTV.[10] In the present study, EVLW was obtained mainly by measuring water in the interstitium which increased during pulmonary interstitial edema. This suggests that the EVLW measured by the present study may be a more sensitive indicator than the LTV, because LTV includes the volume of fluids in other places, such as intracellular water, the myocardial wall, and possibly the mediastinum and chest wall where heat diffuses. The EVLW/LTV ratio was significantly higher in the NYHA class III than in NYHA class I or II. This may be due to an increased pulmonary interstitial fluid volume in left-sided heart failure combined with an underestimation of lung water by LTV.

(2) Extravascular lung water and lung thermal volume in left-sided heart failure

Many reports have related a variety of radiographic criteria for cardiogenic pulmonary edema to the clinical signs and hemodynamic findings in patients with left ventricular dysfunction. MacCredie et al.[16] measured EVLW in patients with valvular heart disease by the double dilution indicator method with radioiodinated serum albumin and tritiated water in 1967, and reported that EVLW was significantly higher in NYHA classes II, III, and IV than in NYHA class I, and that there was a positive correlation between EVLW and pulmonary artery wedge pressure (PAW). Several reports[21–23] showed a positive correlation between LTV using heat and indocyanine green and PAW. It was reported that in subjects with various left-sided heart diseases, LTV of the patients with congestive heart failure was higher than that of patients without heart failure.[23] In present study, EVLW was significantly higher in the NYHA class III patients than in the "normal" control, and patients in NYHA class I or II. It is therefore proposed that the EVLW measurement with ^{99m}Tc-RBC and ^{99m}Tc-DTPA is useful for the evaluation of left-sided heart failure.

APPENDIX

In this Appendix we will describe our approach to the correction of EVLW for radioactivity of chest wall origin, and also for the attenuation of radioactivity by the chest wall and lung.

PBV and EVLW are measured on planar images recorded from the anterior-posterior projection. The recorded counts include not only the radioactivity from the lung field but also that originating in the anterior and posterior chest wall. As a result, correction for these factors is necessary. To determine the fraction of counts originating in the lung in the total counts on the chest, we first measured the thickness of the anterior and posterior chest wall and the lung field by X-ray CT scan and by SPECT in same patients. A model experiment was then performed to determine the attenuation of ^{99m}Tc using slices of meat and water. Finally, we calculated the degree of attenuation by the chest wall and water based on these two studies.

(1) Measurement of the thickness of each region of the thorax studied by CT scan

CT scan of the chest was performed in ten subjects with normal cardiac function to measure the thickness of three regions, i.e. the anterior chest wall, the lung field and the posterior chest wall, at the apex (the level of the aortic arch) and the base (immediately above the diaphragm). As a result the average thickness was, for the anterior chest wall, 1.8± 0.6 cm, for the posterior chest wall 3.0±1.7 cm, and for the lung field 15.6±2.3 cm. (Fig. 5)

(2) Counts from each region of thorax studied by SPECT

In five of the above control subjects, RN-angiocardiography with either ^{99m}Tc-RBC or ^{99m}Tc-DTPA was performed, followed by SPECT in the equilibrium phase. In the lateral view, ROIs were set

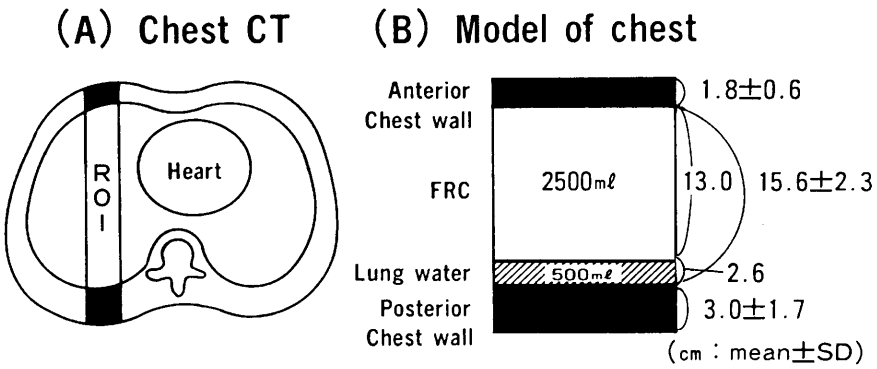

Fig. 5 CT image of thorax and a simplified scheme of the thorax. (A) CT scan of the chest was performed in 10 subjects to measure thickness of the anterior chest wall, lung field, and posterior chest wall. (B) Measured and assumed values of the thickness of constituents of the chest.

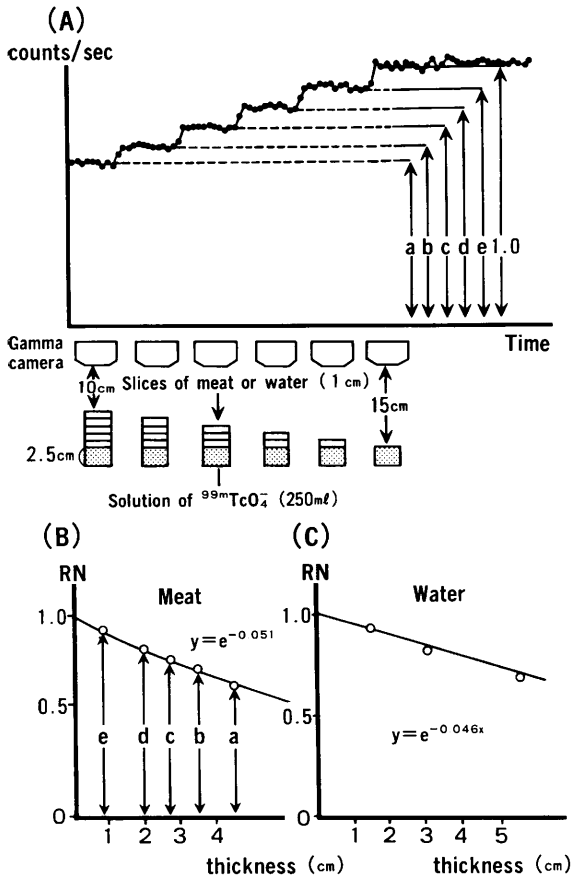

Fig. 6 Attenuation of ^{99m}Tc radioactivity by layers of meat or water.

at the anterior chest wall, the lung field and the posterior chest wall i.e., the same places as previously measured by CT scan. Radioactivity was measured at each ROI. As a result, RN count of the anterior chest wall divided by RN count for the lung field was 0.12±0.10, while the RN count for the posterior chest wall divided by the RN count for the lung field was 0.16±0.13 in SPECT with ^{99m}Tc-RBC. The ratios were 0.17±0.10, and 0.20±0.14, respectively, in SPECT with ^{99m}Tc-DTPA.

(3) Attenuation of ^{99m}Tc radioactivity

Layers of meat and water each 1 cm thick were used to mimic the chest wall and lung water, respectively, to calculate the degree to which the radioactivity of a source beneath the layers of meat or water was attenuated. The thickness of meat or water placed in a tray sitting on a box of $^{99m}TcO_4^-$, solution was variably changed. RN counts were recorded from above at a distance of 10 cm in the case of 5 layers, and 15 cm without any layer (Fig. 6A). Attenuation of RN counts was measured by decreasing the thickness of meat in steps of 1 cm from the initial thickness of 5 cm (Fig. 6A). The layers of meat and water used contained no radioactivity. Attenuation of the RN count due to meat was corrected for the physical decay. The degree of penetration could be related to the thickness x in the form of $y=e^{-0.051x}$ (Fig. 6B). A similar examination conducted with water revealed that attenuation occurred in the form of $y=e^{-0.046x}$ (Fig. 6C)

(4) Estimated degree of attenuation due to the chest wall and lung water

Assuming that attenuation in the anterior chest wall was caused by a layer of meat 1.8 cm thick (Fig. 5B) and that all the γ rays emanated at midway in this thickness, the degree of penetration through the anterior chest wall was calculated as

$$y=e^{-0.051\times1.8/2}=0.96$$

It was assumed that the attenuation in the lung field was caused by a layer of water 2.6 cm thick (Fig. 5B) which is equivalent to 1/6 of the antero-posterior diameter of the lung (15.6/6=2.6). It was also as-

Table 3 An example of calculating the fraction of RN counts on the planar image that are originating from the three constituents of the thrax

ROI	SPECT (count)	Approximate degree of penetration	Planar (count)
Anterior chest wall	(A)6212	0.96	(A′)5964
Lung	(B)30041	0.86	(B′)25835
Posterior chest wall	(C)4123	0.75	(C′)3092
Total			(D′)34891

sumed that the gas volume at Functional Residual Capacity (FRC) was 2,500 m*l*, and that the volume of the lung water was 500 m*l* (500/3,000=1/6), based on a study of normal autopsy cases by Mihm et al.[2] who reported the lung water volume to be 523 g (body weight 60 kg). It was also assumed that ^{99m}Tc existing in the lung field radiated midway within the thickness of the lung water. As a result the degree of penetration through the lung water was calculated as $e^{-0.046\times2.6/2}$. In addition, also considering attenuation by the anterior chest wall, the degree of penetration through the lung field was calculated as

$$y=e^{-0.051\times1.8}\times e^{-0.046\times2.6/2}=0.86$$

The degree of penetration from the posterior chest wall origin was similarly calculated as (Fig. 5B).

$$y=e^{-0.051\times1.8}\times e^{-0.046\times2.6}\times e^{-0.051\times3.0/2}=0.75$$

(5) The ratio of counts originating in the lung field on a planar image

RN counts at each ROI (anterior chest wall, lung field, posterior chest wall) as measured by SPECT (Table 3A, B, C) in every subject were multiplied by the degree of penetration of each site in the thorax (Table 3 (A′), (B′), (C′)). These values were regarded as approximately the effective RN counts from each site of the thorax as represented on the planar image on the anterior chest wall A total of these values (Table 3 (D′)) would be the total counts of the planar image. The quotient obtained by dividing the RN counts of the ROI of the lung field by the total of these values would be the fraction of RN count on the planar image originating in the lung field (E).

$$E=B/D'=0.86$$

The mean of the ratios (E) in the subjects obtained with ^{99m}Tc-RBC was 0.89 ± 0.08, while that in those obtained with ^{99m}Tc-DTPA was 0.84 ± 0.10. Thus with these values, RN count for the ROI on the anterior chest lung field in each subject was corrected by multiplying RLr by 0.89, and by multiplying (RLd-R′Lr) by 0.84.

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