The scatter correction for cardiac output in the radionuclide first pass measurement

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Abstract: The measurement of cardiac output (CO) can be done with gamma camera using conventional first pass technique, where the region of interest (ROI) is delineated around the left ventricle (LV). Remarkable amount of scattered radiation, coming from the right ventricle and lungs, always gathers on this region. In this study scatter correction was done by using the dual window subtraction method, where the second window (93 - 125 keV, 30 %) was placed below the primary photopeak window (126 - 154 keV, 20 %). The effect of this correction was tested by recalculating a group of 16 patients sent to ejection fraction and CO study for several reasons. The average of the percentage correction was 4.1 % (range 1.1 - 10.4 %). The scatter correction had small but consistent influence on the values of cardiac output.

INTRODUCTION

The portion of scattered radiation in gamma images can be subtracted by making the data acquisition simultaneously with two or more energy windows. The effect of the scatter correction on emission tomography (SPECT) imaging has been extensively studied by many investigators [1,2], but very little has been published about planar imaging. The scatter disturbs all gamma imaging in the same way, but the error caused is prominent whenever quantitative values are searched. Scatter could also be especially harmful in studies where high activity is moving through closely placed compartments. In this study CO was measured by the first pass method with and without scatter correction, where the correction used was the dual window subtraction method.

METHOD

The group of patients consists of 13 males and 3 females between 46 and 77 years (average 59 years). They were primarily sent to the nuclear medicine department for gated ejection fraction (EF) measurement.

At first the total blood volume (TBV) was measured using a dilution technique and 180 kBq of ^{125}I -human serum albumin (Amersham, UK).

The CO and EF measurements were made with 560 MBq of ^{99m}Tc (MAP Technologies, Finland). This activity was tagged onto red blood cells using a 0.03 mg/kg dosage of stannous agent (Amersham, UK) 20 minutes before the bolus injection [3].

The gamma camera (Picker Dyna Camera) was placed on the patient's chest at the left anterior oblique position of approximately 45 degrees without caudal tilt. A high resolution collimator was used and the data were collected into 64 × 64 matrices (16 bits). The first group was 100 × 0.5 s (50 seconds) and the second group was 50 × 30 s (25 min). The computer system was a PDP11/83 with TSX+ operating system and a PCS-512 image handling program (Nuclear Diagnostic, Sweden).

The primary energy window was set on the maximum of ^{99m}Tc gamma spectrum 20 % in width. The scatter window was set beside this to smaller energies of 30 % in width, where the average was 109 keV. Collected data were split in two datafiles, one for photopeak window and the other for the scatter window. The scatter image set was subtracted from the primary file using a self made program, which was a convenient way to interactively choose the suitable weighting factor. The best value for the weighting factor here was 0.4.

Scatter free data were used in the Stewart-Hamilton type computation of cardiac output. The calculation was carried out by using the formula:

$$CO = \frac{H}{A} \times TBV,$$

where H was the activity level after complete mixing of the tracer obtained by mathematical extrapolation. A was the area under the first pass section of LV-curve, integrated numerically using the analytical formula of the gamma variate [3,4].

Background correction was done only on the end part of the LV-curve, because at the first pass phase there was not yet a real background over and beneath the heart in the thoracic wall. Background correction was done using the selected ROI multiplied by a factor of 0.6. This factor was estimated by searching the plane source sensitivity curves measured in water and the actual left ventricle diameters and their actual depth inside the thorax.

The delineation of LV was done manually after addition of a few frames around the peak activity. The ROI was first drawn to the uncorrected image and then the same ROI was dropped onto the corrected image. Using this method the effect of different location of ROIs was avoided. In the scatter corrected image the edges of the heart appear more clearly. The depth of heart was roughly estimated using the Links method [5].

RESULTS

Scatter correction had an effect on the shape of the activity curves as shown in figure 1. The scattered counts were subtracted using different weighting factors and curves were scaled to 100 % from their maximum to make the comparison easier. The premature peak (near the 5 s time) was apparently scatter coming from the right ventricle. It diminished in the scatter subtraction process.

The magnitude of correction did correlate clearly with the depth of the heart, but did not correlate with plain body weight.

CONCLUSION

The dual window scatter correction had a small, but clear effect on the cardiac output values of the patient group.

Figure 1. Time activity curves of the left ventricle when different weighting factors (k) are used in subtraction.

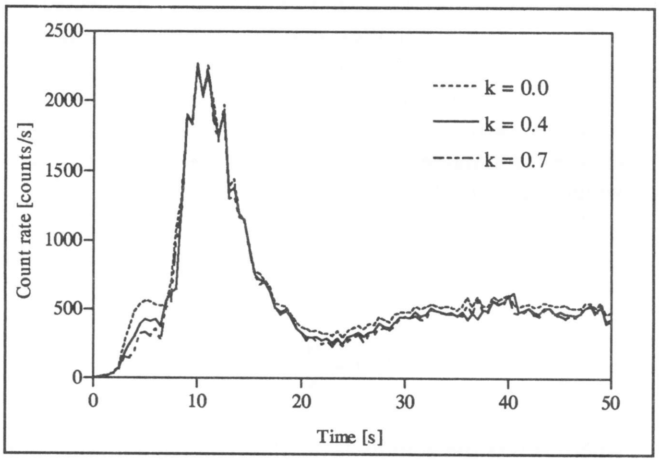

Table 1. The essential results of cardiac output with (CO_c) and without (CO_{nc}) scatter correction.

Patient	CO_{nc} [l/min]	CO_c [l/min]	ΔCO [l/min]	ΔCO [%]
1	5.99	6.20	0.21	3.5
2	3.76	3.94	0.18	4.8
3	3.85	3.92	0.07	1.8
4	4.31	4.53	0.22	5.1
5	5.65	5.87	0.22	3.9
6	7.39	8.16	0.77	10.4
7	5.05	5.18	0.13	2.6
8	2.68	2.72	0.04	1.5
9	4.59	4.78	0.19	4.1
10	5.71	5.77	0.06	1.1
11	4.25	4.37	0.12	2.8
12	5.13	5.29	0.16	3.1
13	3.28	3.41	0.13	4.0
14	3.11	3.29	0.18	5.8
15	4.56	4.77	0.21	4.6
16	5.97	6.31	0.34	5.7
			mean	4.1 %

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