PROBLEMS OF MYOCARDIAL SCINTIGRAPHY WITH THALLIUM-201

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Abstract

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Because of the low energy of ^{201}Tl, the scan of thick organs is problematic. In a layer of about 4 cm thickness only half of the first value can be measured. The margins of the organ of interest become blurred through the Compton effect and the movement of the organ in the field of the collimator, the movement of the organ being the biggest influence. Model investigations show that the area of the organ is influenced by the surrounding activity. With an equal count rate a high background activity results in a lower area of the organ and vice versa. Additionally misinterpretations of defects are produced because of incorrect background subtraction. Water cylinders with height 6 cm, 2.5 cm and 1.5 cm were placed in a thallium-activated layer successively. If the non-activated cylinder of 6 cm is as high as the activated layer, 33% of the activity of the original activity is measured. If the cylinder reaches half the height of the activated layer, 70% of the activity is measured. Such a decrease in the count rate can be obtained if the absorption layer between the collimator and the organ is increased by up to three or more centimetres. These results demonstrate that the interpretation of defects in a myocardial scintigram, especially in studies of redistribution and follow-up studies, is difficult.

INTRODUCTION

Thallium is a common radionuclide for the visualization of the human myocardium. The half-life of thallium-201 is 73.5 h. It decays by electron capture to mercury-201, followed by the emission of gamma rays of 135 and 167 keV and X-rays of 65–82 keV [1]. The irradiation procedure also yields lead-200 and lead-202m, decaying to thallium-200 ($T_{1/2}$ = 26.1 h) and thallium-202 ($T_{1/2}$ = 288 h). By a proper selection of process parameters these have been limited to a minimum. Their physical properties lead to an interval in which disturbances from scattering and collimator septum penetration are minimal.

The uptake of ^{201}Tl by the myocardium depends on intact myocardial perfusion [2–4] and a functional sodium-potassium pump in the myocardial cell. Thallium-201 appears to be the best of the potassium analogues at present available for myocardial imaging [5], but the visual interpretation of the images is complicated by some nonhomogeneity of tracer uptake by the normal myocardium, especially in the region of the apex [6, 7]. Within the first 30 minutes of injection, myocardial activity exceeds that of the surrounding structures [8]. During this time the myocardium can be well demonstrated by 'image processing'. The relatively fast myocardial kinetics of ^{201}Tl ($T_{1/2}$ = 33 min) make it necessary, strictly speaking, to use a scintillation camera. The distribution of ^{201}Tl in the human body is: myocardium (3.6 ± 0.7) %, liver (8.7 ± 2.1) %, kidney (4.1 ± 1.5) %, muscle and the other organs accounting for the remainder [9]. The interpretation may be rendered more difficult by the use of background subtraction and contrast enhancement technique which will accentuate any normal variation in ^{201}Tl uptake. The best results came from exercise studies with ^{201}Tl [10–14].

METHOD

Investigations of the model and of the patients were recorded with a large field scintillation camera (Scintag-Berthold) with a high-sensitivity, low-energy parallel-hole collimator. One million counts were recorded over the region of the myocardium with a 20% window set symmetrically around the X-ray peak. Patient images were obtained in the anterior, 30° left anterior oblique and left lateral positions.

RESULTS AND DISCUSSION

The low energy of ^{201}Tl is problematic for the demonstration of big organs. Because of the absorption of the low-energy rays in the organ itself and the surrounding background, myocardial defects may be influenced by the unfavourable position of the detector.

The half value layer of the emission of ^{201}Tl is 4 cm, as shown in Fig.1. In this diagram the count rate in correlation to the thickness of the object is demonstrated. For estimating the half value layer the thallium activity was measured after passing a more or less high layer of water.

The self absorption increases with the increase in the height of the ^{201}Tl solution, as shown in Fig. 2. Thallium is dissolved in water. By a threefold increase in the height of the ^{201}Tl solution of the same specific activity, the count rate rises from 4000 to 6000 counts/s (only 50%). The contribution of the deeper layers of the organ to the total count rate decreases. After a height of 15 cm there is practically no increase in the count rate and the curve in the diagram reaches a plateau.

The Compton emission produced with low energy below 100 keV is not very different from photoenergy. Because of the registration of part of that

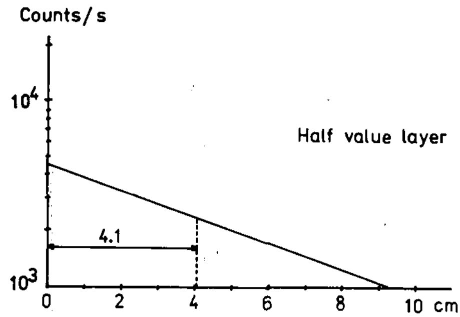

FIG.1. Estimation of the half value layer of the emission of ^{201}Tl. The count rate in correlation with the thickness of the object is demonstrated.

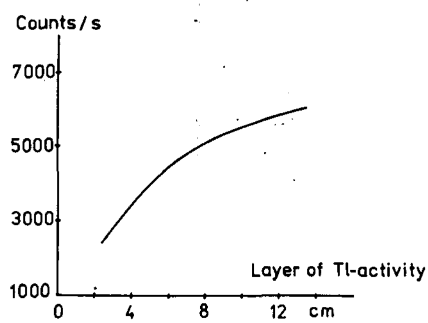

FIG.2. Self absorption estimation. The count rate in correlation with the increase in the height of the ^{201}Tl solution in water is shown, indicating that the contribution of the deeper layers of the organ to the total count rate decreases.

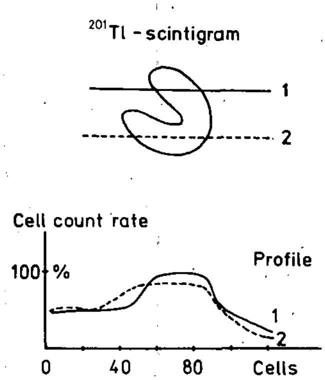

FIG.3. Profile curves of two layers of the myocardium and the surrounding background. Profile 1 shows the myocardium with high activity (———) and profile 2 the myocardium with low activity (– – – –).

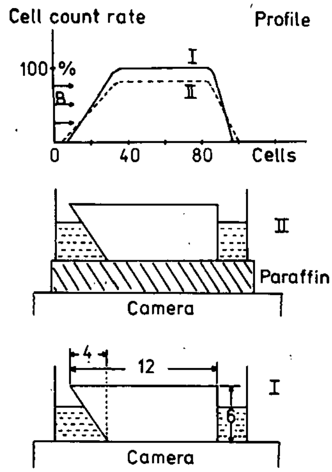

FIG.4. Model of a box, rectangular except that the left wall has an angle of 60°. The upper width is 12 cm, the lower 8 cm, and the height 6 cm. This box is filled with ^{201}Tl solution and placed in a vessel with technetium activity as background. The model is positioned directly above a high-sensitivity low-energy collimator (with and without paraffin absorber). The upper part of the figure shows the profile curves of the model arrangements.

Compton emission the geometrical sharpness is decreased. Pollution of the ^{201}Tl with ^{200}Tl and ^{202}Tl reduces also the quality of the scintigram, because of the scattering radiation of high gamma energy of these isotopes in the septum of the collimator. The movement of the heart is of greater influence on the sharpness of the picture. Therefore the exchange of the high sensitivity collimator with one of high resolution would have no recognizable effect. In contrast to the decrease in sensitivity the statistical blur increases.

In myocardial studies the surrounding tissue must be corrected. Figure 3 shows profile curves of two layers of the myocardium and the surrounding background. Profile 1 demonstrates the myocardium with high activity (full line) and profile 2 the myocardium with low activity (broken line). The size of the myocardial margin depends on the activity of the background, which usually reaches 50% of the maximum of myocardial activity. High activity in the background results in a myocardium with a smaller area. After background correction with lower activity the myocardial area becomes larger. Additionally the areas of accumulated defects in the myocardium increase with high background subtraction. But these defects may be statistically misinterpreted at low count rates. This is noted in repeated studies especially in redistribution studies. In the redistribution the relationship between the myocardium and background changes.

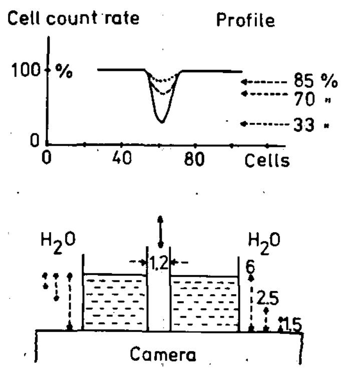

FIG.5. A box with thallium-activated water (lower part). In this activated water is a defect with height 6, 2.5 or 1.5 cm, an area varying from 3 to 5 cm² and a width varying from 1.2 to 1.7 cm. The profile curves (upper part) show the results of the three defect arrangements. A defect with a height of 6 cm results in a count rate of 33%, 2.5 cm in a count rate of 70%, and 1.5 cm in a count rate of 85% of the measured maximal activity.

Figure 4 demonstrates changes in the areas in a model through background activity and also by an absorption layer. The upper part shows the profiles of the arrangement of two studies. Number I demonstrates the profile at different background activities and Number II the same arrangement with an absorption layer. The model consists of a rectangular box except that the left wall has an angle of 60°. The upper width is 12 cm, the lower 8 cm and the height is 6 cm. This box is filled with a ^{201}Tl solution, and is in a vessel which is filled with ^{201}Tl activity as background. The two vessels are positioned as follows: first, directly about the high-sensivity low-energy collimator (lower diagram); second, between the collimator and the vessels is a layer of paraffin with a thickness of 3 cm (middle diagram).

The margin of the box cannot be reconstructed from the profile curves. Nor is this possible without surrounding thallium activity. The box is too large, and the wall is blurred and the oblique wall unrecognizable. An increase in the surrounding activity reduces the expansion of the profile demonstrated by the arrows on the left in the upper diagram. If the surrounding activity reaches 50% of the maximal measured count rate, the image of the box is nearly 30% too small. This ratio is similar to the ratio between myocardium and background in man. The mis-interpretation becomes stronger if there is an absorption layer of paraffin between the model and the collimator (Number II). Because of the absorption the profile is lower at the same time of demonstration as in trial I.

Total defects related to the total height of a thallium-activated water layer with a height of 6 cm, an area of 3 to 5 cm² or a width of 1.2 to 1.7 cm (Fig. 5, lower diagram) result in a count rate of 33% of the activated layer. This is recognizable in the profiles in the upper part of Fig. 5. If the expansion of the defects concerns only parts of the layer, for instance 2.5 or 1.5 cm, the valley of the profile becomes smaller, about 30 to 15% of the measured maximal activity.

Because of statistical problems at a low count rate, the defect from a height and a width of 1.5 cm is not recognizable. It is irrelevant whether the defect is in the upper or lower part of the ^{201}Tl-activated layer. If the defect reaches half of the activated layer the count rate decreases to 70% of the maximal count rate. A decrease in the count rate is also possible when an absorption layer surrounding an investigated organ increases about 3 cm and the accumulation in the organ is homogeneous. This is possible during rotation of the heart between systole and diastole.

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