

201Tl-Redistribution Analysis in Early and Delayed Myocardial Scintigrams of Patients With Coronary Heart Disease (CHD)


Nuklearmedizinische Klinik und Poliklinik and I. Medizinische Klinik der Technischen Universität München, Munich, Federal Republic of Germany

Abstract. Scans were performed on 8 healthy subjects and 25 with coronary heart disease proven by angiography and ventriculography including 6 with previous myocardial infarction at rest, exercise, and 1 and 2 h after exercise. Data were collected by a gamma camera interfaced to a data collection system. In healthy subjects 201Tl distribution was homogeneous at rest and after exercise, the count rate ranging between 100% - as set in the region of maximum - and 80% over other regions of myocardium. In 19 patients with coronary heart disease it was uniform only at rest; 6 patients with previous myocardial infarction had locally diminished 201Tl uptake even at rest. In patients with coronary heart disease without previous myocardial infarction, scans made immediately after exercise showed significant 201Tl hypofixation in region of minimum, the count rate of which was less than 80% of the count rate as determined over region of maximum, 201Tl uptake. Scans made 1 and 2 h after exercise had filling-in of 201Tl within the region of minimum the count rate of which returned to the normal range of at least 80% of the count rate measured over region of maximum uptake. This return to resting distribution was called 201Tl redistribution. Six patients with coronary heart disease and previous myocardial infarction had 201Tl defects larger after exercise than at rest, without redistribution being observed. Redistribution in late postexercise scans is a sign of reversible ischemia in coronary heart disease. Scans at rest may be omitted in coronary heart disease, because transient ischemia is undetectable, unless spontaneous angina occurs during scan procedure.

Introduction

After the introduction of 201Tl for medical use [14] myocardial imaging gained widespread acceptance in patients with CHD with [1, 6, 12, 15, 23, 37] and without previous myocardial infarction (PMI)[4, 10, 11, 16, 18, 19, 24, 39, 40]. Discrepancies were observed between a regional decrease in uptake of 201Tl on early exercise scans and a filling-in of 201Tl in the same patients within several hours, when resting conditions were reached again. These reversible functional disturbances were interpreted as Radiothallium-Redistribution (RRD) [8, 13, 26-28, 30, 32, 33] Controversial statements were made concerning the onset of RRD subsequent to stress-induced regional 201Tl hypofixation [10, 11, 13, 20, 28]. No systematic clinical studies based on quantitative analysis of serial myocardial scintigraphy (SMS) are available. The aim of our investigation was to quantitate RRD in patients with and without previous myocardial infarction. A further question was whether scans at rest are ommittable in this group.

Materials and Methods

Twenty-five patients with CHD including 6 with PMI proven by left ventricular and coronary angiography were investigated. At least one vessel had a stenosis of more than 75%. Eight healthy subjects in whom cardiac disease was excluded by angiography served as controls. Scans were performed in anterior (AP), LAO 30, 45, 60 degree, and LL.

Exercise Scintigraphy

All patients were injected with 2 mCi of 201Tl i.v. during submaximal graded exercise on a bicycle ergometer, beginning with a load of 25 W until maximal heart rate or onset of angina, ST-segment depression, or severe cardiac arrhythmias. 201Tl was injected at
peak exercise and the patients were forced to continue exercising for about 1 min to keep stress-induced conditions during the early myocardial extraction period [41]. Myocardial scans were started 5 min after \(^{201}\)TI injection the patient supine (early scans) in anterior (AP), left anterior oblique (LAO) 30, 45, 60 degrees, and in left lateral (LL) views by rotating the detector. Scans were repeated exactly 1 h after exercise in the same sequence of view. Average scan time per view was 6-8 min. Early and late scans (performed 1 and 2 h after exercise) were compared qualitatively and by a quantitative analysis, as described below.

**Rest Scintigraphy**

Myocardial scans at rest either preceded or were followed by exercise scans, the interval in between ranging from 6 to 8 days, in the same projections.

**Instrumentation and Techniques**

We used an Ohio Nuclear gamma camera (ON 100) interfaced to an ON 150 Data-System. Careful control of field homogeneity was carried out before every investigation. The inhomogeneity of the crystal varied between 5% and 15% in peripheral areas. However, by averaging field homogeneity using a flood field phantom, each picture element count rate was corrected by a scaling factor. Thus in the most homogeneous part of the crystal in which the myocardium was carefully centered, the inhomogeneity was kept between 2.5% (in ROI\(_{\text{max}}\)) and 4% (in ROI\(_{\text{min}}\)).

Constant preselection of count rate was ascertained in each patient by accumulating 1,500 ct using the light pen over the region of maximal \(^{201}\)TI uptake (ROI\(_{\text{max}}\)) in every scan. Uptake was also determined over the region of minimal count rate. The effectively injected \(^{201}\)TI activity was measured under standardized geometrical conditions. Only those counts in ROI\(_{\text{min}}\), which were more than 20% lower than counts measured over ROI\(_{\text{max}}\), were considered to be abnormal. Data were imaged in a digital display matrix of 128 x 128 pixels (8 bit depth, 16K). The size of the ROI was always adjusted to 4 x 4 channels - 1 cm\(^2\) - , equivalent to the spatial resolution capability of our gamma camera.

**Quantitative Analysis**

**Background.** As reference region for background a ROI in the lungs near the myocardium was selected.

**Determination of \(^{201}\)TI Washout Factors (WF)**

\(^{201}\)TI washout was determined over ROI\(_{\text{max}}\) by the ratio of counts 1 h and 2 h after exercise (ctr\(_{t1,2}\)) and immediately after exercise (ctr\(_t0\))

\[
WF_{t1,2} = \frac{\text{ctr}_{t1,2}}{\text{ctr}_{t0}} \times \text{ROI}_{\text{max}}
\]

where WF\(_{t1,2}\) are the washout factors of \(^{201}\)TI representative for the decrease of \(^{201}\)TI activity in ROI\(_{\text{max}}\) i.e., in the viable myocardium with the highest count rate 1 h (WF\(_t\)) and 2 h (WF\(_2\)) after exercise.

**Determination of \(^{201}\)TI Redistribution Factors (RDF)**

If one assumes that the rates of washout from ROI\(_{\text{max}}\) and ROI\(_{\text{min}}\) are the same, one can calculate what the count rate normally should be for ROI\(_{\text{min}}\) at 1 h by starting with the measured ctr (ROI\(_{\text{min}}\)) shortly after exercise and multiplying this rate by the washout factor for 1 h, WF\(_1\) respectively for 2 h (WF\(_2\)) according to the relation

\[
[RDF] = \frac{\text{ctr}_{t0} \times \text{ROI}_{\text{min}}}{\text{ROI}_{\text{max}} \times WF} = \frac{\text{ctr}_{t1,2} \times \text{ROI}_{\text{min}}}{\text{ROI}_{\text{max}} \times WF_{1,2}}
\]

One can then compare this calculated ctr (using subscript c) with the measured ctr at 1 h (using subscript m). The redistribution factor (RDF) is the ratio of the measured value to the calculated "normal" value.

Redistribution of \(^{201}\)TI in terms of redistribution factors (RDF) in ROI\(_{\text{min}}\) may be determined by the ratio of measured ctr over ROI\(_{\text{min}}\) 1 and 2 h after exercise (ctr ROI\(_{\text{min}}\) \(_{t1,2}\)) and calculated ctr over ROI\(_{\text{min}}\) 1 and 2 h after exercise (ctr ROI\(_{\text{min}}\) \(_{t1,2}\))

\[
\text{RDF} = \frac{[\text{ctr}_{t1,2} \times \text{ROI}_{\text{min}}]}{[\text{ctr}_{t1,2} \times \text{ROI}_{\text{min}}]_{c}}
\]

**Results**

**Healthy Controls**

Eight healthy controls showed a homogeneous distribution of \(^{201}\)TI in the left ventricular myocardium. In all of them the right ventricular wall was visualized immediately after exercise. Serial myocardial scintigraphy (SMS) 1 and 2 h after exercise revealed no zones of different tracer accumulation in comparison to early images. For these normal controls, the 1 h washout factor, WF\(_1\), was 0.88 ± 0.12; the 2 h factor, WF\(_2\) = 0.79 ± 0.1 (SEM) (Fig. 2).

The ratio of \(^{201}\)TI activity (ROI\(_{\text{max,Myocardium}}\) / ROI\(_{\text{Lung}}\)) was 2.50 ± 0.21 (at rest), 3.70 ± 0.85 (immediately after exercise), 3.12 ± 0.69 (1 h after exercise), 2.94 ± 0.33 (2 h after exercise).

**Patients With Coronary Heart Disease**

Twenty-five patients with CHD had, in at least one view, a regional decrease of \(^{201}\)TI uptake less than 80% of the ctr as measured over ROI\(_{\text{max}}\). Washout of \(^{201}\)TI measured over ROI\(_{\text{max}}\) and 2 h after exercise did not differ from that observed in healthy controls (Figs. 1 and 2). The 19 patients with locally decreased \(^{201}\)TI uptake only on exercise scans presented a significant increase of \(^{201}\)TI accumulation over the region of minimal \(^{201}\)TI uptake (ROI\(_{\text{min}}\)) 1 and 2 h after exercise (Fig. 3). Myocardial scintigrams taken 2 h after exercise gave \(^{201}\)TI distribution comparable to myocardial scintigrams performed at rest (Fig. 4).

Six patients with \(^{201}\)TI defects both at rest and exercise scan had a lack of \(^{201}\)TI redistribution in that area of left ventricular defect.