Identification of Left Ventricular Thrombi in Man
Using Indium-111-labeled Autologous Platelets
A Preliminary Report

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SUMMARY Indium-111 (111In) bound to 8-hydroxyquinoline can be used to label platelets without impairing their ability to participate in active thrombosis. The purpose of this study was to identify intracardiac thrombi using 111In platelet scintigraphy. Twenty-nine patients were studied. Twenty-one had discrete left ventricular aneurysms (group 1). The remaining eight patients (group 2) had normal or minimally narrowed coronary vessels (< 50%) and a global ejection fraction of 54 ± 14% (mean ± SD) without segmental dysfunction on contrast ventriculography. Six of the eight patients with insignificant coronary disease had severe mitral valve disease requiring surgery. Each intravenous injection contained 3.4 ± 1.6 × 109 platelets labeled in a solution of acid citrate dextrose and saline (1:7, pH 6.5) with 454 ± 114 μCi (mean ± SD) 111In complexed to 8-hydroxyquinoline with a final labeling efficiency of 67 ± 17%. Platelet recovery at 15 minutes was 37.8 ± 14.5% (mean ± SD; n = 15). Imaging was performed in the anterior, left anterior oblique 45° and left lateral views (the right anterior oblique 45° view was included in all except patients 1–5 in group 1) on the day of injection and at 1–2-day intervals for a maximum of 8 days. In group 1, nine patients had abnormal areas of increased activity within the left ventricle. Four required aneurysectomy and had left ventricular thrombi; a fifth died and at autopsy evidence of a thrombus was found. In four patients (the only patients in whom these data were obtained), surface thrombus 111In activity was at least 9.7 times greater than that of blood, noninvolved myocardium and deeper aspects of the thrombus. Twelve patients with aneurysms had normal scintiphotos. Six required aneurysmectomy and were negative for thrombi. All the patients in group 2 had negative platelet scintiphotos. The six patients who required mitral valve replacement had no thrombi at surgery. Therefore, the diagnostic accuracy of platelet scintigraphy (both groups) in the 17 patients in whom surgical or postmortem confirmation of thrombus could be obtained, five of whom had positive scintiphotos, was 100%. We conclude from this preliminary study that 111In platelet scintigraphy promises to be a reliable method for the identification of left ventricular thrombi.

INDIUM-111 (111In) is a gamma-emitting radionuclide that emits two photons per disintegration with energies of 173 and 247 KeV and has a half-life of 67 hours. It is well suited for scintigraphic imaging. When bound to 8-hydroxyquinoline, it forms a lipidsoluble compound that is an effective platelet label and does not appear to affect the ability of the cell to participate in thrombus formation. Therefore, platelets labeled in this way seem suitable for the detection of hematologically active intracardiac thrombi.

Thirty to 70 percent6-8 of patients with left ventricular aneurysms, proved at autopsy or surgery, have mural thrombi. In clinical studies, systemic emboli occur in 6–13%6, 8, 10 of patients with aneurysms, and the incidence is even higher in autopsy studies.6,11 Mural thrombi can only be definitively identified at autopsy or surgery. Diagnostic tests, including contrast ventriculography, cross-sectional echocardiography,12-14 and scanning with labeled fibrinogen15, 16 and antibodies to fibrinogen,17 have significant limitations.

Contrast ventriculography is invasive and not suitable for repeated studies when seeking information concerning the natural history, continuing activity and efficacy of therapy. In addition, it is not a validated standard against which other techniques can be measured, and lacks sensitivity.18-20 Cross-sectional echocardiography is limited by the necessity for studies of particularly good quality to differentiate artifact from true lesions, and its value in the assessment of thrombus activity is uncertain. However, it provides spatial orientation not possible with M-mode studies and is noninvasive, and therefore, suitable for serial examinations. Fibrinogen labeled with 125I and 131I and antibodies to fibrinogen have been used successfully to identify intracardiac thrombi. However, the physical properties of 125I (not suitable for scintigraphic examination) and 131I (poor resolution) severely limit their clinical applicability. The use of antibodies to fibrinogen carries the risk of reaction to foreign protein, especially when given intravenously. In this report, we show that active left ventricular thrombi can be readily identified using 111In-labeled platelet scintigraphy, a technique that may not only define the location of the thrombus, but also reflect its activity.

Material and Methods

Patient Population

Twenty-nine patients were studied, 24 males and five females, mean age 52 ± 12 years (± SD) (range
The patients were divided into two groups: those with left ventricular aneurysms (group 1) and those with insignificant coronary disease (group 2).

**Group 1 (table 1)**

Group 1 consisted of 21 patients. Each had discrete aneurysms that showed paradoxical wall motion in the apical or anteroapical area of the left ventricle. In 12 patients, persistent ST-segment elevation (defined as 1 mm of ST-segment elevation 30 days or more after the last myocardial infarction) was present. In six patients, a double precordial pulsation was palpable on physical examination, suggesting a dyskinetic area involving the left ventricle. The interval from the last myocardial infarction to the scintigraphic study varied from 6 days to 13 years. In six patients, this time interval could not be clearly determined. Seven patients (33%) had clinical evidence for systemic emboli, in the form of transient cerebral ischemic episodes or clear-cut peripheral emboli. All patients except patient 21 had contrast ventriculography in both left anterior oblique (LAO) and right anterior oblique (RAO) views because symptoms of heart failure or angina necessitated evaluation of their suitability for surgery. In patient 21, the diagnosis of aneurysm was made by nuclear ventriculography. The criteria for the diagnosis of an intracardiac thrombus on contrast ventriculography was the presence of a constant filling defect in relationship to the aneurysm, usually in both views.

**Group 2 (table 2)**

Group 2 consisted of eight patients. Six had significant mitral valve disease requiring surgery. The remaining two patients had nonsurgical disease: 30–50% occlusion of the right coronary artery with normal left ventricular function in the first and a myopathic ventricle with normal coronary arteries in the second. In all patients, 45° RAO and LAO contrast ventriculograms were performed. None of the patients had regional wall motion abnormalities. The global ejection fraction was 54 ± 14% (mean ± SD) in this group.

**Preparation of \(^{111}\)In-labeled Platelets**

We used the method developed by Thakur et al.\(^{21}\) and Heaton et al.\(^{22}\) Certain centrifugation times were reduced by us in all patients, except patients 1–6 in group 1, to reduce damage to the platelets. The desired activity of \(^{111}\)In chloride in dilute HCl (Mediphysics, Inc.) was complexed to 50 μl of 8-OH quinoline (oxine) in absolute alcohol (1 mg/ml) diluted in 4 ml of a solution of acid citrate dextrose (ACD).

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**Table 1. Patients with Left Ventricular Aneurysms (Group 1)**

<table>
<thead>
<tr>
<th>Pt</th>
<th>Age (years)</th>
<th>Sex</th>
<th>ECG*</th>
<th>Clinical†</th>
<th>Interval since last infarct</th>
<th>Aneurysm site</th>
<th>Clinical emboli</th>
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<td>43</td>
<td>F</td>
<td></td>
<td>-</td>
<td>-</td>
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<td>Apical</td>
</tr>
<tr>
<td>2</td>
<td>77</td>
<td>M</td>
<td>+</td>
<td>+</td>
<td>16 months</td>
<td>Anteroapical</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>46</td>
<td>M</td>
<td>+</td>
<td>+</td>
<td>10 years</td>
<td>Apical</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>63</td>
<td>M</td>
<td>-</td>
<td>-</td>
<td>5 years</td>
<td>Apical</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>65</td>
<td>M</td>
<td>+</td>
<td>+</td>
<td>2 months</td>
<td>Anteroapical</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>62</td>
<td>M</td>
<td>+</td>
<td>-</td>
<td>Not known</td>
<td>Anteroapical</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>37</td>
<td>M</td>
<td></td>
<td></td>
<td>4 months</td>
<td>Anterior</td>
<td>-</td>
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<tr>
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<td>M</td>
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<td>-</td>
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<tr>
<td>9</td>
<td>56</td>
<td>M</td>
<td>-</td>
<td>+</td>
<td>8 days</td>
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<td>M</td>
<td>+</td>
<td>+</td>
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<td>-</td>
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<tr>
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<td>49</td>
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<td>3 months</td>
<td>Anterior</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>38</td>
<td>M</td>
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<td></td>
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<tr>
<td>13</td>
<td>55</td>
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<td>-</td>
<td>13 years</td>
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</tr>
<tr>
<td>14</td>
<td>60</td>
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<tr>
<td>15</td>
<td>62</td>
<td>M</td>
<td></td>
<td></td>
<td>4 months</td>
<td>Anterior</td>
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<tr>
<td>16</td>
<td>50</td>
<td>M</td>
<td>+</td>
<td>-</td>
<td>4 years</td>
<td>Anterior</td>
<td>+</td>
</tr>
<tr>
<td>17</td>
<td>24</td>
<td>M</td>
<td>+</td>
<td>+</td>
<td>5 years</td>
<td>Anteroapical</td>
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<td>18</td>
<td>54</td>
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<tr>
<td>20</td>
<td>41</td>
<td>M</td>
<td></td>
<td></td>
<td>3 months</td>
<td>Anteroapical</td>
<td>-</td>
</tr>
<tr>
<td>21</td>
<td>73</td>
<td>M</td>
<td></td>
<td></td>
<td>6 days</td>
<td>Anterior</td>
<td>+</td>
</tr>
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</table>

*Persistent ST-segment elevation.
†Double precordial impulse.
Abbreviations: + = present; − = absent.
and saline (1:7). The pH was adjusted to 6.5–7.0 with 0.1 N NaOH solution in a tuberculin syringe with a 26-gauge needle. The oxine solution was prepared daily in 100% ethanol. Sterile suspensions of 111In-labeled platelets were prepared at room temperature under aseptic conditions in a laminar flow hood. Starting solutions were sterilized by millipore filtration. After the patients gave informed consent, whole blood was collected by venipuncture using a 19-gauge butterfly needle. Into a first syringe, 18 ml of blood were drawn into 2 ml of 38 g/l sodium citrate solution. Subsequent centrifugation at 2000 g for 10 minutes produced platelet-poor plasma, which was transferred into a plastic tube and saved. Into a second syringe, 43 ml of blood were drawn into 7 ml of modified ACD solution (Squibb). The blood was transferred to a sterile 50-ml conical plastic centrifuge tube and centrifuged at 200 g for 15 minutes. The upper three-quarters of the platelet-rich plasma was transferred with sterile plastic disposable pipettes into 12-ml conical plastic tubes and centrifuged at 2000 g for 10 minutes.* The resultant platelet-poor plasma was saved and the cell button resuspended in ACD saline and centrifuged at 2000 g for 10 minutes.* The supernatant was decanted and the platelets were resuspended in the ACD saline solution containing the 111In-oxine complex and incubated at room temperature for 20 minutes. The labeled platelet suspension was centrifuged at 2000 g for 10 minutes* and the supernatant carefully decanted. The 111In activity remaining with the platelets was determined to estimate the in vitro labeling efficiency. The platelets were then resuspended in 4.0 ml of platelet-poor ACD plasma and incubated for 7 minutes to remove any non-cell-bound indium. The suspension was then centrifuged at 2000 g for 10 minutes* and the supernatant decanted. The platelet labeling efficiency was determined a second time. The platelet button was finally resuspended in 5–8 ml of platelet-poor citrated plasma. Phase contrast microscopy was used to detect gross platelet aggregates and contaminating leukocytes. Platelet aggregates were small and never exceeded five per high-power field. Contaminating leukocytes were sparse. The platelet suspension was injected intravenously using a 19-gauge butterfly needle.

### Radionuclide Imaging

Images were obtained daily or on alternate days, including the day of injection, for a minimum of 5 days and a maximum of 8 days. All patients were imaged in the anterior, left lateral and LAO 45° views. An additional LAO 45° image was obtained in all patients except patients 1–5 in group 1. In all patients, 200,000 count images were obtained. In 27 patients, imaging was performed on a large-field-of-view gamma scintillation camera that was fitted with a medium-energy collimator and set on both photopeaks of 111In with a 20% window. Images from the remaining two patients were obtained with a standard-field-of-view gamma scintillation camera (Searle Radiographics) using a 410 high-energy, parallel-hole collimator centered on both photopeaks of 111In with a 30% window. All images were interpreted by two observers without knowledge of the clinical and laboratory data.

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*Centrifugation times reduced to 5 minutes in the last seven patients.
The criterion for positivity was an obvious area of increased activity in the region of the left ventricle, increasing with time against a decreasing blood pool.

Tissue Radionuclide Estimations

In 17 patients, 11 from group 1 and six from group 2, the presence or absence of clot within the left ventricle could be determined at surgery or autopsy. In these patients, it was possible to inject the platelets 6 days before surgery and in the case of the autopsy patient, 4 days before his death. This permitted scintigraphic imaging, operative or autopsy identification of clot within the aneurysm or ventricle and tissue $^{111}$In activity determinations. In four of five patients, the surface of the thrombus was carefully removed, weighed and the $^{111}$In activity compared with the activity in the blood, noninvolved myocardium and deeper aspects of the thrombus. Because activity in the noninvolved myocardium and deeper aspects of the thrombus in all cases were considerably lower than blood activity, the activity on the surface of the thrombus was compared with blood activity. Blood samples were obtained at surgery.

Calculation of Platelet Recovery

Platelet recovery was defined as the percentage of $^{111}$In activity that remained with the platelets 15 minutes after the intravenous injection of the labeled platelets. It reflects the physiologic status of the platelet because abnormal or damaged platelets are sequestrated in the spleen, whereas physiologically normal platelets remain within the circulation. The platelet recovery was calculated as:

$$\frac{\text{CPM (1 ml WB*)} \times \text{BV} \times 100}{\text{CPM (Std)} \times \text{dilution factor}}$$

$$\frac{\text{CPM (1 ml plasma*)} \times (100-\text{HCT}) \times \text{BV}}{\text{CPM (Std)} \times \text{dilution factor}}$$

where WB = whole blood, HCT = hematocrit, CPM = counts per minute, Std = standard (0.1 ml of the platelet suspension in 1.9 ml of distilled water), dilution factor $\times$ Std = total amount of activity injected, and BV = blood volume (tables of Hurley). All samples were prepared in duplicate and counted in batches using a NaI (TI) crystal well detector with the spectrometer set to detect both peaks as well as the summation peak of $^{111}$In.

Results

Cardiac Imaging (table 3)

In all patients, well-defined images of the cardiac blood pool and great vessels were seen on day 1 (fig. 1). Patients 2, 3, 5, 8, 9, 11, 14, 20 and 21 developed areas of increased and abnormal activity within the cardiac blood pool. This was first evident in patients 2, 5 and 21 at 60 hours, in patients 8 and 14 at 96 hours and in the remainder by 72 hours. Images remained clearly positive through the 120-hour image in all patients except patients 9 and 14, whose images were still positive 144 hours after the injection of the platelet suspension. All patients undergoing surgery had their last image at about 120 hours.

Increased and abnormal activity usually manifested in all views with equal intensity so that localization to the left ventricle was possible (figs. 2 and 3). However, in patient 3, scintiphotos were positive in the 45° and left lateral views with equal intensity and with lesser intensity in the anterior view. This patient was not imaged in the RAO 45° view. In patient 8, abnormal activity was confined to the LAO 45° view.

Positive images varied in appearance. Abnormal and increased activity in some patients appeared as a doughnut-shaped image in the LAO and anterior views and as a crescent shaped image in the left lateral view (fig. 3). More commonly, a homogenous area of intense activity was evident (fig. 2). In patient 20, two thrombi were seen on the scintiphotograph and confirmed at surgery.

Surgery or Autopsy (table 3)

Eleven patients from group 1 with intractable angina or heart failure underwent surgery. All patients except patient 7 underwent aneurysmectomy and coronary bypass surgery. Aneurysmectomy was not performed in patient 7 because the aneurysm not surgically resectable. Patient 21 died. The remaining patients were not considered surgical candidates because of an acute major psychiatric illness (patient 1), age and poor function of ventricle not involved in the aneurysm (patient 2) and improvement of angina or symptoms of failure in patients 9 and 11-16.

Therefore, among nine patients with positive scintigrams, tissue confirmation of clot was possible in four patients at surgery and in one at autopsy (fig. 4).


In all these patients, the surface of the thrombus appeared red and friable. The findings at surgery are summarized in Table 4.

Of 12 patients with negative platelet studies, six patients from group 1 were operated on and did not have thrombi at surgery. Six patients from group 2 underwent mitral valve replacement. Inspection of their ventricles revealed no thrombi, confirming their negative platelet scans.

### Table 3. Results from Group 1 (Aneurysm Group)

| Pt | Clot at surgery/autopsy | Platelet scan | Clot on ventriculogram | Activity of injected platelets (μCi) | No. of platelets (× 10⁹) | T₁/₂T₁ | Efficiency before/after plasma wash (%)
<table>
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<tr>
<th></th>
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<th></th>
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<td>1*</td>
<td>No surgery</td>
<td>Negative</td>
<td>+</td>
<td>650</td>
<td>4.8</td>
<td>230</td>
<td>87/84</td>
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<td>No surgery</td>
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<td>-</td>
<td>509</td>
<td>3.7</td>
<td>170</td>
<td>73/68</td>
</tr>
<tr>
<td>3*</td>
<td>Positive</td>
<td>+ at 60 hours</td>
<td>-</td>
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<td>ND</td>
<td>175</td>
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<td>Negative</td>
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<td>415</td>
<td>ND</td>
<td>147</td>
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<tr>
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<td>+ at 60 hours</td>
<td>-</td>
<td>392</td>
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<td>120</td>
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<tr>
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<td>661</td>
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<td>118</td>
<td>82/76</td>
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<td>14</td>
<td>No surgery</td>
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<td>ND</td>
<td>343</td>
<td>1.5</td>
<td>101</td>
<td>55/47</td>
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*Images obtained with a standard-field-of-view gamma scintillation camera using a high-energy, parallel-hole collimator.
†No aneurysmectomy; coronary artery bypass only.
Abbreviations: T₁/₂T₁ = time from collection of whole blood to injection of platelet suspension; + = present; − = absent; ND = not done.

### Platelet Preparation

The platelet preparation consisted of 3.4 ± 1.6 × 10⁹ (mean ± SD) platelets, with ¹¹¹In activity of 454 ± 144 μCi (mean ± SD) and a final labeling efficiency of 67 ± 17%. Thrombus-positive patients were not statistically different from thrombus-negative patients with respect to injected ¹¹¹In activity and the final labeling efficiency. However, more platelets were in-

**Figure 2.** This scintiphoto was obtained 96 hours after injection of the platelet suspension. The orientation is similar to that in figure 1. An additional 45° right anterior oblique (RAO) image (panel C) is illustrated. In this view, the liver is superimposed on the spleen and occupies the lower zone of the frame. In all four views, the round homogeneous areas of increased and abnormal indium-¹¹¹ activity (arrows) represent active thrombus in a large anteropapical left ventricular aneurysm. The blood pool activity is markedly decreased compared with that shown in figure 1. LAO = left anterior oblique.
jected in the thrombus-negative patients (4.7 ± 1.9 \times 10^8, mean ± sd) than in the thrombus-positive patients (2.4 ± 1.1 \times 10^8) (p < 0.02).

The fate of the labeled platelets after injection of the suspension was determined in 15 patients. The percentage of labeled and injected platelets remaining in the circulation after 15 minutes was 37.8 ± 14.5% (mean ± sd). This indicates that less than half of the platelets remained undamaged and within the circulation and thus were able to participate in any active thrombotic process that might be in progress. A comparison of the thrombus-positive and thrombus-negative patients showed no statistically significant difference between the two groups (39.7 ± 17.5% for thrombus-positive patients vs 36.8 ± 13.7% for thrombus-negative patients).

Discussion

The scintigraphic and surgical data provide convincing evidence that hematologically active intraventricular thrombi can be identified using $^{111}$In platelet scintigraphy. Scintigraphic findings were confirmed at surgery in the 11 patients undergoing aneurysmectomy and in six patients of the control group, while tissue samples from four of the scintigraphic positive patients revealed high concentrations of $^{111}$In activity on the surface of the thrombus. This latter finding is further confirmation that the abnormal and increased cardiac activity identified by platelet scintigraphy was from the surface of thrombus, the most active portion of the clot. Normalized by mass, the $^{111}$In activity on the surface of the thrombus was 9.7-401.1 times greater than blood activity. In all patients, $^{111}$In activity below the surface of the clot was almost at background levels. The variation in surface activity may reflect differences in sample collection; some samples contained surface clot diluted with less active clot below the surface.

Contrast ventriculography that showed a constant filling defect identified only 50% of the scintigraphically positive thrombi, and thus lacks the sensitivity of the new technique. This finding is supported by data comparing ventriculography with surgery. In these studies, the sensitivity of ventriculography varied from 8-48%.27-29 In two other patients, not operated upon and with negative scintiphotos, filling defects on the RAO contrast ventriculogram were seen. We assume that if these filling defects represent true lesions, they probably reflect inactive thrombi into which the labeled platelets were not incorporated. Because these patients were not operated upon, this suggestion remains speculative.

McAfee and Thakur26, 29 were the first to label cells with indium. Subsequent studies in animals demonstrated the potential of indium-labeled platelets in the diagnosis of infective endocarditis,27 myocardial in-

![Figure 3](https://circ.ahajournals.org/)

**Figure 3.** Indium-111 scintiphoto obtained 72 hours after injection of the platelet suspension. The orientation is similar to that in figure 1. The doughnut-shaped area of increased activity in panels A and B (arrows) and the crescent-shaped image in frame C (arrow) represent active mural thrombus in a left ventricular aneurysm. Compared with that in figure 1, the blood pool activity is significantly reduced. LAO = left anterior oblique.

![Figure 4](https://circ.ahajournals.org/)

**Figure 4.** A pathologic specimen of part of an aneurysm removed at surgery. The rounded thrombus (T) within a sacular component of the aneurysm is typical of the lesion identified by platelet scintigraphy of the type described in figure 2. M = myocardium involved in the aneurysm without adherent thrombus.

<table>
<thead>
<tr>
<th>Pt</th>
<th>Thrombus at surgery</th>
<th>Thrombus surface: blood $^{111}$In activity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>6 x 6 x 3 cm</td>
<td>401:1 (1 sample)</td>
</tr>
<tr>
<td>5</td>
<td>2 x 2 x 0.5 cm</td>
<td>354:8:1 (1 sample)</td>
</tr>
<tr>
<td>8</td>
<td>1.5 x 1.5 x 0.5 cm</td>
<td>9.7 ± 1.3:1 (mean ± sd, 3 samples)</td>
</tr>
<tr>
<td>20</td>
<td>Two thrombi, each</td>
<td>131.2 ± 39:8:1 (mean ± sd, 5 samples)</td>
</tr>
<tr>
<td>21</td>
<td>1.5 x 1.5 x 0.5 cm</td>
<td>45.6:1 (1 sample)</td>
</tr>
</tbody>
</table>

*Normalized by mass.
fraction, coronary bypass grafts and experimental coronary thrombosis. Successful identification of deep vein thrombosis and systemic and pulmonary artery thrombi in man have also been reported. We believe this to be the first detailed study of the detection of intracardiac thrombi by this technique in humans, although we and others have published earlier studies in abbreviated or abstract form.

Our preliminary studies show that 

111In platelet scintigraphy promises to be a reliable technique for identifying left ventricular thrombi in man. Theoretically, because the increased 

111In activity reflects an active thrombus surface and not the volume or mass of the thrombus, and on the basis of the 17 operated patients, we suspect that this method will prove very sensitive provided the injected platelet suspension contains enough labeled, physiologically active platelets. These studies suggest that approximately 3 x 10^6 platelets, with a final labeling efficiency of greater than 50% and a total injected radioactivity of about 350 μCi, would ensure detection of active intracardiac thrombi by this scintigraphic technique. Further, as a test of in vivo viability, the platelet recovery at 15 minutes should be greater than 30%. Our experience suggests that the difficulty of the labeling technique can be overcome and that good coordination of clinical and laboratory staff would make this technique suitable for clinical investigation.

We had some problems with interpreting platelet images. In patients with elevated left hemidiaphragms, activity from the spleen may be confused with thrombi in the apex of the heart. The distinction is that splenic activity appears within minutes of injection, whereas thrombus activity is clearly visible only after 60 hours. It is also important to differentiate between increased blood pool activity due to increased blood volume and stasis in a large aneurysm from increased activity due to thrombus. Blood pool activity decreases with decay of the isotope and removal of platelets from the circulation whereas thrombus activity increases with time as more platelets accumulate at the site of thrombosis. Because emboli occur in 6–13% of patients with aneurysms, the relationship between the results of platelet scintigraphy and clinically important systemic emboli need to be studied in a larger series.

We conclude that the agreement between platelet scintigraphy and surgery in 17 operated patients, of which five were positive for thrombi, out of a total of 29, was 100%. Thus, this technique promises to be a sensitive and reliable method for the detection of hematomatically active left ventricular thrombi.

Acknowledgment

We thank Dr. Carl Smith for allowing us to use his Nuclear Medicine facility. We gratefully acknowledge Ronnie Lee, Phil Hood, Carl Ryals, Tom Sheperd, George Hoebing, Ron Raftery and Stephen W. Herren for their technical assistance. We also thank Sharon Rieker for typing the manuscript, the housestaff in the Department of Medicine for referring patients and Drs. Ralph Lazazra and Benjamin Scherlag for valuable advice concerning the manuscript.

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Significance of Coronary Arterial Thrombus in Transmural Acute Myocardial Infarction

A Study of 54 Necropsy Patients

FRANK C. BROSIUS III, M.D., AND WILLIAM C. ROBERTS, M.D.

SUMMARY In 54 necropsy patients with transmural acute myocardial infarction (AMI) and coronary arterial thrombi, histologic sections of coronary arteries that contained the thrombi were examined by videoplanimetry to determine if the amount of luminal narrowing caused by thrombi was comparable to that produced by underlying atherosclerotic plaques, and to determine the amount of luminal narrowing by plaques immediately proximal and distal to the thrombi. The 54 coronary arteries in the 54 patients were narrowed 33-98% (mean 81%) by atherosclerotic plaque alone in cross-sectional area at the site of the thrombus (occclusive in 47 and nonocclusive in seven), from 26-98% (mean 75%) within the 2-cm segment proximal to the thrombus, and from 43-98% (mean 79%) within the 2-cm segment distal to the thrombus. Of the 54 arteries, 52 (96%) were narrowed 76-98% in cross-sectional area by atherosclerotic plaque alone at or immediately proximal or distal to the thrombus and 26 (48%) were narrowed 91-98% by plaque alone. The thrombi were 0.1-6.0 mm² (mean 1.4 mm²) in cross-sectional area and the underlying atherosclerotic plaques were 3.0-21.0 mm² (mean 8.7 mm²). Thus, among necropsy patients with transmural AMI, coronary thrombi occur at sites already severely narrowed by atherosclerotic plaques.

THROMBES in coronary arteries of necropsy patients with transmural acute myocardial infarction (AMI) have been observed in numerous studies. Herrick, in 1912 and 1919, found them in four patients with fatal AMI, and for many decades thrombi were believed to have precipitated AMI. They were considered so important in causing this acute event that the term "coronary thrombosis" was used for years to describe the event that most physicians now call "acute myocardial infarction." In recent years the primary role of coronary thrombus in precipitating AMI has been questioned. To evaluate the significance of coronary thrombus in AMI, we examined in detail the coronary arteries containing thrombi in 54 necropsy patients with transmural AMI. Several previously undescrbed observations on coronary thrombi resulted, which clarify the significance of coronary thrombi in AMI.

Patients and Methods

All necropsy patients with transmural AMI accessioned in the Pathology Branch, National Heart, Lung, and Blood Institute, were reviewed. Of 235 such patients, 99 had histologic sections available from each 5-mm segment of each of the four major coronary arteries (right, left main, left anterior descending and left circumflex). Movat-stained histologic sections, approximately 55 per patient, were reviewed, and a thrombus was found in one of the four major coronary arteries in 54 patients (55%). These 54 patients constitute the study group.

In each patient, the coronary artery that contained the thrombus was examined. The maximal degree of
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Circulation. 1981;63:803-810
doi: 10.1161/01.CIR.63.4.803
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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