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CLINICAL STUDIES

First Transit and Equilibrium Radionuclide Angiography in Patients With Inferior Transmural Myocardial Infarction: Criteria for the Diagnosis of Associated Hemodynamically Significant Right Ventricular Infarction

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To define radionuclide criteria for identifying hemodynamically significant right ventricular infarction, 33 consecutive men with inferior transmural infarction were evaluated prospectively by right heart catheterization and first transit and equilibrium radionuclide angiography within 36 hours of the onset of symptoms. Hemodynamically significant right ventricular infarction was present in 6 of the 33 patients (Group I); the remaining 27 patients did not demonstrate the hemodynamics characteristic of right ventricular infarction (Group II). A right ventricular ejection fraction of less than 40% separated Group I and Group II patients by equilibrium ($p = 0.003$) but not by first transit (p = NS) radionuclide angiography. However, a right ventricular ejection fraction of less than 35% separated Group I and II patients by both techniques ($p = 0.02$ and $p = 0.005$, respectively). The presence of a right ventricular regional wall motion abnormality on either first transit or equilibrium radionuclide angiograms separated Group I and II patients ($p < 0.001$). The combination of both a right ventricular ejection fraction of less than 40% and a regional wall motion abnormality separated Group I and II patients using either equilibrium ($p < 0.001$) or first transit ($p = 0.02$) radionuclide angiography.

It is concluded that in patients with acute inferior transmural myocardial infarction, a right ventricular regional wall motion abnormality alone or in combination with a right ventricular ejection fraction of less than 40% by either first transit or equilibrium radionuclide angiography is a useful criterion for establishing the presence of hemodynamically significant right ventricular infarction, while its absence argues against the diagnosis of right ventricular infarction.

The early noninvasive diagnosis of acute hemodynamically significant right ventricular infarction would be useful so that hemodynamic monitoring and appropriate therapy can be instituted rapidly. First transit radionuclide angiographic studies (1–3) have shown that right ventricular ejection fraction is reduced in patients with acute inferior myocardial infarction compared with that in patients with anterior transmural infarction. Gated equilibrium radionuclide angiographic studies (4,5) have demonstrated enlargement and regional wall motion abnormalities of the right ventricle in patients with acute inferior myocardial infarction. These initial radionuclide studies suggest that either a reduction in right ventricular performance or right ventricular enlargement and regional wall motion abnormalities might be useful for identifying patients with hemodynamically significant right ventricular infarction. However, hemodynamic measurements are required to make this diagnosis (6–11). Prior first transit and equilibrium radionuclide studies are potentially limited by the lack of hemodynamic measurements to establish the diagnosis of hemodynamically significant right ventricular infarction (1–3). In addition, in some of these

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studies (4,5) the patients were referred for evaluation and treatment of cardiogenic shock. Thus, few prospective data are available regarding the utility of an early first transit or equilibrium radionuclide angiographic assessment of right ventricular performance and regional wall motion for identifying acute hemodynamically significant right ventricular infarction. Accordingly, the purpose of this investigation was to evaluate prospectively a consecutive series of patients with acute inferior transmural myocardial infarction to establish useful first transit and gated equilibrium radionuclide angiographic criteria for identifying hemodynamically significant right ventricular infarction.

Methods

Patients. The study patients consisted of 33 consecutive men with acute inferior transmural myocardial infarction who gave written informed consent on a form approved by our institutional review board for right heart catheterization and radionuclide studies within 36 hours of the onset of symptoms. Their ages ranged from 49 to 76 years (mean 61). All patients had acute inferior transmural myocardial infarction manifested by: 1) chest pain of at least 30 minutes' duration, 2) electrocardiographic changes including evolving ST-T wave changes and pathologic Q waves in leads II, III and aVF, and 3) elevation in serum creatine kinase and creatine kinase-MB isoenzyme (12). A history or electrocardiographic evidence, or both, of prior myocardial infarction was present in 8 (24%) of the 33 patients. In addition, at the time of these studies, two patients were being treated with digoxin, four with beta-adrenergic blocking agents and two with long-acting nitrates. Seventeen patients were in Killip clinical class I, 15 in class II and 1 in class IV. One of the 15 patients in clinical class II rapidly progressed to class IV within 24 hours of the initial evaluation. Patients with a left to right shunt, chronic obstructive pulmonary disease with pulmonary hypertension, cardiomyopathy, biventricular failure and chronic renal failure were excluded from this study.

Hemodynamics. Right heart catheterization was performed using a balloon-tipped flow-directed thermodilution catheter. Calibrated recordings of the phasic and mean right atrial and pulmonary artery wedge pressures were recorded using Statham P23Db transducers leveled at the mid chest. The right atrial/pulmonary artery wedge pressure ratio was also calculated. The hemodynamic criteria considered as evidence for acute hemodynamically significant right ventricular infarction were a right atrial pressure of 10 mm Hg or more and a right atrial/pulmonary artery wedge pressure ratio of 0.8 or more at rest or after volume loading. Nineteen of the 33 patients had a pulmonary artery wedge pressure of less than 15 mm Hg and received normal saline solution (200 to 1,200 ml). These hemodynamic criteria were derived from the hemodynamic data of Cohn et al. (6) and the recent correlative hemodynamic and necropsy study of Lopez-Sendon et al. (7).

Radionuclide angiography. First transit and equilibrium radionuclide angiograms were performed sequentially within 30 minutes of each other and within 2 hours of the hemodynamic measurements. The first transit radionuclide angiograms were acquired in the 30° right anterior oblique position using a single crystal gamma scintillation camera (Ohio Nuclear 420) equipped with a multipurpose parallel-hole collimator and a dedicated computer cart (VIP 550) for data acquisition and processing. An external technetium-99m source was used to position the heart within the central camera field of view. The initial radioisotope bolus of 10 to 12 mCi of technetium-99m human serum albumin was then injected using a standard method (2). Image data were acquired using serial mode into 64 × 64 word matrix for approximately 20 seconds. The image data were stored on high speed magnetic disks for later processing. The remainder of the 20 to 25 mCi technetium-99m human serum albumin dose was injected and equilibrium radionuclide angiography was performed in the anterior and left anterior oblique position that best separated the right and left ventricles in the plane of the interventricular septum. Image data were acquired using frame mode into 64 × 64 byte matrix for consecutive corresponding 40 ms frames to 250,000 counts per frame. Again, the image data were stored on high speed magnetic disks for later processing.

First transit angiographic assessment. The first transit radionuclide angiographic studies were processed in the following manner. The initial passage of the bolus from the superior vena cava through the right ventricle was made into a composite movie consisting of 40 frames. This movie was viewed in real time to assess qualitatively right ventricular regional wall motion. Regional wall motion abnormalities were considered present when either akinesia or dyskinesia was observed. Hypokinesia of the right ventricle was difficult to differentiate from normal wall motion; thus, it was not considered definitive evidence for a regional wall

Figure 1. Representative example of a first transit radionuclide angiographic time-activity curve (**left**) and the composite curve from which the right ventricular ejection fraction was taken (**right**).

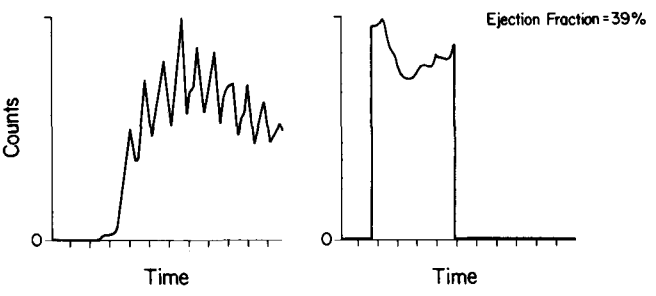


Table 1. Hemodynamic Profile of Patients With Right Ventricular Infarction

Case	RA	PAWP	RA/PAWP	CI	SVI	RVSWI
			Group I: Hemodynamically Significant Infarction			
1	19	19	1.00	1.3	27	1.8
2	19	19	1.00	2.3	33	2.2
3	15	18	0.83	3.2	44	4.2
4	15	15	1.00	1.9	19	2.6
5	14	17	0.82	2.6	34	4.2
6	12	14	0.86	3.4	43	4.1
Mean	16	17	0.92	2.5	33	3.2
±SD	3	2	0.10	0.8	10	1.1
			Group II: No Hemodynamically Significant Infarction			
7	10	15	0.66	2.2	36	5.4
8	9	17	0.53	1.9	27	5.1
9	10	22	0.46	2.6	35	9.0
10	10	17	0.59	2.4	31	6.7
11	10	18	0.55	3.3	37	10.6
12	10	15	0.67	3.8	48	11.8
13	9	16	0.56	3.4	41	7.2
14	5	14	0.36	2.5	33	7.2
15	10	20	0.50	2.8	35	11.4
16	2	16	0.13	2.5	27	9.5
17	15	22	0.68	2.2	34	8.3
18	10	15	0.66	3.0	36	4.9
19	2	17	0.12	1.9	32	10.4
20	3	13	0.23	2.6	35	9.0
21	8	15	0.53	3.4	43	7.0
22	6	15	0.40	3.2	45	8.6
23	6	20	0.30	3.0	28	9.1
24	10	13	0.78	2.3	31	3.8
25	5	16	0.31	1.9	26	9.5
26	3	14	0.21	3.1	48	10.4
27	14	18	0.78	2.3	21	2.6
28	10	18	0.56	2.3	36	6.4
29	8	15	0.53	2.4	28	4.6
30	11	20	0.55	3.2	53	11.5
31	4	18	0.19	2.4	29	9.1
32	8	12	0.67	4.7	60	8.2
33	7	11	0.64	3.1	39	4.8
Mean	8	16	0.49	2.8	36	7.9
±SD	3	3	0.19	0.6	9	2.8

CI = cardiac index (liters/min per m^2); PAWP = pulmonary artery wedge pressure (mm Hg); RA = right atrial pressure (mm Hg); RA/PAWP = right atrial/pulmonary artery wedge pressure ratio; RVSWI = right ventricular stroke work index (g-m/m^2); SVI = stroke volume index (ml/beat per m^2).

motion abnormality. Then, regions of interest were drawn over the superior vena cava, right ventricle and a right paraventricular background area. The background region of interest was a horseshoe-shaped area drawn around the right ventricular apex excluding the right atrium and pulmonary artery. A time-activity curve for the initial passage of the bolus through the superior vena cava was produced and evaluated for the adequacy of the bolus injection. An adequate bolus was present when a full width at half maximum (the width of the superior vena cava time-activity curve at one-half peak activity) of 1.5 seconds or less was calculated. Four (12%) of the 33 patients did not have an adequate bolus.

Thus, 29 first transit radionuclide studies were available for further evaluation. A right ventricular time-activity curve was generated from the right ventricular region of interest. Background was normalized to the right ventricular region of interest and subtracted on a frame by frame basis from the right ventricular time-activity curve. Subsequently, cursors were placed at peaks of the right ventricular time-activity curve for three to five cardiac cycles on the exponential downslope of the background-subtracted right ventricular time-activity curve. The end-diastolic and end-systolic counts of each cardiac cycle were obtained and a composite curve was calculated to obtain a first transit right ventricular ejection fraction (Fig. 1).

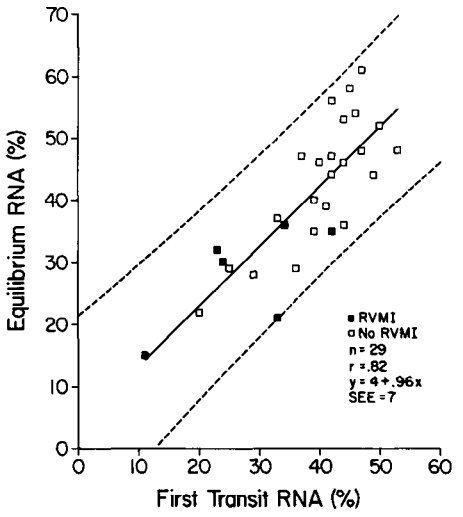


Figure 2. Equilibrium radionuclide angiographic (RNA) right ventricular ejection fraction values (**ordinate**) are compared with those obtained by first transit radionuclide angiography (**abscissa**). The correlation coefficient, regression equation, standard error of the estimate (SEE), regression line and 95% confidence intervals are shown. RVMI = right ventricular myocardial infarction.

Gated equilibrium angiographic assessment. The gated equilibrium radionuclide angiograms were initially assessed in movie format to evaluate qualitatively right ventricular regional wall motion. Similar to the first transit studies, regional wall motion abnormalities were considered present when either akinesia or dyskinesia was noted. The processing of right ventricular ejection fraction was performed as described by Maddahi et al. (13). Briefly, nine point spatial smoothing and background subtraction were performed. Background was obtained from an end-diastolic left ventricular paraventricular region of interest. Then, a right ventricular end-diastolic region of interest was manually drawn by the operator and a right ventricular time-activity curve generated. From this background-subtracted right ventricular time-activity curve, the end-systolic frame was identified and a second region of interest was drawn excluding the right atrium to obtain right ventricular end-systolic counts. The right ventricular ejection fraction was calculated by subtracting end-systolic from end-diastolic counts, dividing by end-diastolic counts and multiplying by 100.

Data analysis. The first transit and gated equilibrium radionuclide angiographic right ventricular ejection fraction values were compared using least squares linear regression analysis to obtain correlation coefficients, regression equations and standard errors of the estimate. Nonpaired *t* tests were used to assess differences in continuous variables between patient groups. Fisher's exact test was used to assess differences in discrete variables between patient groups. A significant difference was considered present when a probability (p) value of 0.05 or less was observed.

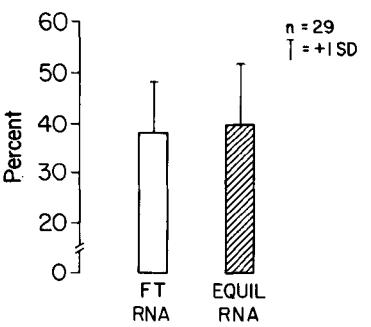
Results

Patient group hemodynamic profiles. These 33 consecutive patients with inferior transmural myocardial infarction were separated into two groups based on their initial hemodynamic profile. Group I consisted of 6 patients who had hemodynamically significant right ventricular infarction, while Group II comprised the remaining 27 patients without hemodynamic evidence of right ventricular infarction (Table 1). The Group I patients had a higher average right atrial pressure compared with Group II patients (16 ± 3 versus 8 ± 3 mm Hg, respectively, $p < 0.001$), while the average pulmonary artery wedge pressures did not differ significantly. Thus, the mean right atrial/pulmonary artery wedge pressure ratio was higher in Group I compared with Group II (0.92 ± 0.1 versus 0.49 ± 0.2, respectively, $p < 0.001$). There was no significant difference in the average cardiac or stroke volume index. However, the Group I patients had a lower mean right ventricular stroke work index compared with Group II patients (3.2 ± 1.1 versus 7.9 ± 2.5 g-m/m^2, respectively, $p < 0.001$).

First transit and equilibrium radionuclide angiographic comparison. The first transit and equilibrium radionuclide angiographic right ventricular ejection fraction values correlated well ($r = 0.82$, Fig. 2). In addition, the average (± 1 standard deviation) first transit radionuclide right ventricular ejection fraction of 38 ± 10% (range 11 to 53%) did not differ significantly from the mean equilibrium radionuclide right ventricular ejection fraction of 41 ± 12% (range 15 to 61%) (Fig. 3).

Radionuclide identification of acute right ventricular infarction (Fig. 4). The mean first transit radionuclide angiographic right ventricular ejection fraction in the Group I patients of 28 ± 11% was less than the 41 ± 8% value for the Group II patients ($p < 0.05$). Similarly, the average equilibrium radionuclide right ventricular ejection fraction of 28 ± 8% for Group I was less than the 44 ± 10% value for the Group II patients ($p = 0.002$). Eleven (33%) of the 33 patients had right ventricular regional wall motion abnormalities evidenced by akinesia or dyskinesia of the in-

Figure 3. Comparison between the average right ventricular ejection fraction values by first transit (FT) and equilibrium (EQUIL) radionuclide angiography (RNA).



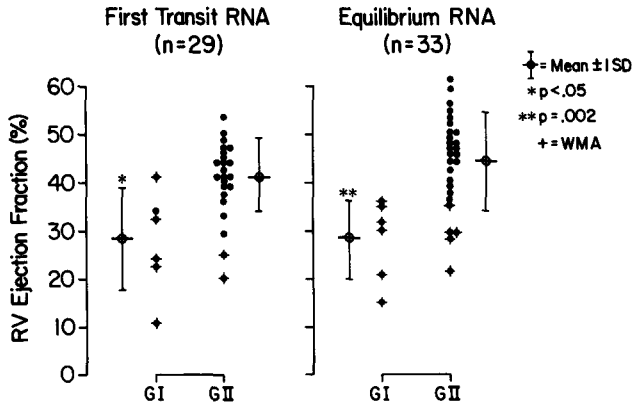


Figure 4. Individual right ventricular ejection fraction values by first transit and equilibrium radionuclide angiography (RNA) are illustrated for Group (G) I and Group II. The mean (± 1 standard deviation) for each group is shown. Significant differences are illustrated. RV = right ventricular; WMA = right ventricular wall motion abnormality.

ferior or apical regions by equilibrium radionuclide angiography, while 7 (24%) of the 29 patients had abnormal right ventricular regional wall motion by first transit radionuclide angiography. All seven patients who had abnormal right ventricular regional wall motion by first transit radionuclide angiography had abnormal wall motion on the equilibrium radionuclide study.

Reduced ejection fraction, abnormal wall motion, or both. Breakpoint analysis of continuous first transit and equilibrium radionuclide right ventricular ejection fraction values and analysis of the presence or absence of right ventricular regional wall motion abnormalities (akinesia or dyskinesia) were compared between patients in Groups I and II to determine the optimal separation between the two groups of patients (Table 2A). Five of the 6 patients in Group I and 2 of the 23 patients in Group II had right ventricular regional wall motion abnormalities by first transit radionuclide angiography ($p = 0.001$). Right ventricular ejection fraction by first transit radionuclide angiography was less than 40% in 5 of the 6 patients in Group I and 8 of the 23 patients in Group II (p = NS); it was less than 35% in 5 of the 6 patients in Group I and 4 of the 23 patients in Group II ($p = 0.005$). The combination of a right ventricular ejection fraction of less than 40 or 35% and a regional wall motion abnormality by first transit radionuclide angiography was present in 4 of the 6 patients in Group I and 2 of the 23 patients in Group II ($p = 0.02$).

Table 2. Radionuclide Identification of Hemodynamically Significant Right Ventricular Myocardial Infarction

Variable	First Transit RNA	Equilibrium RNA
A. Before Exclusion of Patients With Prior Myocardial Infarction (n = 33)		
RV WMA	$p = 0.001$	$p < 0.001$
RV EF < 40%	p = NS	$p = 0.003$
RV EF < 35%	$p = 0.005$	$p = 0.02$
RF EF < 40% and WMA	$p = 0.02$	$p < 0.001$
RV EF < 35% and WMA	$p = 0.02$	$p = 0.02$
B. After Exclusion of Patients With Prior Myocardial Infarction (n = 25)		
RV WMA	$p < 0.001$	$p < 0.001$
RV EF < 40%	p = NS	$p = 0.005$
RV EF < 35%	$p = 0.004$	$p < 0.05$
RV EF < 40% and WMA	$p = 0.002$	$p < 0.001$
RF EF < 35% and WMA	$p = 0.002$	$p < 0.001$

EF = ejection fraction; RNA = radionuclide angiography; RV = right ventricular; WMA = wall motion abnormality (akinesia or dyskinesia).

All 6 Group I patients and 5 of the 27 Group II patients had right ventricular regional wall motion abnormalities by equilibrium radionuclide angiography ($p < 0.001$). Right ventricular ejection fraction by equilibrium radionuclide angiography was less than 40% in all 6 Group I patients and 8 of the 27 Group II patients ($p = 0.003$); it was less than 35% in 4 of the 6 Group I patients and 4 of the 27 Group II patients ($p = 0.02$). A right ventricular ejection fraction of less than 40% and a regional wall motion abnormality by equilibrium radionuclide angiography were present in all 6 Group I patients and 5 of the 27 Group II patients ($p < 0.001$), while a right ventricular ejection fraction of less than 35% and a regional wall motion abnormality were present in 4 of the 6 patients in Group I and 4 of the 27 patients in Group II ($p = 0.02$).

Analysis after exclusion of patients with prior infarction. Since a right ventricular regional wall motion abnormality or reduced ejection fraction, or both, may be caused by a prior myocardial infarction, an analysis of these variables was performed after the eight patients with a history or electrocardiographic evidence, or both, of prior myocardial infarction were excluded (Table 2B). All eight patients were in Group II. Five of the 6 patients in Group I and none of the 16 patients in Group II had right ventricular regional wall motion abnormalities by first transit radionuclide angiography ($p < 0.001$). Right ventricular ejection fraction by first transit radionuclide angiography was less than 40% in 5 of the 6 Group I patients and 5 of the 16 Group II patients (p = NS); it was less than 35% in 5 of the 6 Group I patients and 2 of the 16 Group II patients ($p = 0.004$). The combination of a right ventricular ejection fraction of less than 40 or 35% and a regional wall motion abnormality by first transit radionuclide angiography was present in 4 of the 6 Group I patients and none of the 16 Group II patients ($p = 0.002$).

All 6 patients in Group I and 3 of the 19 patients in Group II had a right ventricular regional wall motion abnormality by equilibrium radionuclide angiography ($p < 0.001$). Right ventricular ejection fraction by equilibrium angiography was less than 40% in all 6 Group I patients and 6 of the 19 Group II patients ($p = 0.005$); it was less than 35% in 4

of the 6 Group I patients and 2 of the 19 Group II patients ($p < 0.05$). A right ventricular ejection fraction of less than 40% and a regional wall motion abnormality by equilibrium radionuclide angiography were present in all 6 Group I patients and 3 of the 19 Group II patients ($p < 0.001$), while a right ventricular ejection fraction of less than 35% and a regional wall motion abnormality were present in 4 of the 6 Group I patients and 2 of the 19 Group II patients ($p < 0.001$).

Hospital follow-up. In Group I, one patient died suddenly and one patient's condition deteriorated from clinical class II to class IV, although he survived. All patients in Group II did well during their in-hospital convalescence.

Discussion

Prior first transit radionuclide studies. Prior first transit radionuclide data (1–3) from patients with acute myocardial infarction suggest that right ventricular performance is reduced in patients with inferior compared with anterior transmural myocardial infarction, and that this abnormality is due to right ventricular infarction. Steele et al. (1) reported that the average right ventricular ejection fraction (± 1 standard error of the mean) of 50 ± 2% in 11 patients with inferior infarction was less than the value of 57 ± 1% in 14 normal men ($p < 0.001$), while that in 15 patients with anterior infarction averaged 54 ± 1% and did not differ significantly from the normal value. Subsequently, Tobinick et al. (2) studied 24 patients with acute anterior or lateral myocardial infarction and 19 patients with acute inferior transmural myocardial infarction to assess right ventricular performance. The average right ventricular ejection fraction (± 1 standard deviation) of 47 ± 10% in the inferior infarction group was less than that in the control group ($p < 0.03$) and the anterior infarction group ($p < 0.005$). In addition, 7 of the 19 patients with inferior infarction had right ventricular uptake on technetium pyrophosphate myocardial scintigraphy, while 11 patients did not and 2 patients could not be scanned satisfactorily. In the group with a positive right ventricular scintigram, the mean right ventricular ejection fraction of 39 ± 5% was less than the 51 ± 10% value in the group with a negative scintigram ($p < 0.01$). Finally, Reduto et al. (3) reported that the average right ventricular ejection fraction was significantly reduced in patients with inferior transmural infarction compared with patients with anterior transmural infarction (48 ± 2 versus 56 ± 2%, respectively, $p < 0.01$).

There are limitations to these initial first transit radionuclide studies. First, there was no assessment of the composite movie display to determine qualitatively whether wall motion abnormalities of the right ventricle were present. Right ventricular regional wall motion abnormalities during the acute phase of an inferior transmural infarction may be more useful alone or combined with a reduction in right ventricular performance for identifying the presence of associated hemodynamically significant right ventricular infarction than would right ventricular ejection fraction alone. Second, hemodynamic measurements are necessary to make this diagnosis (6–11). These initial first transit radionuclide angiographic studies, although implicating hemodynamically significant right ventricular infarction as the reason for a reduced right ventricular ejection fraction in patients with inferior transmural infarction, do not provide hemodynamic data to substantiate this diagnosis. Thus, although a reduced right ventricular ejection fraction may be useful for identifying acute hemodynamically significant right ventricular infarction, radionuclide criteria based on hemodynamic subsets in patients with inferior transmural infarction have not been previously reported.

Prior equilibrium radionuclide studies. Prior equilibrium radionuclide studies in patients with acute infarction have also assessed whether hemodynamically significant right ventricular infarction can be identified in patients with inferior transmural infarction (4,5). Initially, Rigo et al. (4) reported that an average right ventricular/left ventricular area ratio in patients with inferior transmural myocardial infarction without shock did not differ from that in 10 normal volunteers. However, in three patients with inferior transmural infarction and shock, this ratio was significantly increased. Subsequently, Sharpe et al. (5) evaluated 26 patients with acute transmural infarction by equilibrium radionuclide angiography and right heart catheterization. Six (40%) of the 15 patients with inferior transmural infarction had either an abnormal technetium pyrophosphate myocardial scintigram with localization to the right ventricular free wall or a right ventricular regional wall motion abnormality. They observed that patients with a positive myocardial scintigram or a right ventricular regional wall motion abnormality had a larger mean right/left ventricular area ratio compared with patients with inferior infarction but without these findings at end-diastole (1.30 ± 0.28 versus 0.74 ± 0.23, respectively, $p < 0.05$) and at end-systole (1.53 ± 0.76 versus 0.72 ± 0.29, respectively, $p < 0.01$). Hemodynamic data demonstrated that patients with inferior infarction with a positive myocardial scintigram or a regional wall motion abnormality had a higher mean right ventricular filling pressure (11 ± 3 mm Hg) in contrast to patients without these radionuclide findings (5 ± 1 mm Hg, $p < 0.0001$). Recently, Baigrie et al. (14) reported a reduction in right ventricular ejection fraction in patients with acute inferior transmural infarction compared with normal subjects (34 ± 4 versus 42 ± 2%, $p < 0.05$), but not among patients with inferior infarction with and without hemodynamically significant right infarction hemodynamics. Thus, these equilibrium radionuclide studies suggest that right ventricular dilation and regional dysfunction might be useful markers for the diagnosis of hemodynamically significant right ventricular infarction.

There are potential limitations to these initial equilibrium radionuclide studies. First, the patient groups were relatively selective. In the study reported by Rigo et al. (4), only patients with inferior myocardial infarction and shock were found to have an enlarged right ventricle compared with that of normal volunteers. Second, hemodynamic criteria regarding the right atrial/pulmonary artery wedge pressure ratio were not used to identify the presence of right ventricular infarction in some of these studies (4,5). The value of radionuclide data might be better assessed in hemodynamically defined subsets of patients with inferior transmural infarction. Finally, in some of these studies right ventricular performance was not assessed by the equilibrium radionuclide technique which is now commonly employed in the clinical evaluation of patients with acute and chronic ischemic heart disease (4,5); and in one study (14) no difference was observed in mean right ventricular ejection fraction in patients with inferior transmural infarction with and without hemodynamically significant right ventricular infarction. Thus, the usefulness of a right ventricular ejection fraction determination by equilibrium radionuclide angiography for identifying hemodynamically significant right ventricular infarction in patients with acute inferior transmural infarction remains unclear.

Present radionuclide investigation. Our investigation was performed on a prospective group of consecutive patients with inferior transmural myocardial infarction. All of these patients had early right heart catheterization for the determination of the presence of hemodynamically significant right ventricular infarction before and after volume loading. Using strict hemodynamic criteria, two subsets of patients with inferior transmural myocardial infarction were defined, one with (Group I) and the other without (Group II) associated hemodynamically significant right ventricular infarction. The data indicate that both first transit and equilibrium radionuclide angiograms performed early in the course of acute inferior transmural myocardial infarction can identify patients with associated right ventricular infarction. The best single first transit and equilibrium radionuclide variable for separating Group I from Group II with the least overlap between the groups was the presence or absence of a right ventricular regional wall motion abnormality. The presence of a right ventricular ejection fraction of less than 35% by first transit radionuclide angiography also separated the two groups, while a right ventricular ejection fraction of less than 40% was not useful as an isolated criterion in separating the two groups. However, the combination of a right ventricular ejection fraction of less than 35 or 40% and the presence of a right ventricular regional wall motion abnormality by first transit radionuclide angiography was valuable for identifying patients with hemodynamically significant right ventricular infarction.

By equilibrium radionuclide angiography a right ventricular ejection fraction of less than 35% or less than 40% separated patients with from those without hemodynamically significant right ventricular infarction. Moreover, a right ventricular ejection fraction of less than 40% and a regional wall motion abnormality by equilibrium radionuclide angiography provided an excellent separation between these two groups of patients, while a right ventricular ejection fraction of less than 35% and a regional wall motion abnormality separated the two groups less well. Furthermore, these first transit and equilibrium radionuclide variables demonstrated a similar separation of Group I and II patients after patients with a prior myocardial infarction were excluded.

Limitations of the study. Certain limitations of the present investigation must be considered. *First*, 4 (12%) of the 33 patients had first transit radionuclide angiograms that were inadequate for analysis. These four patients had an inadequate bolus infection; thus, adequate curves were not obtained and three or more end-diastolic peaks were not available to calculate right ventricular ejection fraction. Since the statistical reliability of using less than three peaks to calculate right ventricular ejection fraction by first transit methods is poor and the additional potential of bolus smearing exists, it was deemed reasonable to exclude these first transit data from the study (15).

Second, a single crystal gamma scintillation camera was used for acquiring the first transit radionuclide data. At high count rates, dead time data loss may occur. We performed a dead time determination for the camera-computer system and determined that an insignificant dead time loss occurred up to a bolus dose of 12 mCi of technetium-99m human serum albumin. Thus, the first transit radionuclide data were acquired with a 10 to 12 mCi bolus injection. This should have avoided any significant data loss that may have affected the statistical reliability of the first transit radionuclide right ventricular ejection fraction determinations.

Third, the right ventricular ejection fraction determinations from the equilibrium radionuclide data were dependent on observer-defined end-diastolic and end-systolic hand-drawn regions of interest. Because of the high operator involvement, there may have been variation in the right ventricular ejection fraction determinations that may have affected the data. However, there was a correlation with the corresponding first transit radionuclide right ventricular ejection fraction values. Thus, the equilibrium radionuclide right ventricular ejection fraction values were probably accurate and reliable.

Fourth, there was overlap in the right ventricular ejection fraction determinations, with several low values for right ventricular ejection fraction in patients without hemodynamically significant right ventricular infarction. This was less apparent when right ventricular regional wall motion abnormalities were used alone or in combination with a right ventricular ejection fraction of less than 35 or 40% by either radionuclide technique. Thus, radionuclide criteria for right

ventricular infarction may be present in some patients despite an absence of hemodynamic evidence for right ventricular infarction, suggesting that there may be a spectrum of right ventricular involvement. However, the absence of these radionuclide abnormalities argues against the presence of hemodynamically significant right ventricular dysfunction.

Conclusions. We conclude from these data that: 1) first transit and equilibrium radionuclide determinations of right ventricular ejection fraction correlate in patients with acute inferior transmural infarction, and 2) the presence of a right ventricular regional wall motion abnormality (akinesia or dyskinesia) is the most useful single variable for identifying the presence of hemodynamically significant right ventricular infarction in patients with inferior transmural infarction. This, in combination with a right ventricular ejection fraction of less than 40% on first transit or equilibrium radionuclide angiography, is also a useful criterion for determining the presence or absence of hemodynamically significant right ventricular infarction in patients with inferior transmural infarction. Thus, either first transit or equilibrium radionuclide angiography when performed early in patients with inferior transmural infarction is a useful screening study for suggesting the presence or absence of hemodynamically significant right ventricular infarction so that decisions regarding more aggressive hemodynamic monitoring and the institution of appropriate therapy may be made rapidly.

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