Increased Stress Right Ventricular Activity on Dual Isotope Perfusion SPECT
A Sign of Multivessel and/or Left Main Coronary Artery Disease
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OBJECTIVES
This study sought to determine the anatomic and physiologic correlates of increased right ventricular (RV) activity on exercise single-photon emission computed tomography (SPECT) perfusion imaging in patients with coronary artery disease (CAD).

BACKGROUND
Because SPECT perfusion imaging delineates relative myocardial blood flow, patients with global left ventricular (LV) hypoperfusion but normal RV perfusion may have increased relative RV tracer uptake as an indicator of multivessel CAD.

METHODS
Rest thallium-201 and exercise 99mTc-sestamibi or 99mTc-tetrofosmin SPECT perfusion images were analyzed for peak RV and LV activity (RV:LV index) in 315 patients, including 240 patients with documented CAD, 39 patients with no significant CAD on arteriography, and a "normalcy" group of 36 patients with a low pre- and posttest probability of CAD.

RESULTS
Resting RV:LV perfusion index ranged from 0.32 to 0.34 in each group, increasing to 0.36 with exercise in control and normalcy groups. CAD patients with the highest exercise RV:LV were those with severe left main CAD (or "left main equivalent"), with a lesser degree of proximal right CAD (0.51, n = 14, p < 0.001 vs. other groups). An exercise RV:LV >0.42 with an exercise:rest ratio >1.2 was present in 93% patients with this pattern of CAD, but was absent in 97% of the normalcy group, 92% of patients without significant angiographic CAD, and 100% of patients with proximal right CAD tighter than stenoses in the left system.

CONCLUSIONS
Increased RV:LV activity exercise may occur in patients with acute RV strain, but is otherwise an indicator of exercise-induced RV:LV perfusion imbalance associated with severe CAD, particularly high-grade left main with less severe proximal right CAD. (J Am Coll Cardiol 1999;34:420–7) © 1999 by the American College of Cardiology

Over the past two decades, single-photon emission computed tomography (SPECT) perfusion imaging has become invaluable in the diagnosis, prognosis and management of acute and chronic coronary artery disease (CAD). Its major strength has been in risk stratification in a variety of clinical situations (1–12). Patients with a negative stress SPECT perfusion scan have an extremely low cardiac event rate, estimated at less than 1% per year (6,7). However, a potential limitation of SPECT is that a measure of relative rather than absolute myocardial blood flow is obtained. In patients with multivessel CAD without absolute quantification of regional blood flow, the degree of ischemia may be underestimated owing to relatively balanced global hyperperfusion of the left ventricle (LV). Perfusion deficits may be evident only in comparison with the least ischemic zone, which appears normal. Because of this, only a fraction of patients with three-vessel or left main (LM) CAD have scintigraphic perfusion abnormalities in all the expected coronary arterial territories on planar or SPECT imaging (13–17). Clinical, exercise, and other nonperfusion scintigraphic parameters provide important independent information for the identification of LM or three-vessel CAD by perfusion imaging, because the perfusion pattern alone is often insufficient to describe the full extent of ischemia (13–21). Scintigraphic information that could reliably imply the presence of high-risk CAD would be of great clinical importance because previous studies (13,17) have shown that perfusion defect patterns identify only 19% to 29% of patients with such high-risk patterns of CAD, such as left main stenoses.

This study examined the hypothesis that increased right ventricular (RV) uptake at stress, which is not present at rest, could be a marker for high-risk CAD, specifically left main (LM) or proximal left anterior descending and circumflex CAD, without concomitant proximal right coro-
nary artery (RCA) disease. In theory, this pattern of coronary stenoses would result in global LV hypoperfusion, but allows normal perfusion of the RV.

**METHODS**

**Patient population.** Resting thallium-201 and post-stress Tc-99m-sestamibi or Tc-99m-tetrofosmin SPECT myocardial perfusion images were analyzed in 396 patients. Analyses of the 81 patients who underwent coronary angiography and pharmacologic stress testing with dobutamine (n = 26), dipyridamole (n = 54), or adenosine (n = 1) indicated that there were frequently marked increases (mean increase of 26 ± 7%) in RV:LV from rest to stress. Specifically, 47 of the 81 pharmacologic stress patients had an elevated exercise and exercise:rest RV:LV ratio (defined below). Only one of these 47 patients had >70% LM (90%) stenosis. This patient had an occluded proximal RCA and should not have had an increase in RV:LV. There was no discernible activity level that would indicate the presence or pattern of coronary heart disease with pharmacologic stress. Therefore, the current analysis was confined to the 315 patients undergoing exercise stress testing. This included 240 patients with documented ischemic heart disease, defined as at least one coronary artery stenosis of ≥50% of the intraluminal diameter, 39 patients with no significant CAD by angiography and a normalcy group of 36 patients with a low posttest probability of CAD subjects who were tested for suspicion of having stress-induced reversible myocardial ischemia.

The group of 39 patients with no significant CAD on angiography included 14 patients with minimal CAD (i.e., stenoses of <50% of the intraluminal diameter). The remaining 25 patients had no evidence of coronary stenoses on angiography. The normalcy group comprised 36 patients who were deemed to be at low probability of having CAD based on the following criteria:

1. No more than two of the following coronary risk factors: hypertension, dyslipidemia, smoking, and diabetes;
2. exercise treadmill or leg cycle testing during which the patient attained either: a) a peak systolic blood pressure–heart rate product of 25,000 mm Hg beats/min, or b) at least 85% of predicted maximum heart rate;
3. no exercise-induced angina pectoris during the study; and
4. no evidence for reversible ischemia on rest and stress SPECT perfusion images.

To test the hypothesis that increased RV activity with exercise was due to a relative imbalance of LV and RV increases in flow reserve, the 240 patients with CAD documented by angiography were divided into four subgroups:

1. Patients who should not have increased RV activity with stress because of the presence of a proximal right coronary stenosis, greater than any stenoses in the left coronary system, which would impair the increase in RV myocardial blood flow with exercise (n = 50);  
2. patients who should have increased RV activity with stress because of a LM coronary stenosis (or the “LM equivalent” proximal left anterior descending and circumflex stenoses) of ≥70%, but no greater stenosis of the proximal right coronary artery (n = 14);  
3. patients who may be expected to have increased RV activity because of mild (50% to 70%) LM, or three-vessel disease (≥50% stenoses), with the most severe stenosis being other than the proximal right coronary artery (n = 64); and  
4. patients who would not be expected to have an increase in RV activity because of mild single or two-vessel coronary artery disease, in which at least one region of LV should have normal myocardial blood flow, thereby preventing the occurrence of “balanced” LV myocardial ischemia (n = 112).

**Resting and post-stress SPECT acquisition and processing.** All patients underwent same-day dual isotope (7,11) rest thallium-201 SPECT followed by exercise testing and stress Tc-99m-sestamibi or -tetrofosmin perfusion studies. Resting SPECT images were acquired 10 to 15 min after injection of 3 to 4.5 mCi of thallium-201 chloride. Scanning was performed from right anterior oblique–45° to left posterior oblique–45° in a circular orbit, using either an Elscint Apex-409AG (Hackensack, New Jersey) large field-of-view gamma camera, or an Elscint Cardial dual-headed gamma camera, both equipped with a low-energy, high-resolution collimation. Forty-five or 60 projections were acquired, each obtained for either 25-s (single-head camera) or 20-s (dual-head camera) duration at 3° or 4° intervals in “step and shoot” mode, using a 64 × 64 byte matrix.

Symptom-limited exercise testing was then performed with either leg cycle or treadmill exercise. At peak stress each patient was injected with 23 to 36 mCi (depending upon the patient’s weight) of Tc-99m-sestamibi or Tc-99m-tetrofosmin. After a delay of 15 to 45 min for hepatic tracer clearance, projections for exercise tomographic reconstruction were acquired using the Tc-99m energy window. The same collimator, acquisition parameters, gamma camera and patient position were utilized.

Images were processed on an Intel-80486-based microcomputer (Elscint Apex-SP1, Hackensack, New Jersey).
After collimator sensitivity and center-of-rotation correction, the resting and stress projections were used for transaxial slice reconstruction. Transaxial slices of 2.88 mm thickness were reconstructed using a Butterworth back projection filter, with a cutoff frequency of 0.35 Nyquist and order of 5.0. The transaxial slices were then reoriented along cardiac planes into short axis, horizontal long axis, and vertical long axis. The short axis images, from 15 to 31 in number, were compressed into 15 slices of varied thickness, depending upon the cardiac dimensions.

**Determination of RV:LV ratio.** Perfusion image analysis was performed after normalizing both rest and stress short axis slice sets to a maximum pixel value of 220 in the LV. These frames were then interrogated for the maximum pixel count in the RV by manually adjusting the upper window until the slice with the maximum pixel count was identified. This image was then zoomed to confirm this setting. The rest and stress RV:LV ratios were determined by dividing the peak RV pixel count by the maximum LV count. Examples of normal and increased RV activity at stress and at both rest and stress (i.e., RV hypertrophy) are shown in Figure 1.

**Statistical analysis.** Comparison of the mean rest and stress RV:LV ratios for each subset of patients was performed using paired \( t \) test, the null hypothesis being that there was no significant change from rest to stress in the RV:LV index. For continuous unpaired data (i.e., the rest RV:LV index, stress RV:LV index, and stress-to-rest RV:LV ratios) the mean values of each patient subgroup were compared using the unpaired \( t \) test (comparison of means), the null hypothesis being that there was no significant intergroup differences in the rest, stress, and stress/rest RV:LV index. These analyses were performed using SPSS version 8.0. Continuity-corrected chi-square analysis with one degree of freedom was applied to the frequency of an elevated RV:LV index in each of the patient subgroups. A \( p \)-value of less than 0.05 was considered statistically significant for a single comparison. Bonferroni’s correction was applied to multiple comparisons for each of the 15 possible comparisons among the 6 clinical subgroups, reducing the \( p \)-value required for significance to 0.003 for each of these tests. Data are presented as mean and standard deviation. Linear regression analysis was performed to determine the product-moment correlation coefficient (\( r \)) between the rest and stress RV:LV ratios for each group. Statistically significant differences between correlation coefficients were assessed by using a two-tailed Fisher z transformation (22).

**RESULTS**

**Resting RV:LV perfusion image ratios.** The mean values of resting thallium-201 RV:LV index ranged from 0.32 ± 0.09 in the 50 patients with proximal right coronary artery disease and 0.32 ± 0.07 in the normalcy group (\( n = 36 \)), up to 0.35 ± 0.07 in the patients with no significant CAD on angiography (\( n = 39 \)). No significant differences existed between the resting RV:LV perfusion indices in any of the patient subgroups. The trend toward higher resting values in the catheterized group (\( p = 0.038 \), NS) was influenced by the high prevalence of scintigraphic RV hypertrophy (\( n = 8 \)), pulmonary hypertension on catheterization (\( n = 7 \)), or LV dysfunction by pressure measurement or contrast ventriculography (\( n = 26 \)).

**Exercise RV:LV Perfusion Image Ratios.** The fractional increase in the RV:LV ratio from rest to stress in each patient group is shown in Figure 2. The mean value of the RV:LV index increased slightly with exercise in the patients without significant CAD on angiography (from 0.35 ± 0.07 at rest to 0.36 ± 0.08 with exercise; \( p \)-value NS). The mean RV:LV index was similar to this in the normalcy group (0.36 ± 0.05).

In the 240 patients with significant CAD, the mean RV:LV index increased 17% with exercise to 0.38 ± 0.09 (\( p = \) NS vs. normalcy and control groups). However, these results varied widely depending upon the specific pattern of distribution of coronary stenoses.

In the 50 patients with tight proximal right CAD, in whom an increase in RV:LV would not be expected because of diminished capacity for increased RV perfusion with exercise, the mean exercise RV:LV index increased only 12% to 0.35 ± 0.08, similar to the normalcy and no-significant CAD groups.

The group of 112 patients with mild CAD—that is, single- or two-vessel (nonproximal) CAD—also had a small increase (10%) in RV:LV index with exercise RV:LV index of 0.36 ± 0.08. The 64 patients with more severe (50% to 70% LM and/or three-vessel) CAD had a mean exercise RV:LV index of 0.40 ± 0.10, representing a 23% increase from the resting value.

Most important, there was a 60% increase from 0.33 ± 0.07 at rest to 0.51 ± 0.07 with exercise in the 14 patients with the combination of a tight LM (or LM equivalent) and less (or absent) proximal right CAD. This exercise RV:LV index was significantly higher (\( p < 0.001 \)) than those of any other subgroup of patients with or without CAD.

Figure 3 depicts scatterplots of resting versus exercise RV:LV activity ratios for each of these six patient subgroups, with their respective correlation coefficients. Each one of the exercise RV:LV indexes was moderately to highly correlated with the resting values (\( r \)-values ranging from 0.55 to 0.76, each \( p < 0.0001 \)), except for the group of patients with the combination of a tight LM (or its equivalent) and less (or absent) proximal right CAD (\( r = 0.39 \), \( p = \) NS), consistent with the hypothesized imbalance of exercise perfusion between the RV and LV myocardium.

**Scintigraphic criteria for detection of global LV ischemia.** Because patients with RV hypertrophy (as in Fig. 1C) will have elevated rest and exercise RV:LV perfusion indexes, detection of a relative imbalance of RV and LV
flow reserve with stress would require an increase from rest to exercise, as well as the absolute increase in RV:LV. As shown in Figure 3, the best separation between the RV:LV values of the group of patients with LM (or equivalent) with less (or without) proximal RCA disease and the patients without significant CAD on angiography was obtained with the criteria of having:

1. an exercise RV:LV index greater than 0.42, and
2. an exercise-to-rest RV:LV index ratio of 1.2—that is, a 20% increase from rest to exercise.

Using these criteria, an abnormal exercise RV:LV index occurred in 93% (13 out of 14) of the >70% LM (or proximal left anterior descending and circumflex) without proximal right CAD group (see Fig. 4). This was a significantly higher frequency than occurred in any other subgroup (p < 0.001). The only patient in this group who

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Figure 1. Examples of the normal and increased right ventricular (RV) activity are shown. (A) Mid-ventricular horizontal long axis and short axis images are shown in a normal participant at exercise (above) and rest (below). There is a normal degree of RV activity at stress (arrow). The resting scan shows normal RV activity, but with some splanchnic thallium-201 activity that limits the evaluation of the counts in the inferior aspect of the RV. (B) These images are from a patient with left main and three-vessel CAD, but only mild CAD in the proximal right coronary artery. The resting images are normal. With exercise, there were only mild reversible perfusion abnormalities (anterior, inferolateral, lateral-apical, lateral), but exercise-induced ischemic cavity dilatation, consistent with more global ischemia. The relative RV activity was normal at rest, but increased markedly with exercise, consistent with global LV ischemia, preserved RV perfusion, and most possibly an increase in pulmonary pressures with stress. (C) These images were obtained on an elderly patient with an ostium secundum atrial septal defect, severe pulmonary hypertension and marked RV hypertrophy. The increased RV activity is present at rest and stress (RV:LV activity indexes of 0.51 and 0.53, respectively) with a normal exercise to resting ratio of 1.045. CAD = coronary artery disease; LV = left ventricular; RV = right ventricular.
**Figure 2.** Mean values of exercise-to-rest ratios are shown for each of the subgroups of patients with and without coronary artery disease. There was marked increase in RV:LV ratio from the resting thallium-201 to exercise Tc-99m-sestamibi or tetrofosmin in the group of patients with LM or LME CAD and less stenosis of the proximal right coronary artery (*p < 0.001 vs. normals and other CAD groups). CAD = coronary artery disease; Cath = percent diameter stenosis on cardiac catheterization; CX = circumflex CAD; LAD = left anterior descending CAD; LM = left main CAD; LME = “left main equivalent” proximal LAD and CX CAD; LV = left ventricular; RCPa = proximal right CAD; RV = right ventricular; 1 or 2VD = single- or double-vessel CAD.

did not demonstrate an increased RV:LV index had an 80% proximal RCA stenosis, which was probably able to physiologically match with RV ischemia the high degree of LV ischemia from a 95% LM stenosis.

The frequency of an abnormal exercise RV:LV index was 30% (19 out of 64) in the mild LM or three-vessel CAD group, but only 12% (13 out of 112) in the patients with single- and double-vessel CAD.

There were no patients who had a proximal right coronary stenosis as their tightest lesion and who met these criteria for an exercise-induced increased RV:LV index. Similarly, there were very few patients in the normalcy (1 of 36, 3%) and no-significant CAD (3 of 39, 8%) groups who met these criteria for an abnormal exercise RV:LV index. The only patient in the normalcy group with an abnormal exercise RV:LV index had radiographic evidence for emphysema, and his exercise test was stopped because of symptomatic dyspnea, suggesting the presence of an acute rise in pulmonary artery pressures with stress. Each of the three patients with no-significant CAD and an increase in RV:LV index with exercise had systolic LV dysfunction by contrast ventriculography and diastolic dysfunction by an elevated LV end-diastolic pressure at rest.

**Identification of high-risk coronary anatomy with other exercise and SPECT indexes.** In the 14 subjects with the >70% LM (or proximal left anterior descending and circumflex) without proximal right CAD, there were only 5 (36%) who developed angina during exercise, 9 (64%) who developed ST-segment depression, 5 (36%) with marked (>3 mm) ST-segment depression, 5 (36%) with prolonged ST-segment depression in recovery (>10 min duration), only 3 (21%) with both markedly positive exercise ECG and exercise induced angina and 4 (29%) with a subnormal rise or fall in systemic systolic blood pressure at peak exercise. The SPECT perfusion scans were abnormal in all 14 subjects, including 12 (86%) with at least one severe perfusion defect, 1 with at most moderate regional hypoperfusion and 1 with only mild defects. However, the “LM pattern” of left anterior descending plus circumflex territory abnormalities was detected in only 7 of these 14 subjects (50%).

**DISCUSSION**

For the past two decades, perfusion scintigraphy has focused primarily on the examination of LV perfusion (1–21). Relatively few studies have described RV findings (23–32). These have focused on increased RV activity in patients or experimental animals with acute or chronic pulmonary hypertension, or LV dysfunction, and decreased RV regional uptake in patients with obstructive CAD of the proximal or mid-RCA. The present study demonstrates that dual-isotope SPECT RV perfusion imaging is useful in the identification of contralateral global LV hypoperfusion. In patients without significant CAD, the increase in LV perfusion tracer uptake, reflecting coronary flow reserve and tracer extraction and retention, is matched by a similar increase in RV tracer uptake, such that the ratio of RV:LV activity is increased only slightly with exercise. This slight increase (5% to 17%) may be related to better RV count recovery, with the Tc-99m-labeled perfusion tracer at exercise compared with thallium-201 at rest, due to the slightly lessened effect of tissue attenuation on 140 keV (Tc-99m) versus 68 to 83 keV (thallium-201) photons. When, however, there is a mismatch between the increment of RV and LV tracer uptake with stress, as would occur in a patient with the combination of tight LM and distal right coronary stenoses, there is a marked increase in relative RV perfusion with stress, which serves as an indicator of severe CAD with global LV hypoperfusion. This was not an uncommon finding in patients with three-vessel or milder degrees of stenoses (50% to 70%) of the LM, but was rare in patients with single-vessel disease. It did not occur in patients with proximal RCA stenoses.

**Identification of high-risk CAD with SPECT.** Christian et al. (17) estimated that as few as 29% of patients with three-vessel or LM CAD have scintigraphic perfusion abnormalities in all territories, which would suggest extensive CAD. In another study, Rehn et al. (13) found that 19% of patients with LM, proximal left anterior descending and circumflex, or triple-vessel disease were identified by a multivessel pattern of perfusion abnormalities. In the current report, SPECT identified 50% of these subjects as having a “LM pattern” of disease.

Clinical and exercise parameters have been utilized by
Figure 3. Scatterplots of individual data points of rest and exercise RV:LV perfusion ratio for each patient in the study are shown, grouped by CAD anatomic features or normalcy. The RV:LV perfusion ratios are highly correlated ($p < 0.0001$) for each subgroup of patients, except for the patients with LM CAD or LME CAD and a lesser degree of (or absent) RCAp disease (A), in whom the exercise RV:LV index is much greater than the resting RV:LV, with $r = 0.39$, $p = \text{NS}$. The criteria of an exercise RV:LV ratio of $>0.42$ and exercise to resting RV:LV index ratio of $>1.2$ was met by the majority of this group, but by no one with a proximal RCA lesion as their tightest stenosis. These criteria were met by only three patients with no significant CAD on Cath and only one patient in the normalcy group (B). The frequency of this finding increased as the degree of CAD increased (C). Abbreviations are the same as in Figure 2.
some investigators (18–20) to provide important independent information that could aid the identification of LM or three-vessel CAD, which is not clearly evident by scintigraphy. These parameters (angina, prolonged and severe ST-segment depression or hypotension with exercise) occurred in a small fraction of the subjects with the most severe disease pattern. Thus, a marker as described in the present study, which would indicate the presence of high-risk CAD patterns, resulting in exercise-induced global LV hypoperfusion or an acute rise in pulmonary artery pressures, would be useful.

Increased RV activity on perfusion scintigraphy. Nearly two decades ago, Khaja et al. (23) demonstrated that the presence of increased RV activity could be visualized on planar thallium-201 scintigraphy. They found that this was related to the presence of pulmonary hypertension with anatomic RV hypertrophy. In that study, 85% of patients with pulmonary hypertension demonstrated increased RV activity, whereas none of the control subjects with normal pulmonary pressures had this finding.

Wackers et al. (24) showed that an acute increase in RV myocardial blood flow due to acute RV strain after pulmonary banding in a canine model resulted in an increased ratio of RV:LV activity, even before the development of RV hypertrophy. In that experiment, the mean baseline RV:LV thallium-201 ratio was 0.30 ± 0.06, similar to the baseline and normal ratios of 0.32 to 0.34 noted in this report. Within minutes of pulmonary banding, which resulted in an increase in pulmonary arterial pressure from a mean of 30 mm Hg in the control group to 82 mm Hg, the RV:LV thallium-201 ratio increased to 0.45 ± 0.07, with perfusion images that were indistinguishable from those of dogs with established chronic RV hypertrophy. This was most likely due to increased myocardial blood flow and tracer delivery owing to the acute rise in RV wall stress, a major determinant of myocardial oxygen consumption.

For these reasons, patients with chronically elevated pulmonary pressures and RV hypertrophy should have an increased RV:LV ratio at rest and at stress. Also, patients with acutely elevated pulmonary pressures during stress testing, such as a patient with exercise-induced pulmonary hypertension, edema or bronchospasm, may develop an increased RV:LV index that is not due to LV hypoperfusion. This was a very infrequent finding in the normalcy group (one of 36 patients) reported herein, but occurred in three additional patients out of the angiographic control group who had evidence for nonischemic LV systolic and diastolic dysfunction on cardiac catheterization.

An acute elevation in pulmonary arterial pressures may have occurred in many patients with three-vessel or mild LM disease, or even with proximal single-vessel CAD, due to exercise-induced LV dysfunction during the study, resulting in the 30% and 12% incidence, respectively, of an increased RV:LV index.

Study limitations. One limitation of this study is the need for an angiographic reference standard. It is likely that some patients in this study were incorrectly categorized by contrast lumenography and caliper assessment of percent diameter stenosis (33). For example, a patient with a long, eccentric 70% proximal right coronary stenosis, an 80% distal right coronary artery stenosis and a discrete 80% LM stenosis may be expected to have an increased RV:LV activity ratio, when in fact flow reserve to the RV may be more severely impaired than that of the LV. Also, any patient with prior RV infarction with only a mild residual stenosis in the infarct-related artery may be unable to demonstrate increased RV uptake with stress, despite a relatively greater RV than LV flow reserve.

The findings of this study are limited to dual-isotope exercise stress perfusion imaging. The quantitative results would likely be different with exercise thallium-201 with redistribution or reinjection imaging. Furthermore, it was observed that a markedly increased RV:LV ratio was common with pharmacologic stress perfusion imaging, using the criteria for abnormality determined with the exercise test population.

Finally, as with any retrospective study, the likelihood of referral bias exists. In the worst case, this would preferentially or selectively examine only those patients with the most severe clinical and subsequent angiographic findings, resulting in overestimation of the overall frequency of this finding. This concern is mitigated by the large size of the angiographic population, with the wide distribution of coronary anatomic severities, with most patients having mild CAD.
Conclusions. With dual-isotope SPECT perfusion imaging, an increased RV:LV activity ratio with exercise (>0.42) when compared with rest (exercise-to-rest ratio > 1.2) is an indicator of either acute RV strain or an exercise-induced RV:LV perfusion imbalance. This pattern is associated with severe CAD, particularly high-grade LM (or LM equivalent) stenoses with less severe proximal right CAD. This scintigraphic sign cannot be utilized in the presence of severe proximal right CAD with its consequent impairment of exercise RV flow reserve. An increase in RV:LV activity ratio may be seen without high-risk CAD in patients with exercise-induced increase in pulmonary artery pressures of any cause. Also, these criteria for an abnormal RV:LV index with exercise are not applicable to patients undergoing pharmacologic stress testing.

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