Central Pulmonary Artery Lesions in Chronic Obstructive Pulmonary Disease

A Transesophageal Echocardiography Study

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Background—In patients with acute pulmonary embolism, transesophageal echocardiography (TEE) often reveals presumably thrombotic lesions within the central pulmonary arteries (CPAs). These CPA lesions, when found in patients with primary pulmonary hypertension, have been attributed to in situ thrombosis or atherosclerosis. We hypothesized that similar CPA lesions may also develop in patients with chronic obstructive pulmonary disease (COPD) in the absence of pulmonary embolism.

Methods and Results—We examined by TEE 25 patients with COPD and 27 control patients with left heart disease. None of the patients had previous pulmonary embolism or ileofemoral and popliteal vein thrombosis. By use of TEE, CPA lesions were found in 12 COPD patients (48%) and 2 control patients (7.4%) ($P<0.01$). When CPA lesions were subdivided into types 1 (protruding and mobile) and 2 (wall-adherent), type 1 lesions proved to be uncommon, being found within the pulmonary trunk in 12% and 3.7% of COPD and control patients, respectively (P=NS). Conversely, type 2 lesions, which were always localized in the right pulmonary artery, were frequent in COPD patients (36%) and rare in control patients (3.7%) ($P<0.01$). When available, helical CT and MR angiography confirmed TEE findings, supporting an atherosclerotic origin of type 2 lesions, which were different from typical thrombotic lesions. FEV_1/FVC ratio, RV/TLC ratio, Pa_{O_2}, hematocrit value, and pulmonary artery systolic pressure were not significantly different in COPD patients with and without CPA lesions. At TEE, however, COPD patients with CPA lesions showed a larger size of the main and right pulmonary arteries.

Conclusions—TEE often reveals CPA lesions in stable patients with COPD even in the absence of significant pulmonary hypertension and not in close relation with the severity of pulmonary dysfunction. **(*Circulation*. 1999;100:1808-1815.)**

Key Words: echocardiography ■ thrombus ■ pulmonary heart disease

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In patients with acute pulmonary embolism, transesophageal echocardiography (TEE) frequently shows extensive (presumably thrombotic) lesions within the central pulmonary arteries.[1–12] In most patients, the source of these central pulmonary artery (CPA) lesions is probably embolization from peripheral veins.[13,14] However, CPA lesions with similar morphology were also found in some patients with pulmonary hypertension but no previous pulmonary thromboembolism.[15] In these patients, CPA lesions were attributed to development of in situ thrombosis, although an atherosclerotic origin could not be excluded.[15] CPA lesions found at TEE may be unsuspected clinically, as demonstrated in critically ill patients.[16] The prevalence of these CPA lesions in other clinical settings, and in particular in patients in stable condition, remains unknown.

In an old autopsy study, 28% of patients with chronic pulmonary disease and no previous pulmonary thromboembolism had CPA lesions.[17] This high rate is not surprising, because chronic pulmonary diseases are associated with pulmonary hypertension[18,19] and hypercoagulability,[20] which may promote either in situ thrombosis or atherosclerosis within the great pulmonary arteries. No data exist, however, on the prevalence in vivo of CPA lesions in patients with chronic pulmonary disease. Accordingly, we used TEE to determine whether vascular lesions compatible with in situ thrombosis or atherosclerosis are present at the level of the great pulmonary arteries in patients with chronic obstructive pulmonary disease (COPD) and no previous or recent pulmonary embolism. As a control, we examined a group of patients with left heart disease of various origins.

Methods

Patients

Between January 1995 and January 1997, we examined by TEE 27 consecutive outpatients with chronic pulmonary disease (obstructive

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pattern) and, as a control group, 27 consecutive patients with left heart disease of various origins. All patients were in stable clinical condition. In particular, patients did not have a history of pulmonary embolism or recent symptoms suggesting a diagnosis of pulmonary embolic events, such as sudden onset of dyspnea or pleuritic chest pain.[14] Moreover, all patients were <75 years old, and none of them had acquired conditions often associated with pulmonary embolism, such as recent surgery, trauma, immobilization, cancer, obesity, or localized or unilateral swelling of an extremity.[14] All patients in both the study and the control groups underwent color Doppler ultrasonography of the lower extremities, and neither ileofemoral nor popliteal vein thrombosis was detected in any of them.

COPD was diagnosed on the basis of clinical history, physical examination, chest radiograph, arterial blood gas analysis, and pulmonary-function tests (FEV_1/FVC <70% of the predicted value). As an index of lung hyperinflation, the residual volume/total lung capacity ratio (RV/TLC) was calculated. Two patients with COPD were excluded from analysis because of incomplete echocardiographic examination owing to severe discomfort during the procedure. Thus, the study group consisted of 25 patients (22 men and 3 women, mean age±SD 65±6 years, ranging from 53 to 74 years). In the control group, there were 15 men and 12 women (mean age±SD 61±14 years, ranging from 39 to 72 years). Ten patients had ischemic heart disease, 11 had mitral valve disease (6 with pure mitral valve stenosis), and 6 had primary dilated cardiomyopathy.

Echocardiography

Transthoracic echocardiography (TTE) and TEE were performed with an Aloka SSD-870 or an Acuson 128 XP/5 system using 2.25- or 3.5-MHz transducers for TTE and 5.0-MHz multiplane transducers for TEE. All studies were stored on a ½-inch video recorder for subsequent review. Two observers unaware of the clinical findings reviewed each study.

TTE was performed with the patient lying in the left recumbent position. Craniocaudal and lateral dimensions of the right atrium and ventricle were measured in the 4-chamber apical view at end systole and end diastole, respectively. Fixed or mobile lesions within the right atrium or ventricle were noted. Tricuspid regurgitation was determined by color Doppler. Pulmonary artery systolic pressure (PASP) was estimated by continuous-wave Doppler analysis of tricuspid regurgitation jet.

TEE was performed in the fasting state and after the patients' histories had been assessed for esophageal disorders. We did not administer sedatives or analgesics intravenously to any of the patients. The transducer was introduced with the patient lying in the left recumbent position. The base of the heart was first imaged in the short-axis view. Then the transducer was tilted and withdrawn superiorly to visualize the main and proximal right and left pulmonary arteries.[1] The left pulmonary artery could be imaged on the transverse plane only in its proximal segment because of interposition of the left main bronchus. The right pulmonary artery was imaged on the transverse plane along its entire course up to the division into its major lobar branches. For longitudinal plane imaging, the transducer was rotated slightly to the right to visualize the pulmonary valve and the main pulmonary artery up to its bifurcation. With further rightward rotation, the right pulmonary artery could be imaged in the short-axis view. Similarly, the left pulmonary artery was imaged by rotating the transducer laterally after imaging of the main pulmonary artery. The diameter of the main, right, and left pulmonary arteries was measured at the origin of the vessels whenever possible.

We noted any echolucent lesions present in both transverse and longitudinal scanning in any segment of the great pulmonary arteries. On the basis of their pattern and mobility,[1] CPA lesions were classified as type 1 when they were in part protruding and mobile, suggesting thromboembolism, and as type 2 when they were totally wall-adherent (either laminated or only in part protruding). No attempt was made to subdivide type 2 lesions into thrombotic and atherosclerotic on the basis of their TEE morphology. Artifact images within the pulmonary arteries were excluded through fine adjustments of the transducer rotation in each plane, by modifying the gain regulation settings, and with the aid of color Doppler flow imaging. Location and mobility patterns of structures adjacent to the transducer were also considered to exclude a reverberation phenomenon. In particular, fine linear echoes within the right pulmonary artery were considered to be probable reverberation from the right pulmonary posterior wall.[21] A spontaneous contrastographic effect inside the pulmonary artery was also noted.

Other Imaging Techniques

Helical CT, MR angiography after Gd-DTPA injection, and conventional pulmonary angiography were available in 6, 4, and 1 COPD patients, respectively.

Statistical Analysis

Comparisons of continuous and discrete variables were made by the *t* test for unpaired data and either χ^2 or Fisher's exact test as appropriate. A value of $P<0.05$ was considered to be significant.

Results

Patients With COPD Versus Control Patients

Atrial fibrillation was present in 4 COPD patients (16%) and 11 control patients (40.7%) ($P=0.09$) (Tables 1 and 2). On TTE, no COPD or control patient had right atrial or ventricular thrombus. There was no difference in the size of the right atrium and ventricle or prevalence of tricuspid regurgitation between COPD and control patients. PASP tended to be greater in COPD patients than in control patients, considering only individuals in whom PASP could be assessed (n=14 and 17, respectively), but the difference was not significant. At TEE, the main and right pulmonary arteries were visualized along their entire course in transverse and longitudinal planes in all COPD and control patients. In contrast, the left pulmonary artery was visualized exclusively in its proximal portion (transverse plane) and in only 19 of 25 COPD patients (76%) and 19 of 27 control patients (70%) (P=NS). The diameter of the CPA was not different between COPD and control patients.

CPA lesions were found in 12 COPD patients (48%) and 2 control patients (7.4%) ($P<0.01$) (Table 3). Examples of type 1 and type 2 CPA lesions are shown in Figures 1 and 2, respectively. The 2 control patients with CPA lesions (1 of type 1 and 1 of type 2) had mitral valve stenosis with mild pulmonary hypertension. Type 1 and type 2 CPA lesions were found in 3 (12%) and 9 (36%) COPD patients, respectively (P=NS and $P=<0.01$, respectively, versus control group [both: 3.7%]). One patient with COPD had 2 type 2 CPA lesions in the right pulmonary artery.

All type 1 CPA lesions were found at the level of the pulmonary trunk, in contrast with those of type 2, which were found exclusively at the level of the proximal right pulmonary artery. No patient had lesions in the left pulmonary artery. No CPA lesion was occluding or obstructive, as assessed by color and pulsed-wave Doppler. All type 1 CPA lesions were attached to the vessel wall. Their size ranged from 2 to 5 cm in length and from 1×3 to 2×5 cm in cross section. Type 2 CPA lesions measured 3 to 7 cm in length and 2×2 to 3×5 cm in cross section. In no patient was a spontaneous echo-contrast phenomenon noted.

Helical CT was available in 4 COPD patients with CPA lesions (1 of type 1 and 3 of type 2) and in 2 without. In all these patients, CT scanning confirmed TEE findings. How-

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TABLE 1. Clinical and Echocardiographic Data in COPD Patients

Patient	Sex	Age, y	Atrial Fibrillation	Pulmonary Artery Lesions: Type; Localization	PASP,* mm Hg	Pa_{O_2}, mm Hg	FEV_1/FVC, %	RV/TLC, %	Main Pulmonary Artery Diameter, mm	Right Pulmonary Artery Diameter, mm	Left Pulmonary Artery Diameter, mm
1	M	53			30	58	53	48	22	14	14
2	M	65			28	68	66	45	23	15	13
3	M	66			28	55	40	52	20	10	10
4	M	59			33	59	48	54	19	12	12
5	M	66		1; main	32	61	62	46	23	21	21
6	M	67			70	33	37	60	35	33	34
7	M	68		2; right		66	30	53	21	19	18
8	M	67		2; right	38	68	65	47	35	29	
9	F	70	+	1; main	62	69	68	52	42	37	37
10	M	70		2; right	38	56	42	56	26	19	19
11	M	72	+			61	56	49	24	19	19
12	M	72		2; right		69	63	48	20	16	
13	M	70				60	47	53	22	19	19
14	F	51				69	64	44	24	18	18
15	M	55		2; right	80	69	64	62	23	20	
16	M	61				70	62	47	20	15	15
17	M	64		2 type 2; right	40	69	65	48	31	20	20
18	M	65		1; main		67	58	53	21	19	19
19	M	67		2; right	32	66	36	61	23	20	18
20	M	70	+	2; right	46	65	39	59	31	26	24
21	M	64	+			62	44	58	19	12	12
22	M	74				53	32	56	25	17	
23	F	67				71	50	52	21	19	
24	M	56				77	40	46	17	10	9
25	M	61		2; right	70	46	64	53	30	24	
Mean		64.8			44.8	62.7	51.8	52.1	24.7	19.3	18.5
SD		6.1			17.9	9.2	12.3	5.3	6.1	6.6	7.2

*Patients with tricuspid regurgitation at continuous-wave Doppler.

ever, CPA lesions appeared to be smaller by helical CT scanning than by TEE. An example of a type 2 CPA lesion at helical CT scanning is shown in Figure 3. MR angiography after Gd-DTPA injection was available in 4 COPD patients with CPA lesions (2 of type 1 and 2 of type 2). In 3 of them (2 with type 1 and 1 with type 2 lesions), MR angiography confirmed the presence of some abnormality within the CPA. Also with MR angiography, type 1 lesions were similar to

TABLE 2. TTE and TEE Data in COPD and Control Patients

	COPD (n=25)	Control (n=27)	*P*
TTE			
Right ventricle superoinferior diameter, mm	49±9	46±14	NS
Right ventricle laterolateral diameter, mm	29±7	33±7	NS
Right atrium superoinferior diameter, mm	40±7	46±10	NS
Right atrium laterolateral diameter, mm	37±6	37±6	NS
Tricuspid regurgitation, %	56	63	NS
PASP,* mm Hg	45±18	40±9	NS
TEE			
Main pulmonary artery diameter, mm	25±6	25±3	NS
Right pulmonary artery diameter, mm	19±7	20±4	NS
Left pulmonary artery diameter,† mm	19±7	18±4	NS

*Only patients with tricuspid regurgitation at continuous-wave Doppler.
†The left pulmonary artery was visualized in 19 COPD (76%) and 19 control patients (70%).

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TABLE 3. Pulmonary Artery Lesions at TEE in COPD and Control Patients

	COPD (n=25)	Control (n=27)	*P*
Type 1 lesions, n (%)	3 (12.0)	1 (3.7)	NS
Type 2 lesions, n (%)	9 (36.0)	1 (3.7)	<0.01
Type 1+type 2 lesions, n (%)	12* (48.0)	2 (7.4)	<0.01

*In 1 patient with COPD, 2 type 2 lesions were present.

those often visible in pulmonary thromboembolism. The type 2 lesion was stratified on the right pulmonary artery wall and was well evident in either the coronal or sagittal plane (Figure 4). In the other patient with a type 2 lesion by TEE, no CPA abnormality was found by MR angiography. Another patient with a type 2 lesion underwent conventional pulmonary angiography, which confirmed the presence of a lesion within the right pulmonary artery.

COPD Patients With CPA Lesions Versus Those Without

COPD patients with and without CPA lesions were similar in age, prevalence of atrial fibrillation, hematocrit value, Pa_{O_2}, FEV_1/FVC ratio, and RV/TLC ratio (Table 4). The right atrial and ventricular sizes and prevalence of tricuspid regurgitation were similar in COPD patients with and without CPA lesions. Among patients in whom it could be assessed (75% and 38% of those with and without CPA lesions, respectively), PASP tended to be greater in those with CPA lesions than in those without (49±18 versus 38±18 mm Hg, respectively; *P*=NS). PASP could be assessed in 7 of 9 patients with type 2 CPA

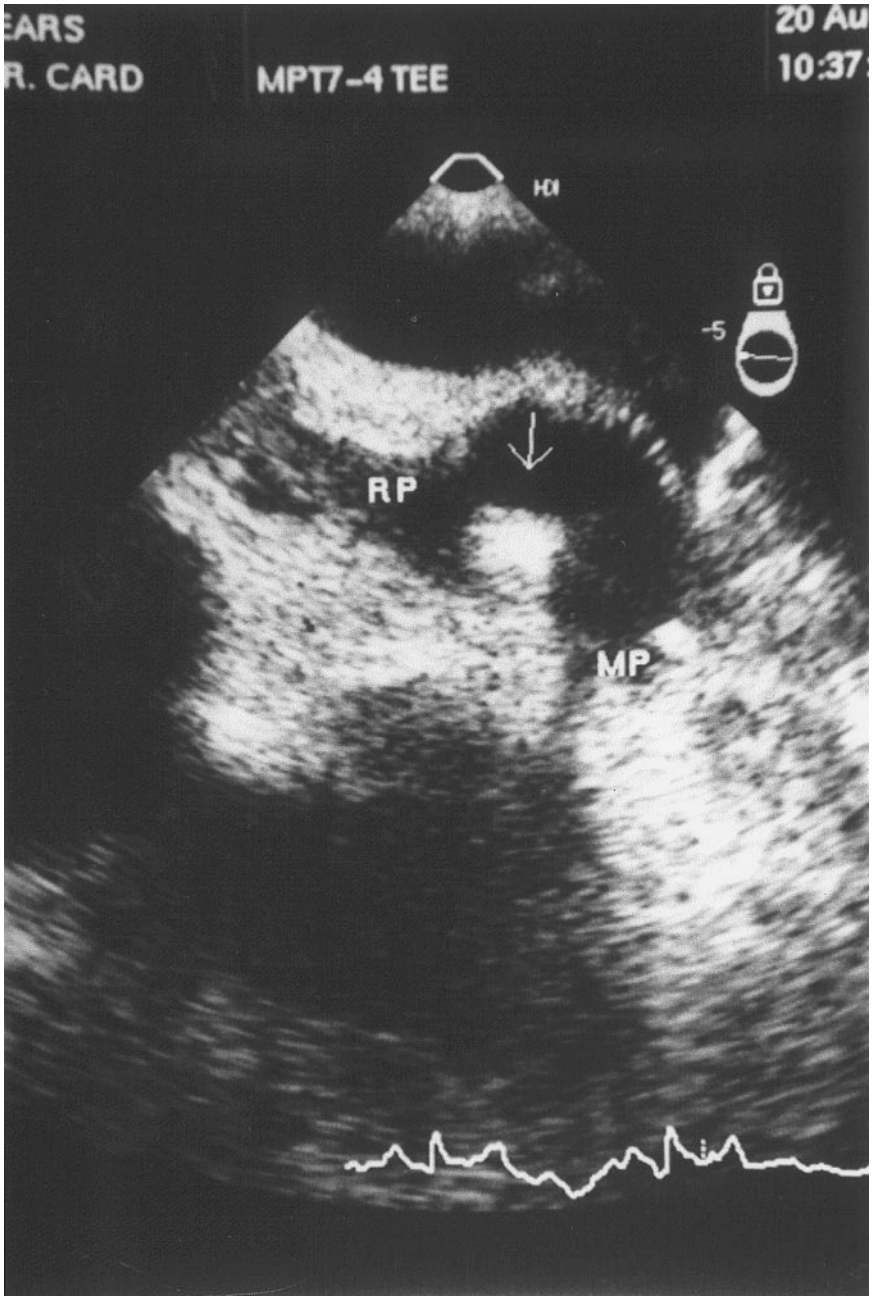

Figure 1. TEE section intermediate between longitudinal and transverse planes in a patient with COPD: a protruding lesion (arrow) is present within main pulmonary artery (MP) before origin of right pulmonary artery (RP). In real time, this lesion appeared to be attached to artery wall through a fixed base and slightly motile. This type 1 lesion had some features similar to thromboembolism.

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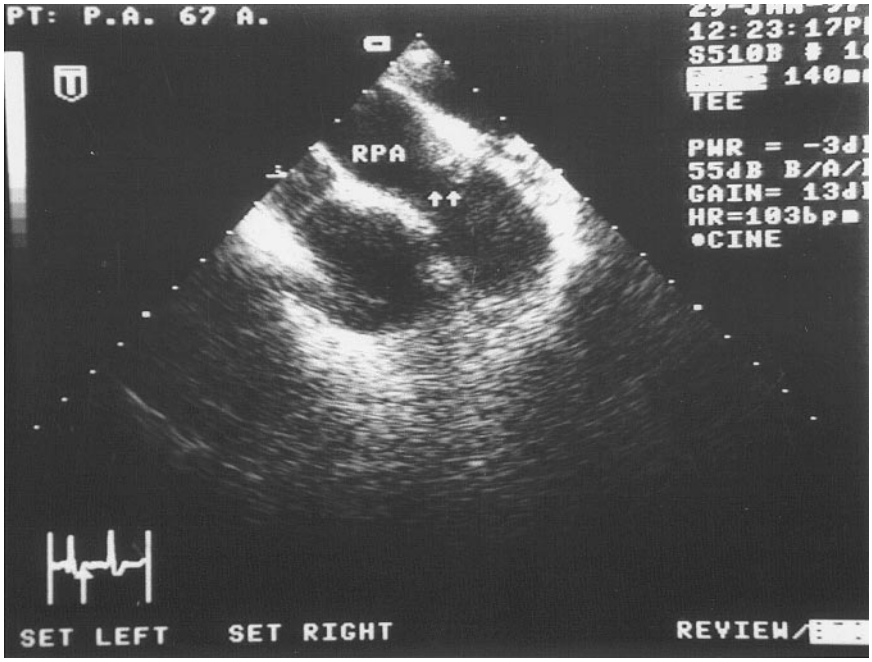

Figure 2. TEE transverse plane section in a patient with COPD: a round lesion (arrows) is present, totally adherent to right pulmonary artery (RPA) wall. In real time, this lesion was not motile. This type 2 lesion was considered to be possible in situ thrombosis or atheroma.

lesions and was ≥40 mm Hg in 4 patients and <40 mm Hg in 3. The diameters of the pulmonary trunk and right pulmonary artery were significantly greater in patients with CPA lesions than in those without ($P=<0.05$ for both).

Discussion

We have hypothesized that patients with chronic pulmonary disease and no pulmonary embolism may show CPA lesions at TEE. In COPD patients, in fact, reversible or fixed pulmonary hypertension,[18,19] prothrombotic state,[20] and hypoxemia[22] might promote metabolic and structural changes in the artery wall resulting in in situ thrombosis or atherosclerosis. Confirming our hypothesis, CPA lesions were detected by TEE in 48% of our COPD patients, who were clinically stable and did not have previous pulmonary embolism. Specifically, 12% of COPD patients had slightly motile masses that were protruding into the pulmonary trunk (type 1 lesions), and 36% of them had flat or rounded lesions that

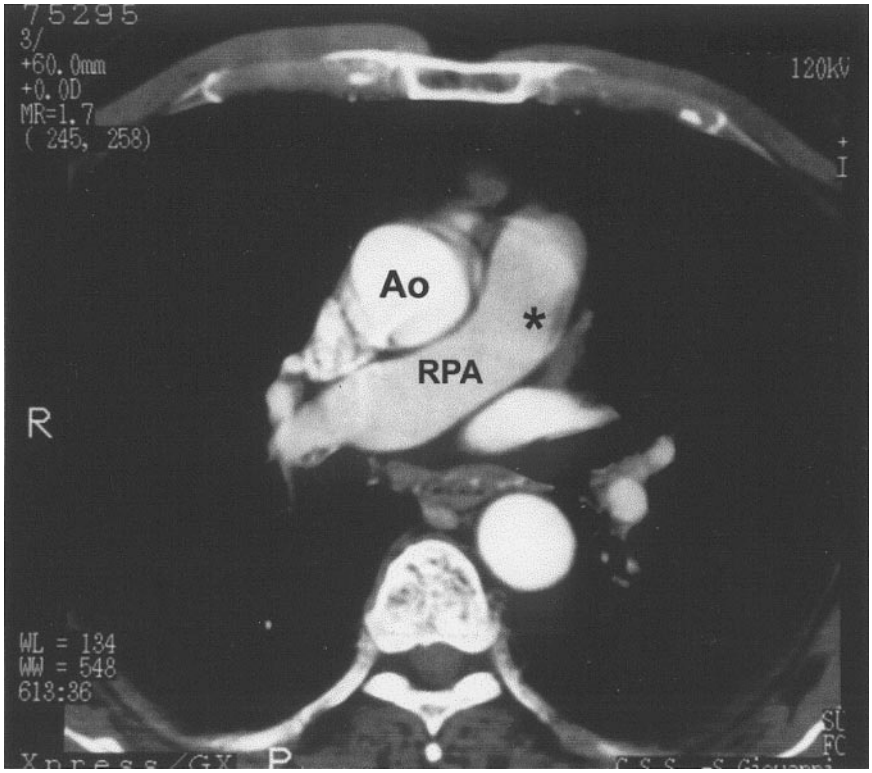

Figure 3. Helical CT scanning in COPD patient with type 2 lesion by TEE presented in Figure 2. A round lesion (*) is evident totally adherent to right pulmonary artery (RPA) wall. Ao indicates aortic root.

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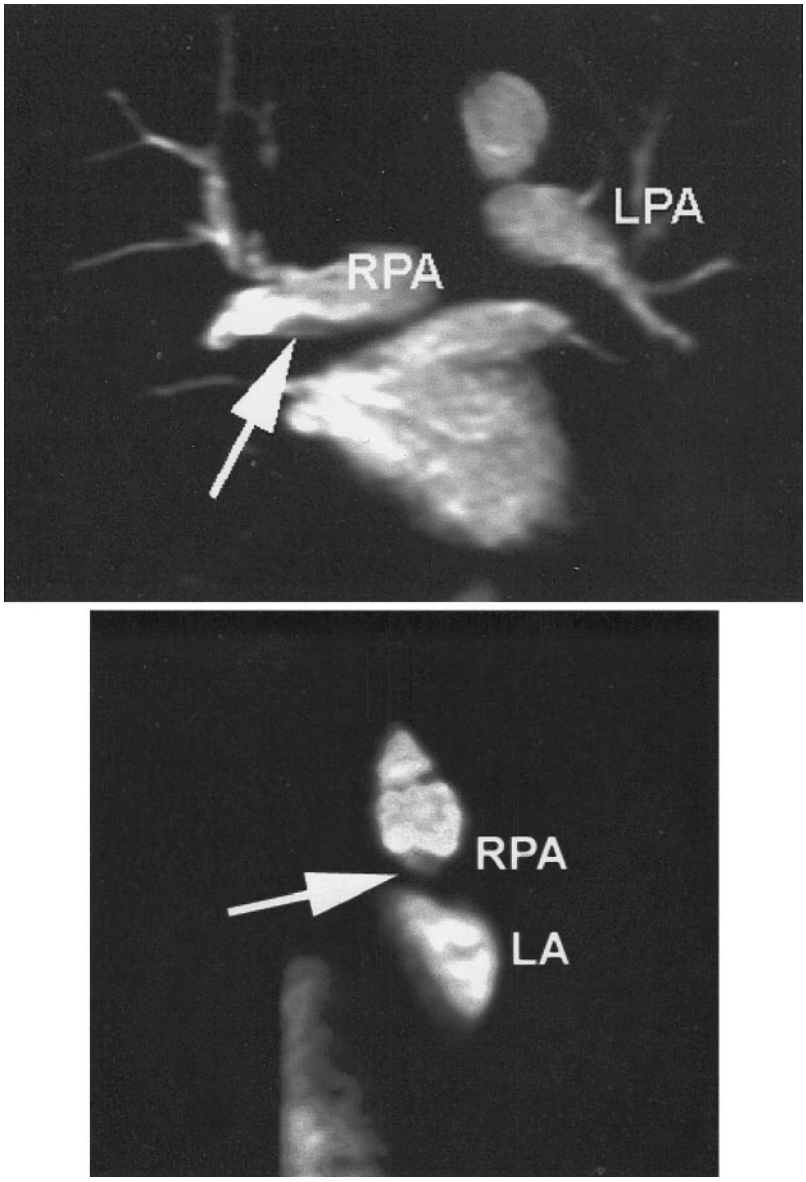

Figure 4. MR angiography after Gd-DTPA bolus intravenous injection in a COPD patient with type 2 lesion by TEE. An abnormality (arrow) stratified on inferior wall of main branch of right pulmonary artery (RPA) is visible in both coronal (top) and sagittal (bottom) planes. LA indicates left atrium; LPA, left pulmonary artery.

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were totally adherent to the right pulmonary artery wall (type 2 lesions). CPA lesions were remarkably frequent in COPD patients in comparison with the low prevalence (7.4%) in cardiac patients.

These findings in COPD patients can be explained by silent thromboembolism, in situ thrombosis, or pulmonary atherosclerosis. The first mechanism is convincing only for type 1 CPA lesions. These lesions, in fact, were morphologically similar to typical thromboembolism except for their modest motility and absence of obstruction.[1–12] The localization of type 2 CPA lesions in the right pulmonary artery may be in favor of thromboembolism, because the right branch is prone to receive emboli for flow continuity with the pulmonary trunk.[5] Conversely, they were morphologically different from thromboembolism. Moreover, silent thromboembolism is rare, being described only in patients with prolonged immobilization from bed rest, recent major surgery, severe congestive heart failure, intubation, etc,[16] a clinical context different from that of our study patients, who did not have recent or worsening dyspnea or peripheral vein thrombosis. Thus, although we did not perform pulmonary scintigraphy or lung and abdominal CT scans as a protocol, we judge silent thromboembolism to be an unlikely pathogenetic mechanism because of the high prevalence of CPA lesions and their peculiar occurrence in stable COPD patients.

Type 2 CPA lesions may be more appropriately explained by in situ thrombosis or, alternatively, by wall thickening with superimposed atherosclerotic debris. In fact, pulmonary arteries often develop thrombosis or wall hypertrophy in response to injury.[23–25] Thrombotic lesions are common in the peripheral nonelastic pulmonary arteries of patients with pulmonary hypertension.[26–28] Similar lesions have also been detected in the central elastic pulmonary arteries of a few patients with primary pulmonary hypertension and were considered to be engrafted on intimal injury caused by prolonged exposure to high blood pressure.[15] However, atherosclerosis also may develop in the presence of increased pulmonary flow or pressure.[24,25] A definitive distinction

TABLE 4. Clinical and Echocardiographic Data in COPD Patients With and Without Pulmonary Artery Lesions

	With Lesions (n=12)	Without Lesions (n=13)	P
Age, y	71±6	66±7	NS
Male, %	100	85	NS
Atrial fibrillation, %	17	16	NS
Hematocrit, %	41±8	45±6	NS
Pa_{O_2}, mm Hg	64±7	61±11	NS
FEV_1/FVC, %	55±14	49±11	NS
RV/TLC, %	53±5	51±5	NS
PASP,* mm Hg	49±18	38±18	NS
Main pulmonary artery diameter, mm	27±7	22±4	<0.05
Right pulmonary artery diameter, mm	22±6	16±6	<0.05
Left pulmonary artery diameter,† mm	22±6	16±7	NS

*Only patients with tricuspid regurgitation at continuous-wave Doppler.

†The left pulmonary artery was visualized in 8 patients with lesions (67%) and 11 without (85%).

between layered in situ thrombus and atheroma is probably very difficult by available techniques, including intravascular ultrasound.[29] Helical CT scans and MR angiography were available in some of our COPD patients with CPA lesions. The presence of some CPA abnormality was in most cases confirmed by both CT and MR angiography, but the lesions were less evident by these techniques than by TEE. Most importantly, also at CT and at MR angiography, CPA type 2 lesions appeared to be different from typical pulmonary thrombotic lesions. Rather, they showed some morphological similarities with the atherosclerotic lesions of the aorta.[30] Consequently, even in the absence of firm anatomic confirmation, we suggest that TEE type 2 lesions may actually represent CPA atherosclerosis.

We never found lesions within the left pulmonary artery. However, having imaged this artery only proximally and only in 76% of COPD patients, we could not exclude a more distal localization of lesions in it. It is possible, then, that CPA lesions are more frequent in COPD patients than found in this study.

CPA lesions were rare in our control patients with left heart disease, although PASP was not lower in them than in COPD patients. In particular, the 2 patients with mitral valve stenosis showing CPA lesions (1 of type 1 and the other of type 2) had only mild pulmonary hypertension. Our data then suggest that at least type 2 CPA lesions may be peculiar to COPD. However, more data are necessary to determine their exact prevalence in various cardiac diseases.

When we compared PASP, FEV_1/FVC ratio, RV/TLC ratio, Pa_{O_2}, and the right atrial and ventricular size in COPD patients with and without CPA lesions, no significant differences were found. CPA lesions were not closely related to the degree of pulmonary dysfunction or to PASP, as assessed at the time of the study. We emphasize that CPA lesions were also present in some patients with mild ventilatory obstruction and without significant pulmonary hypertension. The only parameter separating COPD patients with and without CPA lesions was the size of the main and the right pulmonary arteries, which was greater in the former group. It remains to be determined whether dilatation, either primary or secondary to reversible pulmonary hypertension, may predispose CPA to development of shear-related wall lesions. The absence of a relation in our patients between the degree of pulmonary hypertension and the severity of airflow obstruction, which was in general not severe, may be explained in part by lung hyperinflation: in fact, some of our patients with elevated PASP estimates but only moderate airflow obstruction showed disproportionate increase in the RV/TLC ratio, indicative of significant air trapping. In these patients, however, unsuspected chronic thromboembolic pulmonary vascular disease with extensive downstream vascular obstruction could not be definitively excluded.

It can be hypothesized that coagulation disorders and endothelial dysfunction may also promote in situ thrombosis or atherosclerosis within CPA in COPD patients. The only pertinent parameter assessed in our study was the hematocrit, which was not different in COPD patients with and without CPA lesions. However, platelet functions[31] or hemocoagulative parameters, including prothrombin F_{1+2} fragment and fibrinogen plasma levels,[20] may be more relevant and warrant further studies.

Conclusions

Our findings may have some clinical implications. In the absence of thromboembolism arising from peripheral veins, unexplained acute respiratory failure might be attributed in some COPD patients to distal migration of atherothrombotic material from the great pulmonary arteries. Moreover, the progressive growth of CPA lesions might contribute to further increase in pulmonary artery pressure, with possible therapeutic implications, such as long-term anticoagulation. Further studies in large populations are necessary, however, to confirm our TEE findings in obstructive and nonobstructive forms of chronic pulmonary disease and to understand their mechanisms.

References

1. Wittlich N, Erbel R, Eichler A, Schuster S, Jakob H, Iversen S, Oelert H, Meyer J. Detection of central pulmonary artery thromboemboli by transesophageal echocardiography in patients with severe pulmonary embolism. *J Am Soc Echocardiogr*. 1992;5:515–524.
2. Lengyel M. The role of transesophageal echocardiography in the management of patients with acute and chronic pulmonary thromboembolism. *Echocardiography*. 1995;12:359–366.
3. Klein AL, Stewart WC, Cosgrove DM, Mick MJ, Salcedo E. Visualization of acute pulmonary emboli by transesophageal echocardiography. *J Am Soc Echocardiogr*. 1990;3:412–415.
4. Barton CW, Eisenberg MJ, Schiller N. Transesophageal echocardiographic diagnosis of massive pulmonary embolism during cardiopulmonary resuscitation. *Am Heart J*. 1994;127:1639–1642.
5. Fishel RS, Merlino JD, Felner JM. Diagnosis of main-stem pulmonary thromboemboli by transesophageal echocardiography. *Echocardiography*. 1994;11:189–195.
6. Pruszczyk P, Torbicki A, Kuch-Wocial A, Chlebus M, Miökiewicz ZC, Jedrusik P. Transesophageal echocardiography for definitive diagnosis of haemodynamically significant pulmonary embolism. *Eur Heart J*. 1995; 16:534–538.
7. Torbicki A, Pacho R, Jedrusik P, Pruszczyk P. Noninvasive diagnosis and treatment of a saddle pulmonary embolism. *Chest*. 1996;109:1124–1126.
8. Rittoo D, Sutherland GR, Samuel L, Flapan AD, Shaw TRD. Role of transesophageal echocardiography in diagnosis and management of

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central pulmonary artery thromboembolism. *Am J Cardiol*. 1993;71: 1115–1118.
9. Rittoo D, Sutherland GR. Acute pulmonary artery thromboembolism treated with thrombolysis: diagnostic and monitoring uses of transesophageal echocardiography. *Br Heart J*. 1993;69:457–459.
10. Chan RKM, Johns JA, Calafiore P. Clinical implications of the morphological features of central pulmonary artery thromboemboli shown by transesophageal echocardiography. *Br Heart J*. 1994;72:58–62.
11. Neökovic AN, Popovic AD, Babic R, Otasevic P, Bojic M. Color Doppler transesophageal echocardiography in detection of massive pulmonary embolism. *Echocardiography*. 1996;13:631–633.
12. Cerel A, Burger AJ. The diagnosis of a pulmonary artery thrombus by transesophageal echocardiography. *Chest*. 1993;103:944–945.
13. American College of Chest Physicians Consensus Committee on Pulmonary Embolism. Opinions regarding diagnosis and management of venous thromboembolic disease. *Chest*. 1996;109:233–237.
14. Goldhaber SZ, Morpurgo M, for the WHO/ISFC Task Force on Pulmonary Embolism. Diagnosis, treatment and prevention of pulmonary embolism. *JAMA*. 1992;268:1727–1733.
15. Moser KM, Fedullo PF, Finkbeiner WE, Golden J. Do patients with primary pulmonary hypertension develop extensive central thrombi? *Circulation*. 1995;91:741–745.
16. Patel JJ, Chandrasekaran K, Maniet AR, Ross JJ, Weiss RL, Guidotti JA. Impact of the incidental diagnosis of clinically unsuspected central pulmonary artery thromboembolism in treatment of critically ill patients. *Chest*. 1994;105:986–990.
17. Mitchell RS, Silvers GW, Dart GA, Petty TL, Vincent TN, Ryan SF, Filley GF. Clinical and morphologic correlations in chronic airway obstruction. *Am Rev Respir Dis*. 1968;97:54–62.
18. Burghuber OC, Hartter E, Punzengruber C, Weissel M, Woloszczuk W. Human atrial natriuretic peptide secretion in precapillary pulmonary hypertension. *Chest*. 1988;93:31–37.
19. Miguéres M, Escamilla R, Coca F, Didier A, Krempf M. Pulsed Doppler echocardiography in the diagnosis of pulmonary hypertension in COPD. *Chest*. 1990;98:280–285.
20. Alessandri C, Basili S, Violi F, Ferroni P, Gazzaniga PP, Cordova C, COBH Group. Hypercoagulability state in patients with chronic obstructive pulmonary disease. *Thromb Haemost*. 1994;72:343–346.
21. Evangelista A, Garcia-del-Castillo H, Gonzalez-Alujas T, Dominguez-Oronoz R, Salas A, Permanyer-Miralda G, Soler-Soler J. Diagnosis of ascending aortic dissection by transesophageal echocardiography: utility of M-mode in recognizing artifacts. *J Am Coll Cardiol*. 1996;27:102–107.
22. Ingram RH. Chronic bronchitis, emphysema, and airways obstruction. In: Isselbacher KJ, et al, eds. *Harrison's Principles of Internal Medicine*. 13th ed. New York, NY: McGraw-Hill; 1994; 2:1197–1206.
23. Chaouat A, Weitzenblum E, Higenbottam T. The role of thrombosis in severe pulmonary hypertension. *Eur Respir J*. 1996;9:356–363.
24. Heath D, Wood EH, DuShane JW, Edwards JE. The relation of age and blood pressure to atheroma in the pulmonary arteries and thoracic aorta in congenital heart disease. *Lab Invest*. 1960;9:259–272.
25. Langleben D. Atherosclerosis and the lung. *Can J Cardiol*. 1990;6:VI.
26. Wagenvoort CA, Mulder PGH. Thrombotic lesions in primary plexogenic arteriopathy. *Chest*. 1993;103:844–849.
27. Wagenvoort CA. Lung biopsy specimens in the evaluation of pulmonary vascular disease. *Chest*. 1980;77:614–625.
28. Moser KM, Bloor CM. Pulmonary vascular lesions occurring in patients with chronic major vessel thromboembolic pulmonary hypertension. *Chest*. 1993;103:685–692.
29. Kravitz KD, Scharf GR, Chandrasekaran K. In vivo diagnosis of pulmonary atherosclerosis. *Chest*. 1994;106:632–634.
30. Summers RM, Andrasko-Bourgeois J, Feuerstein IM, Hill SC, Jones EC, Busse MK, Wise B, Bove Ke, Rishforth Ba, Tucker E, Spray TL, Hoeg JM. Evaluation of aortic root by MRI: insights from patients with homozygous familial hypercholesterolemia. *Circulation*. 1998;98: 509–518.
31. Christman BW, McPherson CD, Newman JH, King GA, Bernard GR, Groves BM, Loyd JE. An imbalance between the excretion of thromboxane and prostacyclin metabolites in pulmonary hypertension. *N Engl J Med*. 1992;327:70–75.

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