The Vd for theophylline was 22.2 L on the nondialysis day and was treated as a constant during hemodialysis. According to equation 5, (Kd = CLd/Vd), this information leads to the interpretation that hemodialysis will clear 32 percent (Kd = 0.32/h) of the body store of theophylline per hour. After a continuous 4-h hemodialysis, 79 percent of the body store of theophylline will be cleared.

Total body clearance (164 ml/min) during hemodialysis equals total body clearance of the nondialysis day (45 ml/min) plus dialysis clearance (119 ml/min). According to equation 6, the half-life of theophylline during hemodialysis was reduced to 1.6 h.

**DISCUSSION**

Numerous factors affect the removal (or dialysis) of a drug in hemodialysis, including (a) the physicochemical properties of the drug, eg, molecular weight and water solubility; (b) the mechanical properties of the dialysis system, eg, surface area, porosity, and thickness of the dialyzer membrane; (c) monitoring factors, eg, blood flow and dialysate flow; (d) pharmacokinetic factors, eg, volume of distribution, inherent metabolic clearance, and protein binding.

The effect of hemodialysis on theophylline clearance has been studied by several investigators, and the average hemodialysis clearance ranged from 32.8 to 99 ml/min. In this study, hemodialysis clearance of theophylline was 119 ml/min. The variability observed in dialysis clearance could be related to different blood flow rates (300 ml/min in this study, as compared with 100 to 200 ml/min in previous studies), dialysate flow rates, and the different dialyzer used.

In agreement with previous reports, hemodialysis significantly shortened the elimination half-life of theophylline from 5.7 to 1.6 h. Comparing with 28 to 53 percent removal in the report of Kradjan et al., 79 percent of the drug in the body was removed during a 4-h dialysis in this study. For the patient in this study, 79 percent of the loading dose of theophylline should be added at the onset of dialysis to maintain the serum theophylline level, and aminophylline (Phyllocontin, 450 mg bid) was continued on the nondialysis as well as dialysis days.

Nevertheless, hemodialysis clearance of theophylline varies substantially and may be dependent on the dialysis system, especially the different blood flow rates and different dialyzers used. Patients on hemodialysis who are receiving theophylline should be carefully monitored for exacerbations of bronchospasm during and after the hemodialysis procedure. In addition, serum levels should be obtained to facilitate possible dosage increases that may be required.

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**Imaging of Multiple Coronary Artery Fistulas to Right Ventricle by Transthoracic and Transesophageal Echocardiography**

Chi-Tai Kuo, M.D.; Cheng-Wen Chang, M.D., F.C.C.P.; Ming-Shyan Chern, M.D.; Ying-Shiung Lee, M.D., F.C.C.P.; and Chau-Hsiung Chang, M.D., F.C.C.P.

A 20-year-old woman presented with extremely rare multiple coronary artery fistulas with left circumflex and right coronary arteries as the feeding vessels and two distinct sites of drainage into the posterior wall of the right ventricle near the apex in close proximity. The larger left fistula was well depicted by transthoracic echocardiography, whereas the transesophageal approach better delineated part of the smaller right fistula.

(Chest 1992; 102:1623-25)

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Experience with different patterns of coronary artery fistula (CAF) examined by both the transthoracic and transesophageal two-dimensional echocardiography (TTE)

*From the Section of Cardiology, Department of Internal Medicine, and the Section of Cardiovascular Surgery, Department of Surgery, Chang Gung Memorial Hospital, Taipei, Taiwan.

†Section of Cardiovascular Surgery.

Reprint requests: Dr. Kuo, 159 Ting-Hua N. Road, Chang Gung Memorial Hospital, Taipei, Taiwan, ROC 10582
and TEE, respectively) has been extremely limited.\(^1,\)\(^2\) Herein we present a unique case of multiple unconnected CAFs examined by both diagnostic modalities.

**CASE REPORT**

A 20-year-old woman was referred for evaluation of a cardiac murmur and an episode of infective endocarditis. On admission, her blood pressure was 130/60 mm Hg. The pulse rate was 72 beats per minute and regular. A grade 4/6 to-and-fro murmur was heard over the left lower sternal border. On the chest roentgenogram, mild cardiomegaly was present, with slightly increased lung markings. An electrocardiogram revealed left ventricular hypertrophy by voltage criteria. The standard TTE was performed using an echocardiograph (Hewlett-Packard Sonos 1000) with a 2.5-MHz transducer. The left ventricular dimension at the end of diastole was 54 mm (normal, 36 to 52 mm) and that at the end of systole was 35 mm (normal, 20 to 36 mm), with an ejection fraction of 69 percent. Two-dimensional echocardiography with color Doppler examination revealed a large CAF arising from the left main coronary artery, taking the route of the left circumflex artery and draining into the right ventricular inflow near the apex via the posterior wall (Fig 1). Continuous-wave Doppler echocardiography revealed a continuous jet with a peak velocity of 4 m/s at the drainage site, equivalent to a peak pressure gradient of 64 mm Hg. Also, a mildly dilated tortuous proximal right coronary artery was noted and could represent another CAF. On the modified four-chamber view, a cross-section of a tubular-like structure was noted along the right atrioventricular groove. No abnormal Doppler color flow could be visualized in this structure and the previously mentioned proximal right coronary artery. Color Doppler examination revealed normal flow patterns within the right atrium, pulmonary artery, and left ventricle, thus excluding these chambers as the drainage site of the fistulas. We are not sure if there is a second fistula draining into the neighborhood of the right ventricular apex by any means from the TTE examinations.

Transesophageal echocardiography was performed by use of the same system, with a 5-MHz transducer. The left main coronary artery was noted to be markedly dilated, with an abnormal mosaic pattern flowing away from the transducer demonstrated by color Doppler imaging; however, the entire picture of the left CAF could not be outlined clearly. On the other hand, a second tubular-like CAF was clearly demonstrated along the lateral aspect of the right atrium. Color Doppler imaging did not reveal abnormal flow in this CAF (Fig 2). The cine-spectrogram revealed two distinct fistulas (Fig 3): (1) a large left CAF (left main-left circumflex) to right ventricle; and (2) another smaller right CAF (right coronary) to right ventricle. The drainage sites were nearly contiguous, only 0.5 cm apart, at the posterior wall of the right ventricle near the apex. The Qp/Qs ratio was 2.0. Surgical findings confirmed the presence of two CAFs draining separately into the posterior wall of the right ventricle just distal to the insertions of papillary muscles. Two drainage sites were closed from within the right ventricle.

**DISCUSSION**

A patient was described in whom a larger left CAF was well outlined by TTE, with or without color Doppler imaging,\(^3,\)\(^4\) which also suggested the presence of a second

![Figure 1. Transsthoracic echocardiogram of parasternal short-axis view at ventricular level, showing abnormal mosaic pattern in left circumflex CAF flowing via posterior interventricular groove toward inflow of right ventricle (RV) near apex. F, fistula; and LV, left ventricle.](image1)

![Figure 2. Transesophageal echocardiogram of basal short-axis view at right ventricular inflow clearly demonstrating right CAF along lateral aspect of right atrium (RA) without abnormal Doppler color flow. CS, coronary sinus; F, fistula; and RV, right ventricle.](image2)

![Figure 3. Cine-spectrogram in 30° left anterior oblique view, revealing two distinct CAFs: (1) large left main coronary artery-left circumflex artery-right ventricle fistula and (2) another smaller right coronary artery-right ventricle fistula. Both drainage sites were nearly contiguous at posterior wall of right ventricle (RV) near apex. AO, aorta; F, fistula; LCA, left coronary artery; and RCA, right coronary artery.](image3)
smaller right CAF. Color Doppler imaging enhanced the findings of the left CAF by simultaneously displaying blood flow in the fistulous tract and the right ventricle. Although we were able to visualize the proximal dilated right coronary artery by TTE, no abnormal flow pattern could be obtained with the Doppler technique. Technical difficulties with resolution, gain settings, angulation of the jet flow, failure to image the vessel in the moving heart, and absence of adequate acoustic windows are some of the problems that have been encountered in the TTE examinations.3

In this regard, our case study illustrates enhanced identification of the smaller right CAF by TEE. Because of better resolution and fewer impediments to ultrasound transmission, TEE appreciably complements the TTE examination, particularly the atria, atrial septum, or atrioventricular valves.4 In the literature,1,4 TEE was shown to better define the complete course of the fistula and to map the flow than TTE in two cases with the drainage site in the right atrium. Hence, it did not appear surprising that TEE demonstrated the right CAF at the lateral aspect of the right atrium better than TTE did, although TEE also failed to depict the drainage site in the right ventricle.

Transthoracic echocardiography with color Doppler imaging still could not reveal an abnormal jet in the right fistula, presumably because the flow was perpendicular to the ultrasound beam. The limited utility of TEE in evaluating a left circumflex coronary artery-right ventricle fistula is well demonstrated in this patient. Monoplanar TEE is limited in the scanning plane and also has difficulty in imaging extreme anterior or posterior structures.5 In this case study the drainage sites of both fistulas were in the posterior wall of the right ventricle distal to the insertions of both papillary muscles, quite close to the apex, which is extremely anterior in location. No wonder that TEE could not define the drainage sites clearly.

In fact, TEE and TTE are complementary to each other, rather than competitive. Further studies with different patterns of CAF examined by both TTE and TEE should be extended before we can draw more definite conclusions in terms of relative merits and limitations of these two diagnostic modalities.

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Positive Pressure Mechanical Ventilation Augments Left Ventricular Function in Acute Mitral Regurgitation*

Shaun E. Wright, M.D.; and John E. Heffner, M.D., F.C.C.P.

Although inconclusively established, positive pressure ventilation may augment cardiac function in congestive cardiomyopathies. We report a patient with acute mitral regurgitation who experienced enhanced myocardial performance and resolution of large pulmonary artery v waves during mechanical ventilation. This observation supports the existence of a cardiac booster effect from positive pressure ventilation. (Chest 1992; 102:1625-27)

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Although usually associated with reduction of cardiac output, positive pressure ventilation in patients with depressed left ventricular function and volume overload may augment cardiac performance and improve systemic hemodynamics.1,4 The mechanisms underlying this cardiac “booster” effect of mechanical ventilation, however, remain controversial.3 We report a patient with a myocardial infarction and acute mitral insufficiency who required positive pressure ventilation for the management of pulmonary edema. The presence of large v waves noted with pulmonary capillary wedge pressure (PCWP) monitoring and the patient's sudden self-extubation provided a unique opportunity to observe the effects of positive pressure ventilation on left ventricular function.

CASE REPORT

A 78-year-old man with chronic atrial fibrillation and hypertension was admitted to the hospital because of chest pain and electrocardiographic evidence of an acute, lateral wall myocardial infarction. Lung fields were clear to auscultation and a grade 1/6 murmur of mitral regurgitation was heard. A chest roentgenogram showed cardiomegaly and mild pulmonary edema. The pain responded to morphine sulfate, nitroglycerine, and labetalol. On the second hospital day, myocardial fractions of creatinine phosphokinase were elevated (11.7 percent of 2,305 IU/L). An echocardiogram confirmed moderate to severe mitral insufficiency, left atrial enlargement, and left ventricular wall hypokinesia. Captopril therapy, 6.25 mg every 8 h by mouth, was started.

On the third day, progressive dyspnea and hypoxia (PaO2 of 77 mm Hg on 100 percent face mask O2) developed. A chest roentgenogram revealed worsening pulmonary edema, and a repeat echocardiogram demonstrated severely impaired lateral wall motion, reduced ejection fraction, and severe mitral insufficiency. Treatment with intravenous diuretics, nitroprusside (6.3 µg/kg/min), and dopamine (5 µg/kg/min) was begun after discontinuation of treatment with oral nitrates and labetalol. Placement of a flow-directed pulmonary artery catheter on the fourth hospital day revealed a central venous pressure of 10 mm Hg, PCWP of 21 mm Hg, and pulmonary artery v waves measuring 55 mm Hg (Fig 1, upper).

*From the Department of Medicine, St. Joseph’s Hospital and Medical Center, Phoenix.

Brer requests: Dr. Heffner, St. Joseph’s Hospital and Medical Center, Phoenix 85001-2071

CO = cardiac output; PCWP = pulmonary capillary wedge pressure; PEEP = positive end-expiratory pressure