operation as a result of chronic cardiac failure. In the meantime the second step of total cavopulmonary connection was successfully performed in the four patients who had a bidirectional Glenn anastomosis. These four patients and the remaining seven patients (11/13 = 85%) are clinically well at a mean follow-up of 2.2 years (1.3 to 3.5 years). Although this study was not designed to assess clinical outcome, we believe that inhaled nitric oxide may have positively influenced the early postoperative course in this high-risk cohort.

Despite normal preoperative pulmonary vascular resistance, some patients have a transient elevation of pulmonary vascular resistance in the early postoperative period after Fontan operations. This elevation is caused by pulmonary endothelial dysfunction after cardiopulmonary bypass³ or pulmonary vasoconstriction induced by hypoxia or acidosis. In our study patients, a transient elevation of pulmonary vascular resistance resulting from endothelial pulmonary dysfunction seems likely. Before the start of nitric oxide treatment, all study patients had high central venous pressures (22 ± 0.9 mm Hg, 16 to 25 mm Hg) and transpulmonary pressure gradients (14.2 ± 0.7 mm Hg, 11 to 19 mm Hg) associated with severe hemodynamic compromise. These conditions were present despite maximal conventional therapy and normal pH and carbon dioxide tension and after excluding cardiac and pulmonary causes of systemic venous hypertension by echocardiography and chest roentgenograms, respectively. After starting nitric oxide treatment, all patients had uniform improvement of hemodynamic condition and oxygenation. Unfortunately, we did not use the data at the start of nitric oxide treatment as baseline values in our study. Thus, on the basis of our study design, we cannot exclude a withdrawal phenomenon that transiently raises pulmonary vascular resistance even after a short exposure of low-dose nitric oxide therapy.

We agree with Dr. Day that appropriate preoperative patient selection has the most important influence on clinical outcome after Fontan operations. The postoperative use of inhaled nitric oxide is not a substitute for treatment of patients in whom the Fontan procedure is inappropriate. We believe that inhaled nitric oxide may rather be an additional therapeutic option in the postoperative management after Fontan operations. In accordance with Goldman and coworkers,⁴ we suggest that in the early postoperative period patients with high central venous pressures or transpulmonary pressure gradients associated with cardiocirculatory compromise should be offered a trial of inhaled nitric oxide after failure of conventional treatment and before considering a Fontan takedown. A trial of inhaled nitric oxide may also be of value to direct further investigations toward anatomic and surgically remediable obstructions of pulmonary blood flow.⁵

However, these initial encouraging results of postoperative inhaled nitric oxide therapy in a small number of patients having either the Fontan or Glenn operation warrant further investigations in a larger cohort of patients. A prospective randomized study may clarify the influence of inhaled nitric oxide on postoperative

morbidity and mortality and long-term outcome, respectively.

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Extravascular aortic clamping for minimally invasive coronary artery bypass surgery

To the Editor:

We read with much interest the brief communication on video-assisted minimally invasive valve surgery by Chitwood and associates.¹ We were particularly interested in the technique of transthoracic aortic crossclamping, which allowed them to perform video-assisted mitral valve replacement under safe and cost-effective conditions. With the intention of performing minimally invasive coronary artery bypass grafting (CABG) on the arrested heart, we developed a technique using peripheral cardiopulmonary bypass (CPB), similar transparietal extravascular aortic crossclamping, and antegrade cardioplegia, with the anastomosis being performed on a decompressed and arrested heart.

The left and/or right internal thoracic artery (LITA or RITA) is first harvested by means of a video-assisted technique.² A left anterior minithoracotomy (2.5 inches long) is made in the fifth intercostal space. The pericardium is opened longitudinally and suspended. The site for the future anastomosis is identified on the coronary arteries. After initiation of peripheral CPB, a purse-string suture is placed in the ascending aorta under thoraco-

scopic vision, and an aortic catheter (Medtronic Inc.) is introduced through it for later antegrade delivery of crystalloid cardioplegic solution. A specially designed transparietal aortic crossclamp is introduced through the port previously used for LITA dissection, the posterior jaw being guided in the transverse sinus under thoracoscopic control. After cardioplegic arrest, the distal anastomoses are performed under direct vision.

Ten consecutive patients (mean age 58.07 ± 13.6 years, range 36 to 77 years) underwent a minimally invasive CABG procedure by means of this technique. Seven patients had stable angina, three had unstable angina, and four patients had previously had a myocardial infarction. On preoperative coronary angiograms, seven patients had isolated stenosis of the left anterior descending coronary artery (LAD) (previous angioplasty in three patients) and three had two-vessel disease. The mean ejection fraction was $47.8\% \pm 15.6\%$ (range 20% to 70%). The operative procedure included nine LITA-LAD grafts and one double LITA-LAD and RITA-right coronary graft through only one incision. One patient underwent a right coronary artery angioplasty 3 days later. The mean aortic cross-clamp time was 22 ± 12.7 minutes (range 12 to 54 minutes) and the mean CPB time was 49.9 ± 30 minutes (range 18 to 114 minutes). The mean duration of assisted ventilation was 17.9 ± 12.9 hours (range 6 to 52 hours) and the mean intensive care unit stay was 26 ± 8 hours (range 12 to 96 hours). In each case, the electrocardiogram remained unchanged and the troponin level stayed within normal limits (2.7 ± 1.5 IU, range 0.9 to 5.2 IU).

Minimally invasive procedures were first developed to allow CABG to be performed through a minithoracotomy on the beating heart without extracorporeal circulation.² However, in the presence of intramyocardial, calcified, small, or inaccessible arteries, anastomoses cannot be safely performed on the beating heart and multiple revascularizations are limited. Another technique linking peripheral CPB and endovascular aortic crossclamping³ was recently proposed, allowing minimally invasive coronary surgery on the vented and arrested heart. Similarly, the endovascular clamp, necessitating fluoroscopic or echographic guidance, creates a potential risk of aortic valve injury and occlusion of the head vessels related to improper placement of the balloon. To our knowledge the technique presented in this letter has not been previously described for CABG. Coronary anastomoses can be performed safely once the heart is decompressed during CPB and cardioplegic arrest. This type of aortic crossclamping and cardioplegia provides myocardial protection similar to that obtained with a conventional approach. Contrary to other reports,⁴ multiple coronary anastomoses are feasible through a single incision without a T-graft technique,² which may compromise the long-term patency of the LITA. The technique is simple, safe, and cost-effective. Results are qualitatively similar to those observed after a conventional approach with the advantages of limited chest wall trauma, limited postoperative bleeding, and improved esthetic appearance.

Peripheral CPB, thoracoscopic extravascular aortic clamping, and cardioplegic arrest may be used safely during mini-CABG. This approach represents an alterna-

Fig. 1. Introduction of the transparietal extravascular aortic clamp through the port previously used for LITA dissection. An aortic catheter is placed under thoracoscopic vision on the ascending aorta for antegrade delivery of cardioplegic solution.

tive either to beating heart procedures or endoaortic occlusion techniques.

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