

22 Heart Transplantation

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I. INTRODUCTION

Orthotopic heart transplantation (OHT) is a proven surgical option for selected patients with advanced heart failure refractory to surgical or medical management and poor short-term prognosis but good indications for long-term survival (1). Transesophageal echocardiography (TEE) plays an important role during the process of heart transplantation. Therefore, a clear understanding of the surgical procedure helps to provide key diagnostic information and

appropriate monitoring parameters before, during and after the procedure. This chapter will review the surgical technique and the role of TEE in the perioperative management of heart transplant patients.

II. DONORS AND RECIPIENTS

The availability of donor organs has led to a plateau of the annual number of heart transplants at 5,000 cases worldwide (2). Broader donor eligibility criteria, to include older donors (> 50 years old), marginal donors and resuscitated hearts, have yet to have a substantial impact on the cardiac donor pool (2,3). Currently older donors (50-60 years old) have increased to account for 12% of all donors (4). A marginal donor heart is defined as an organ that fails to meet one or more of the traditional criteria for an optimal donor (3). Marginal donor hearts may have coronary artery disease, reduced left ventricular ejection fraction (LVEF), left ventricular (LV) hypertrophy, and successful resuscitation after asystole or exposure to high dose inotropes. A structurally normal young heart with LV dysfunction can recover normal function after hemodynamic and metabolic management. This form of donor heart resuscitation involves invasive monitoring to optimize fluid status, arginine vasopressin to maintain a normal systemic vascular resistance (SVR) and intravenous treatment of steroids, insulin and thyroid hormone (3).

Donor ischemic time is defined as the time from aortic cross-clamp at harvest to cross-clamp release following implantation. Donor ischemic time has increased beyond the gold standard of four hours without a significant increase in mortality (5).

Immediately prior to transplantation recipients should have a pulmonary artery catheter (PAC) inserted to assess pulmonary artery (PA) pressures. Elevated PA pressures, whether fixed or reactive, are a risk factor for post-transplant right heart failure and may preclude transplantation (6). General guidelines for unacceptable PA pressures and a relative contraindication to heart transplantation include: a) absolute systolic PA pressure > 60mmHg, b) calculated pulmonary vascular resistance (PVR) > 6 woods or PVR index > 6, c) transpulmonary gradient (TPG) = mean PA pressure - mean pulmonary capillary wedge pressure (PCWP) > 16-20 mmHg (6). A vasodilator challenge using nitroprusside, nitroglycerin or nesiritide and diuretics may lower PA pressures though these patients are still

at higher risk of early mortality (7).

III. SURGICAL CONSIDERATIONS

There are two surgical techniques of OHT currently used in clinical practice: the standard technique originally described by Lower and Shumway in 1966 (8,9) and the bicaval technique described by Dreyfus et al. (10) in 1991.

A. Standard Technique

A standard anesthetic preparation for routine cardiac surgery is performed including the use of a TEE probe for monitoring. The right internal jugular vein is left undisturbed for later use for endomyocardial biopsies. The Swan–Ganz catheter is initially inserted to measure real time RV and PA pressure but is pulled back during surgery. Both groins are prepared for emergency cannulation and initiation of cardiopulmonary bypass (CPB) if needed.

Through a median sternotomy following full systemic heparinization, standard cannulation of the ascending aorta (Ao) and both vena cava is performed. Cardiopulmonary bypass is initiated when the donor heart arrives in the Operating Room (OR). Cross-clamping of the Ao is followed by removal of the recipient's failing heart leaving in place the posterior aspect of the left and right atria (LA, RA), and keeping as much as possible of the recipient's ascending Ao and PA tissue. Mild systemic hypothermia is easily reached and maintained throughout surgery (34°C).

While the cardiectomy is performed, the donor heart is inspected and prepared in a cold bath saline solution. The integrity of the atrial septum is ensured and corrected if, for instance, a foramen ovale is detected. The tricuspid and mitral valve (TV, MV) apparatus are also carefully inspected. Proper ligation of the superior vena cava (SVC) is secured, the right atrial wall is opened from the inferior vena cava (IVC) to the right atrial appendage (RAA) and the LA wall is trimmed and prepared. The ascending Ao and the PA are completely dissected and separated to facilitate proper exposure and suturing approach (Fig. 22.1).

The donor heart is brought into the thoracic cavity and the LA anastomosis is performed first with 3.0 polypropylene continuous sutures. To keep the heart as cold as possible during surgical implantation standard cold blood cardioplegia, at a rate of 100–200

mL/min, is administered retrograde through a coronary sinus catheter in addition to application of ice slush onto the right ventricle (RV) (11). The RA anastomosis (Fig. 22.2) is completed with 3.0 polypropylene sutures, leaving a small gap for the coronary sinus catheter prior to completion of both the PA and aortic anastomoses. Donor and recipient pulmonary arteries are prepared, trimmed and anastomosed with a continuous 4.0 polypropylene suture.

Next, snares on both vena cava are released, the coronary sinus catheter is removed, the operating table is put in the Trendelenburg position and the ascending Ao clamp is released. With gentle massage of the heart, air is evacuated from the LV and the ascending Ao through the suture line via the puncture used to inject the antegrade cardioplegic solution at the donor site. The hole created in the left atrial appendage (LAA) to decompress the LV during the harvest of the donor heart is closed with a 3.0 polypropylene suture.

The patient is weaned from the CPB with a heart rate averaging 100 beats/min achieved by an isoproterenol infusion or atrial pacing and a good cardiac performance with systolic blood pressure (SBP) >90–100 mmHg. Atrial and aortic cannulae are removed while 500 mg of solumedrol is administered and protamine is injected intravenously. The Swan–Ganz catheter is refloated through the PA to monitor cardiac output (CO) and PA pressure. Two chest tubes are inserted in the mediastinum. Temporary pacing wires are sutured onto the RV. The sternum is then closed according to a standard technique.

B. Bicaval Technique

This alternative technique of cardiectomy and anastomoses is now more widely accepted as it minimizes the problems arising from oversized post-transplant atria, such as stasis, spontaneous echo contrast and embolic complications (10). The right aspect of the LA is entered as for a routine MV surgical approach. The incision is extended superiorly under the SVC and inferiorly under the IVC (Fig. 22.3). During excision of the RA, generous portions of the SVC and IVC are left to facilitate donor and recipient anastomoses. The donor LA is anastomosed to the recipient LA as described in the standard method. The IVC and SVC are then anastomosed with 4-0 polypropylene suture. The rest of the procedure continues as described above for the standard approach to OHT.

IV. TRANSESOPHAGEAL ECHOCARDIOGRAPHY IN THE PERIOPERATIVE PERIOD

The intraoperative use of TEE is a Society of Cardiovascular Anesthesiologists (SCA) category 2 indication during OHT (12). The role of TEE is less valuable during the pre-CPB period as the recipient's failing heart is completely removed. Rarely, thrombotic material in the native heart can be mobilized during manipulation and lead to pulmonary embolism (Fig. 22.4). During the CPB weaning process, TEE helps to define the etiology of hemodynamic instability, assess the efficacy of de-airing procedures and confirm the integrity of surgical anastomosis in the post-transplantation period.

Hemodynamic instability after heart transplantation may arise from a single or multiple causes such as primary graft failure, hyperacute rejection, RV dysfunction (Fig. 22.5), hypovolemia, vasodilatation, tamponade, right ventricular outflow tract (RVOT) obstruction (Fig. 22.6) or left ventricular outflow tract (LVOT) obstruction (Fig. 22.7).

Nonspecific graft failure is still the most common cause of death in the early postoperative period (13). Severe systolic dysfunction in the recipient may result from inadequate myocardial protection during the harvesting of the donor heart (role of cardioplegic solution, temperature, and duration of ischemia) and/or during transplantation. In rare instances, hyperacute rejection, rather than insufficient myocardial protection, may be responsible for the heart failure.

Right ventricular failure may occur in the recipient with pre-existing and underestimated pulmonary hypertension (PH) (Fig. 22.5). Registry data from the International Society of Heart and Lung Transplantation show that, despite advances in perioperative management, RV dysfunction accounts for 50% of all cardiac complications and 19% of early death after heart transplantation (2,13,14) (Fig. 22.8). There is approximately a fourfold higher mortality among transplanted patients with fixed PH compared with patients without PH (13). Pulmonary hypertension, defined as a PVR >480 dyne s/cm^5 or 6 Wood units, is currently considered a contraindication to OHT. Patients with marked PH (PVR >640 dyne s/cm^5 or 8 Wood units) should be considered for heart and lung transplantation and, more recently, long term LV assistance followed with transplantation. To date, there have been no reports in the literature of a threshold beyond which donor RV heart failure could occur which would constitute a clear contraindication to heart transplantation. A normal preoperative PVR does

provide some potential protection from acute increase in PVR causing RV failure after heart transplantation.

Organ preservation and CPB may have deleterious effects on ventricular function. Indeed CPB has been shown to cause an increase in PVR (13). Reviews have been published on the management of RV failure after heart transplantation and the role for inhaled nitric oxide (NO) treatment (13,15,16).

Transesophageal echocardiography is also useful to evaluate surgical anastomosis in the post-transplantation period (Fig. 22.9). The main PA anastomosis appears as a suture ridge within the vessels. Stenosis should be ruled out by two-dimensional (2D) color Doppler imaging to detect turbulent flow and by continuous wave (CW) Doppler to measure the systolic gradient across the anastomosis. The PAC can also be used to document any gradient across the RV and the PA (Fig. 22.10) (17). The mid-esophageal long-axis (LAX) or two-chamber views show an elongated LA now composed of both donor and recipient atrial tissue (Fig. 22.11). The suture line within the LA and RA also appears predominantly as an echodense ridge (Fig. 22.9). Acquired cor triatriatum may develop secondary to infolding of the redundant tissue from excessive donor atrial tissue (Fig. 22.7). Anastomoses of both cavae are examined to rule out stenosis.

V. ECHOCARDIOGRAPHY IN THE POSTOPERATIVE PERIOD

The early postoperative changes following heart transplantation include RV remodeling, abnormal septal motion, increase in LV mass, presence of pericardial fluid and abnormal LV and RV filling patterns (Fig. 22.12) (18).

A. Right Ventricular Remodeling, Tricuspid Regurgitation, and Abnormal Movement of the Ventricular Septum

The time course of the resolution of PH and RV remodeling after OHT has been described by Bhatia et al. (19). In 24 patients with moderate PH (mean PA pressure <50 mmHg) after heart transplantation, the PH resolved rapidly, with the mean PA pressure approaching normal values at two weeks after surgery. In parallel, the PVR had returned to normal in 80% of patients by one year. Patients with the highest preoperative PVR had the greatest decrease

after the transplantation (ranging from 10% to 84%). Right and left heart filling pressure also decreased to a nadir in the upper normal range at two weeks after surgery and remained unchanged over one year of follow-up.

The donor RV remodels in response to recipient perioperative PH. Initially enlarged, it dilates further during the first month and subsequently returns to its immediate perioperative dimensions at one year after surgery (Fig. 22.13) (19). The RV wall thickness does not increase significantly probably because the PVR declines to normal level. Thus, at one year, while resting hemodynamics are normal, the donor RV remains enlarged, probably as an adaptation to chronic volume overload.

Tricuspid regurgitation (TR) is common after heart transplantation due to the afterload mismatch and RV dilatation. The incidence of TR (grades 1–3) changes from 67% on day one after heart transplantation to 36% at one year. Nevertheless, TR is generally well tolerated and rarely of clinical significance (19). Finally, abnormal diastolic flattening of the ventricular septum was present in all patients immediately postoperatively (Fig. 22.10). This proportion decreased to 75% at one month and 42% at one year. This decline parallels the decrease in TR and RV dimensions. On the other hand, systolic paradoxical septal motion was uncommon, probably because the mean PA pressure decreases significantly immediately after OHT (19).

B. Left Ventricular Mass and Mitral Valve Function

In the immediate postoperative period, both LV wall thickness and mass increase, most likely from perioperative myocardial ischemia and edema. Systemic hypertension and side effects from cyclosporine and corticosteroid administration can further contribute to LV mass augmentation seen at one year. Acute increase in myocardial thickness may also occur later with allograft rejection (Fig. 22.8) (20). Left ventricular contractility and contractile reserve both appear to be normal after heart transplantation (21).

Mild to moderate mitral regurgitation (MR) has been reported to occur with a frequency ranging from 55% to 87% without major clinical implications (19,22). It usually occurs in a donor heart without structural abnormality of the mitral apparatus or LV dysfunction. The MR may arise from biatrial enlargement which exerts tension on the

posterior MV leaflet and causes incomplete closure of the valve and annuloventricular disproportion (19). Moreover, the presence of both donor and recipient atria and sinus nodes results in asynchrony and inhomogenous atrial contraction, which may also play a role in the genesis of MR (19). Finally, MR can occur in association with LVOT obstruction.

C. Pericardial Effusion

Pericardial effusions are commonly observed in 85% of patients after heart transplantation (23). The loss of lymphatic drainage and the discrepancy in size between the new donor heart and the large remaining pericardial cavity are plausible explanations (20). Even though pericardial effusions are common, rarely do they precipitate hemodynamic instability, such as cardiac tamponade. While large but slowly accumulating pericardial effusions usually cause little hemodynamic impairment, a loculated hematoma developing at a critical location may conversely cause acute cardiac tamponade (see Chapter 12). Thus, the relationship between the size of the effusion and the clinical outcome is likely to show a poor correlation (20). Most effusions are nearly, or completely, resolved by 30 days after surgery (23).

D. Left Ventricular Diastolic Function

Diastolic function is also altered in the heart transplant recipient (in the absence of rejection) during the early postoperative period. Initial pulsed wave (PW) Doppler examination of the mitral inflow shows a profile comparable to previously defined restrictive parameters (see Chapter 10); this evolves into a non-restrictive pattern over a six week period leading to progressive improvement in postoperative diastolic function parameters and decrease in left heart filling pressures (24). The presence of recurrent or persistent severe diastolic dysfunction with restrictive filling within six months after transplantation is associated with a reduced late-term actuarial survival, independent of graft rejection (25).

Evidence suggests that retaining normal LA size and shape by using the bicaval technique promotes ventricular filling dynamics which more closely approximates normal physiology (20). Ventricular filling is influenced by the mechanical activity of residual recipient atrial tissue over that of the donor heart. In addition, "parasystolic" contraction of residual recipient atrial tissue also modifies the pulmonary venous flow (PVF): recipient atrial

contraction occurring in late systole results in an increase in the diastolic component (D-wave); if it happens in early systole the systolic component (S-wave) is decreased. End-diastolic atrial contraction will increase the velocity observed during atrial reversal (AR) (18).

E. Normal Echocardiographic Profile after Heart Transplantation

One year after OHT, echocardiograms of recipients doing clinically well are characterized by increased LV wall thickness and mass. Left ventricular dimensions, volumes and ejection fraction are within normal limits. Right ventricular wall thickness and cavity size are increased with preserved RV systolic function. The transplanted heart also shows an anteromedial translational motion during systole. The atria of the transplanted heart have unique echocardiographic features. The anastomotic suture line is easily identified on 2D imaging as the waist of these hourglass-shaped atria (Fig. 22.11). This waist creates a natural point of subdivision within the native and donor atria. The markedly enlarged atrial volume results primarily from an increased LAX dimension (Fig. 22.11), although maximal width or short-axis dimension is also slightly larger than in controls (26). The increase in both donor and recipient atrial size is inversely correlated with survival (27).

F. Abnormal Echocardiographic Findings Following Heart Transplantation

The presence of the atrial suture line, increased atrial size with subcontractile portion of the recipient atrium and asynchrony between the donor and recipient atria contraction, promotes stasis. These factors may account for the high prevalence of atrial spontaneous echo contrast (55%) as assessed with TEE (28). Left atrial thrombi were observed in 38% by TEE and are often missed by transthoracic echocardiography (TTE). Thrombi were located in the donor LAA (10/18), on the posterior wall of the LA (6/18), on the donor component of the atrial septum (1/18) and on the left atrial suture (1/18) (28). Thrombi occurred only in patients displaying spontaneous echocardiographic contrast (Fig. 22.14). Episodes of arterial embolism were documented in 22 % of patients with both spontaneous echocardiographic contrast and LA thrombus (6% of heart transplantation recipients) (28). The use of the modified bicaval OHT technique seems to decrease the incidence of this problem considerably (29).

Transesophageal echocardiography has also been found to be superior to TTE in demonstrating thickening of the atrial septum, bulging of the recipient and donor atrial septum, and shunt at the atrial level (28). It may identify uncommon patent foramen ovale after heart transplantation (30). Coronary fistula is another finding detected by TEE after heart transplantation. The incidence of this iatrogenic complication has been estimated between 5% and 15%, a 20-fold increase over the incidence of congenital coronary artery fistula (31). The increased incidence in this group is attributed to injury from multiple routine surveillance RV endomyocardial biopsy procedures for detection of cardiac rejection, which frequently involves the right coronary artery (RCA). The vast majority of these fistulas communicate directly with the RV, are usually diagnosed by routine coronary angiography and are without hemodynamic significance (31). Finally pseudoaneurysm can occur after cardiac transplantation at any site of major vessel anastomosis (Fig. 22.11).

G. Detection of Acute Allograft Rejection and Coronary Artery Disease

Acute allograft rejection is common, particularly in the first year after transplantation. It constitutes the most frequent cause of death during this period. Morphologic features suggestive of allograft rejection include an increase in myocardial mass due to inflammatory cell infiltration and myocardial edema (Fig. 22.8) (Table 22.1). However, with the addition of cyclosporine to the immunosuppressive medical regimen, cellular rejection is associated with less myocardial edema: the evaluation of ventricular systolic function and myocardial mass has thus become obsolete as a means of detecting early rejection. Doppler parameters of diastolic function have recently been used to detect acute rejection (Table 22.2). It appears that moderate to severe rejection leads to a fall of at least 15% in the mitral deceleration or the isovolemic relaxation time. However, wide inter-patient variability in Doppler variables renders isolated measurement cut-offs less predictive. Each patient acting as her/his own control (from baseline) provides the basis for Doppler-based surveillance of allograft rejection. Currently, Doppler-derived parameters of diastolic function are used as an adjunct rather than a replacement for endomyocardial biopsy. Protocols now combine routine biopsies, with supplemental biopsy in the event of echocardiographic evidence of acutely restrictive physiology (20).

In patients who survive the first two years of transplantation, coronary artery disease (CAD) constitutes an important cause of mortality. There is increasing interest in the ability of dobutamine stress echocardiography to predict adverse cardiac events in OHT recipients. A normal dobutamine stress echocardiography result is a very powerful determinant of a benign clinical course with a negative predictive value in excess of 90–95% (20).

VI. CONCLUSION

In summary, echocardiography may significantly contribute to the evaluation of patients at various stages of heart transplantation (Table 22.3). During the initial perioperative period, it provides timely assessment of cardiac anatomy and physiology and bestows the opportunity to detect specific problems. Later, detection of allograft rejection and accelerated CAD benefits from the addition of this noninvasive diagnostic tool.

Figure 22.1 Classic biatrial technique of orthotopic heart transplantation.

In this technique, the sites of anastomoses between the donor heart and recipient heart are at the level of the atria (Ao, aorta; IVC, inferior vena cava; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava).

Figure 22.2 Atrial anastomosis.

(A,B) Mid-esophageal four-chamber view in a 37-year-old man after heart transplantation shows the thickened atrial anastomotic ridge. (C) Intraoperative view of the right atrial anastomotic line (LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle). (Courtesy of Dr. Denis Bouchard) 

Figure 22.3 Bicaval technique of orthotopic heart transplantation.

In the bicaval technique, the donor vena cavae are anastomosed to the recipient superior vena cava (SVC) and inferior vena cava (IVC) (Ao, aorta; PA, pulmonary artery; RA, right atrium; RV, right ventricle).

Figure 22.4 Right ventricular thrombus prior to orthotopic heart transplantation (OHT).

Zoomed mid-esophageal right ventricular view at 114 ° (A,B) and a modified four-chamber view (C,D) show a laminated thrombus under the anterior leaflet of the tricuspid valve in a 49-year-old woman prior to OHT (LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle). 

Figure 22.5 Right ventricular failure after orthotopic heart transplantation (OHT).

A dilated hypokinetic right ventricle (RV) after OHT is seen in these mid-esophageal four-chamber (A,B) and transgastric (C,D) views. Note the D-shaped RV on the transgastric view (LA, left atrium; LV, left ventricle; RA, right atrium, TV, tricuspid valve). 

Figure 22.6 Right ventricular outflow tract (RVOT) obstruction after orthotopic heart transplantation (OHT).

(A,B) Mid-esophageal right ventricular inflow/outflow view shows dynamic RVOT obstruction. (C) Systolic obliteration is shown on the corresponding M-mode (Ao, aorta; HR, heart rate; LA, left atrium; LV, left ventricle; MPA, main pulmonary artery; RV, right ventricle). 

Figure 22.7 Atrial anastomosis after orthotopic heart transplantation (OHT).

(A,B) Color Doppler mid-esophageal long-axis view of a 47-year-old man after OHT shows flow acceleration in the left ventricular outflow tract upon weaning from cardiopulmonary bypass. Aliasing was also present at the level of the mitral valve most likely from the compressing effect of the edematous atrial anastomosis. This may simulate cor triatriatum (Ao, aorta; LA, left atrium; LV, left ventricle; RV, right ventricle). 

Figure 22.8 Acute rejection after heart transplantation.

A 50-year-old man died from acute rejection after heart transplantation. The autopsy showed a hypertrophied left ventricle (LV) and a dilated right ventricle (RV) (LAD, left anterior descending). (Courtesy of Dr. Tack Ki Leung)

Figure 22.9 Atrial anastomosis after orthotopic heart transplantation (OHT).

(A-C) Mid-esophageal four-chamber views in a 47-year-old man after OHT show the left atrial anastomotic site is edematous with flow acceleration in the left upper pulmonary vein (LUPV) (Ao, aorta; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle). 

Figure 22.10 Right ventricle after orthotopic heart transplantation (OHT).

(A, B) The transgastric mid short-axis view in a 37-year-old man after OHT shows mild right ventricular dilatation with a prominent moderator band. (C) A 10 mmHg systolic pressure gradient is present between the right ventricular pressure (Prv) and the pulmonary artery pressure (Ppa) (EKG, electrocardiogram; IVS, interventricular septum; LV, left ventricle; Pa, arterial pressure; Pra, right atrial pressure; RV, right ventricle). 

Figure 22.11 Atrial anastomosis after orthotopic heart transplantation (OHT).

Mid-esophageal two-chamber views in a patient with end-stage hypertrophic cardiomyopathy before (A,B) and after OHT (C,D) are shown. Note the left atrial suture anastomosis after the

procedure and the increase in the anteroposterior size of the left atrium (LA) (LAA, left atrial appendage; LV, left ventricle). 

Figure 22.12 Right ventricular diastolic function after orthotopic heart transplantation (OHT).

(A) Hepatic venous flow (HVF) in a 37-year-old man after OHT shows an inverted systolic (S) waveform. The right ventricular pressure (Prv) waveform (B) obtained from the right ventricular pacing port of the pulmonary artery catheter (C) is also abnormal with rapid increase in diastolic pressure consistent with abnormal right ventricular filling (EKG, electrocardiogram; PA, pulmonary artery; PROX, proximal; RV, right ventricle). 

Figure 22.13 Right ventricular function after orthotopic heart transplantation (OHT).

Serial right ventricular echocardiographic measurements after OHT (± 1 SD) are compared with control values ($n = 10$). Shown are right ventricular end-diastolic dimensions (RVEDD in cm^2), right ventricular end-diastolic area (RVEDA in cm^2) and right ventricular wall thickness (RVWT in cm) (Adapted with permission from Bhatia et al. (19)).

Figure 22.14 Superior vena cava (SVC) thrombus.

(A,B) Mid-esophageal bicaval views show a SVC thrombus with reduced flow on color Doppler (C) after heart transplantation (IVC, inferior vena cava; LA, left atrium; RA, right atrium). 

Figure 22.15 Aortic pseudoaneurysm after orthotopic heart transplantation (OHT).

(A,B) Mid-esophageal ascending aorta (Ao) long-axis view shows an aortic pseudoaneurysm in a 65-year-old man which developed nine months after OHT. The pseudoaneurysm was located at the anastomotic site of the native Ao. Blood flow in the pseudoaneurysm was present. (C) Tomographic scan of the pseudoaneurysm with both posterior and anterior extension close to the sternal border (LA, left atrium; RPA, right pulmonary artery; RV, right ventricle). 

Table 22.1 International Society of Heart and Lung Transplant (ISHLT) Standardized Cardiac Biopsy Grading ¹

1990	
Grade 0	No rejection
Grade 1, mild	
A – Focal	Focal perivascular and/or interstitial infiltrate without myocyte damage
B – Diffuse	Diffuse infiltrate without myocyte damage
Grade 2 moderate (focal)	One focus of infiltrate with associated myocyte damage
Grade 3, moderate	
A – Focal	Multifocal infiltrate with myocyte damage
B – Diffuse	Diffuse infiltrate with myocyte damage
Grade 4, severe	Diffuse, polymorphous infiltrate with extensive myocyte damage ± edema, ± hemorrhage + vasculitis
2004	
Grade 0	No rejection
R ²	
Grade 1	Interstitial and/or perivascular infiltrate with up to 1 focus of myocyte damage
R ² , mild	
Grade 2	Two or more foci of infiltrate with associated myocyte damage
R ² , moderate	
Grade 3	Diffuse infiltrate with multifocal myocyte damage ± edema, ± hemorrhage ± vasculitis
R ² , severe	

¹The presence or absence of acute antibody-mediated rejection (AMR) may be recorded as AMR 0 or AMR 1, as required.

²Where "R" denotes revised grade to avoid confusion with 1990 scheme. Reproduced with permission from: Stewart et al. (32)

Table 22.2 Detection of Heart Transplant Rejection by Echocardiographic Indices

Study	Design Number	Criteria Used for Rejection*	Events	Index	Cut-off Value	Se (%)	Sp (%)
Valantine et al. 1991 (33)	Retrospective n = 39 b = 114	≥ 2		PHT IVRT	$\geq 15\% \downarrow$	82 82	79 79
Stork et al. 1991 (34)	Retrospective n = 21	$\geq 3a$	11	PHT IVRT	$\geq 8 \text{ msec} \downarrow$ $\geq 12 \text{ msec} \downarrow$	73 82	80 80
Ciliberto et al. 1994 (35)	Retrospective n = 130 b = 1400	≥ 1		PHT IVRT	$\geq 20 \text{ msec} \downarrow$	44 28	98 98
Mouly-Bandini et al. 1996 (36)	Retrospective n = 23	≥ 1		PHT or IVRT	$\geq 20\% \downarrow$	31	93
Puelo et al. 1998 (37)	Retrospective n = 121	$\geq 3a$	16	Em IVRT PHT	$< 0.16 \text{ m/s}$ -	76	88
Stengel et al. 2001 (38)	Retrospective n = 41 b = 151	$\geq 3a$	23	Am	$< 0.087 \text{ cm/s}$	82	53
Dandel et al. 2001 (39)	Retrospective n = 161 b = 408	≥ 2	35	Sm Em	$> 10\% \downarrow$ $> 10\% \downarrow$	88 92	94 92
Vivekananthan et al. 2002 (40)	Retrospective n = 40 b = 80	$\geq 3a$	20	MPI	$\geq 20\% \downarrow$	90	90
Burgess et al. 2003 (41)	Retrospective n = 50	≥ 2	34	MPI PHT IVCT	ns + +	- na	- na
Palka et al. 2005 (42)	Retrospective n = 44	$\geq 3a$		Em	$< 0.12 \text{ m/s}$	69	59
Sun et al. 2005 (43)	Retrospective n = 264 b = 406	$\geq 3a$	138	IVRT E/A PE	$< 90 \text{ msec}$ > 1.7 presence	3 independent predictors of rejection	

* Criteria used to define significant rejection are based on the previous International Society of Heart and Lung Transplant (ISHLT) classification; Grade 3a or 2R rejection in the revised classification usually lead to an increase in immunosuppression (32).

(Am, maximal tissue Doppler late diastolic velocity (mitral annulus); b, total number of biopsies in the study; E/A, ratio of early to late maximal diastolic velocity; Em, maximal tissue Doppler early diastolic velocity (mitral annulus); IVRT, isovolumic contraction time; LVMPI, left ventricular myocardial performance index; n, number; na, not available; ns or -, non significant; PE, pericardial effusion; PHT, pressure half time; Se, sensitivity; Sm, maximal tissue Doppler systolic velocity (mitral annulus); Sp, specificity; +, significant)

Table 22.3 Role of TEE in Cardiac Transplantation

Before the procedure in patient with ventricular assist device

(see Table 21.3)

Perioperative period:

Monitoring after cardiac surgery (see Table 13.1)

De-airing of all four cardiac cavities

Detection of stenotic anastomosis (pulmonary artery, pulmonary veins, inferior and superior vena cava)

Detection of patent foramen ovale

Early and late post-operative period: evaluation of

Left and right systolic and diastolic function

Mitral and tricuspid valves

Atrial anastomosis, thrombus, spontaneous echocardiographic contrast

Presence of coronary fistula

Aneurysm and pseudoaneurysm of the large vessels anastomoses

If hemodynamic instability: detection of

Left and right ventricular acute systolic and diastolic dysfunction

Left and right ventricular outflow tract dynamic obstruction

Severe mitral or tricuspid regurgitation

Hypovolemia and vasodilatation

Cardiac tamponade from circumferential or loculated effusion

Inferior vena cava stenosis

References

1. Hunt SA, Abraham WT, Chin MH et al. ACC/AHA 2005 Guideline Update for the Diagnosis and Management of Chronic Heart Failure in the Adult: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Update the 2001 Guidelines for the Evaluation and Management of Heart Failure): developed in collaboration with the American College of Chest Physicians and the International Society for Heart and Lung Transplantation: endorsed by the Heart Rhythm Society. *Circulation* 2005;112:e154-e235.
2. Taylor DO, Edwards LB, Boucek MM et al. Registry of the International Society for Heart and Lung Transplantation: twenty-fourth official adult heart transplant report--2007. *J Heart Lung Transplant* 2007;26:769-781.
3. Zaroff JG, Rosengard BR, Armstrong WF et al. Consensus conference report: maximizing use of organs recovered from the cadaver donor: cardiac recommendations, March 28-29, 2001, Crystal City, Va. *Circulation* 2002;106:836-841.
4. Renlund DG, Taylor DO, Kfoury AG et al. New UNOS rules: historical background and implications for transplantation management. United Network for Organ Sharing. *J Heart Lung Transplant* 1999;18:1065-1070.
5. Russo MJ, Chen JM, Sorabella RA et al. The effect of ischemic time on survival after heart transplantation varies by donor age: an analysis of the United Network for Organ Sharing database. *J Thorac Cardiovasc Surg* 2007;133:554-559.
6. Mehra MR, Kobashigawa J, Starling R et al. Listing criteria for heart transplantation: International Society for Heart and Lung Transplantation guidelines for the care of cardiac transplant candidates--2006. *J Heart Lung Transplant* 2006;25:1024-1042.
7. Butler J, Stankewicz MA, Wu J et al. Pre-transplant reversible pulmonary hypertension predicts higher risk for mortality after cardiac transplantation. *J Heart Lung Transplant* 2005;24:170-177.

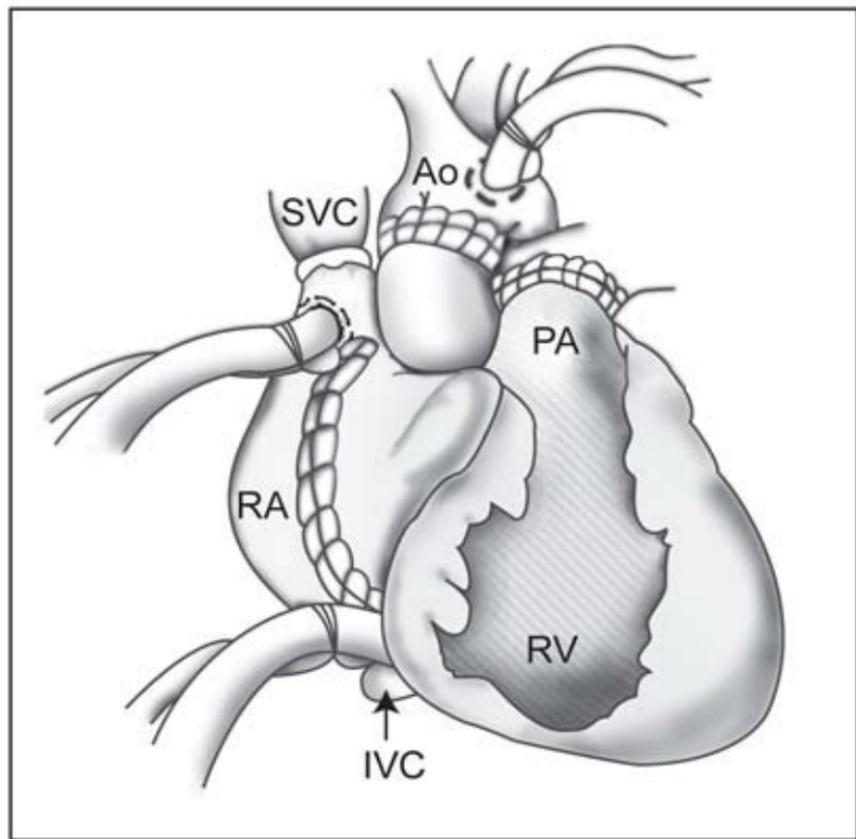
8. Lower RR, Shumway NE. Studies on orthotopic homotransplantation of the canine heart. *Surg Forum* 1960;11:18-19.
9. Shumway NE, Lower RR, Stofer RC. Transplantation of the heart. *Adv Surg* 1966;2:265-284.
10. Dreyfus G, Jebara V, Mihaileanu S et al. Total orthotopic heart transplantation: an alternative to the standard technique. *Ann Thorac Surg* 1991;52:1181-1184.
11. Carrier M, Leung TK, Solymoss BC et al. Clinical trial of retrograde warm blood reperfusion versus standard cold topical irrigation of transplanted hearts. *Ann Thorac Surg* 1996;61:1310-1314.
12. Practice guidelines for perioperative transesophageal echocardiography. A report by the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists Task Force on Transesophageal Echocardiography. *Anesthesiology* 1996;84:986-1006.
13. Stobierska-Dzierzek B, Awad H, Michler RE. The evolving management of acute right-sided heart failure in cardiac transplant recipients. *J Am Coll Cardiol* 2001;38:923-931.
14. Hosenpud JD, Bennett LE, Keck BM et al. The Registry of the International Society for Heart and Lung Transplantation: seventeenth official report-2000. *J Heart Lung Transplant* 2000;19:909-931.
15. Carrier M, Blaise G, Belisle S et al. Nitric oxide inhalation in the treatment of primary graft failure following heart transplantation. *J Heart Lung Transplant* 1999;18:664-667.
16. Haddad F, Couture P, Tousignant C et al. The right ventricle in cardiac surgery, a perioperative perspective: II. Pathophysiology, clinical importance, and management. *Anesth Analg* 2009;108:422-433.
17. Suriani RJ. Transesophageal echocardiography during organ transplantation. *J Cardiothorac Vasc Anesth* 1998;12:686-694.
18. Durennes ME. Échocardiographie transoesophagienne chez le transplanté cardiaque. In: Cohen A, ed. *Échocardiographie transoesophagienne en cardiologie et en anesthésie*. Édition Arnette, 1992:265-279.

19. Bhatia SJ, Kirshenbaum JM, Shemin RJ et al. Time course of resolution of pulmonary hypertension and right ventricular remodeling after orthotopic cardiac transplantation. *Circulation* 1987;76:819-826.
20. Burgess MI, Bhattacharyya A, Ray SG. Echocardiography after cardiac transplantation. *J Am Soc Echocardiogr* 2002;15:917-925.
21. Borow KM, Neumann A, Arensman FW et al. Left ventricular contractility and contractile reserve in humans after cardiac transplantation. *Circulation* 1985;71:866-872.
22. Angermann CE, Spes CH, Tammen A et al. Anatomic characteristics and valvular function of the transplanted heart: transthoracic versus transesophageal echocardiographic findings. *J Heart Transplant* 1990;9:331-338.
23. Weitzman LB, Tinker WP, Kronzon I et al. The incidence and natural history of pericardial effusion after cardiac surgery--an echocardiographic study. *Circulation* 1984;69:506-511.
24. StGoar FG, Gibbons R, Schnittger I et al. Left ventricular diastolic function. Doppler echocardiographic changes soon after cardiac transplantation. *Circulation* 1990;82:872-878.
25. Ross HJ, Gullestad L, Hunt SA et al. Early Doppler echocardiographic dysfunction is associated with an increased mortality after orthotopic cardiac transplantation. *Circulation* 1996;94:II289-II293.
26. Gorcsan J, III, Snow FR, Paulsen W et al. Echocardiographic profile of the transplanted human heart in clinically well recipients. *J Heart Lung Transplant* 1992;11:80-89.
27. Gudmundsson GS, Smull DL, Pisani BA et al. Increase in atrial size in long-term survivors of heart transplant. *J Am Soc Echocardiogr* 2003;16:1043-1048.
28. Derumeaux G, Mouton-Schleifer D, Soyer R et al. High incidence of left atrial thrombus detected by transoesophageal echocardiography in heart transplant recipients. *Eur Heart J* 1995;16:120-125.
29. Riberi A, Ambrosi P, Habib G et al. Systemic embolism: a serious complication after cardiac transplantation avoidable by bicaval technique. *Eur J Cardiothorac Surg* 2001;19:307-311.

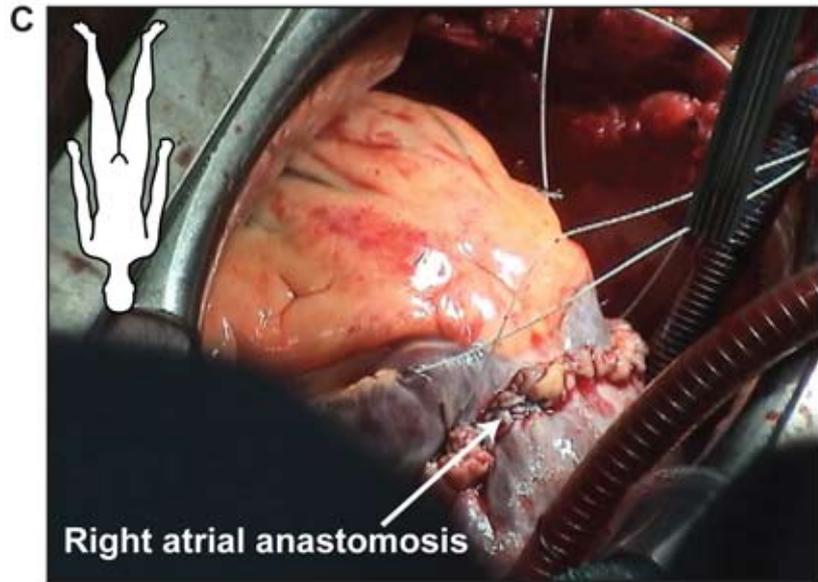
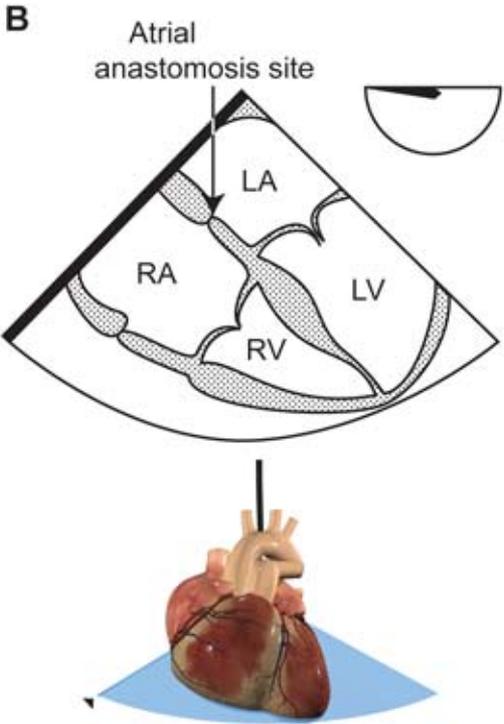
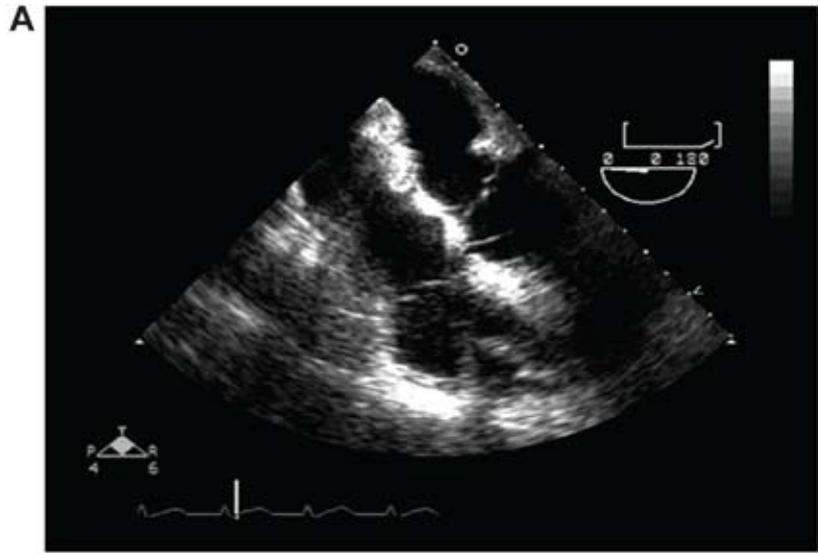
30. Ouseph R, Stoddard MF, Lederer ED. Patent foramen ovale presenting as refractory hypoxemia after heart transplantation. *J Am Soc Echocardiogr* 1997;10:973-976.
31. Lowry RW, Young JB, Kleiman NS et al. Transesophageal echocardiographic demonstration of right coronary artery-to-coronary sinus fistula in a heart transplant recipient. *J Am Soc Echocardiogr* 1993;6:449-452.
32. Stewart S, Winters GL, Fishbein MC et al. Revision of the 1990 working formulation for the standardization of nomenclature in the diagnosis of heart rejection. *J Heart Lung Transplant* 2005;24:1710-1720.
33. Valantine HA, Yeoh TK, Gibbons R et al. Sensitivity and specificity of diastolic indexes for rejection surveillance: temporal correlation with endomyocardial biopsy. *J Heart Lung Transplant* 1991;10:757-765.
34. Stork T, Mockel M, Eichstadt H et al. Noninvasive diagnosis of cardiac allograft rejection by means of pulsed Doppler and M-mode ultrasound. *J Ultrasound Med* 1991;10:569-575.
35. Ciliberto GR, Mascarello M, Gronda E et al. Acute rejection after heart transplantation: noninvasive echocardiographic evaluation. *J Am Coll Cardiol* 1994;23:1156-1161.
36. Mouly-Bandini A, Vion-Dury J, Viout P et al. Value of Doppler echocardiography in the detection of low-grade rejections after cardiac transplantation. *Transpl Int* 1996;9:131-136.
37. Puleo JA, Aranda JM, Weston MW et al. Noninvasive detection of allograft rejection in heart transplant recipients by use of Doppler tissue imaging. *J Heart Lung Transplant* 1998;17:176-184.
38. Stengel SM, Allemann Y, Zimmerli M et al. Doppler tissue imaging for assessing left ventricular diastolic dysfunction in heart transplant rejection. *Heart* 2001;86:432-437.
39. Dandel M, Hummel M, Muller J et al. Reliability of tissue Doppler wall motion monitoring after heart transplantation for replacement of invasive routine screenings by optimally timed cardiac biopsies and catheterizations. *Circulation* 2001;104:I184-I191.
40. Vivekananthan K, Kalapura T, Mehra M et al. Usefulness of the combined index of systolic and

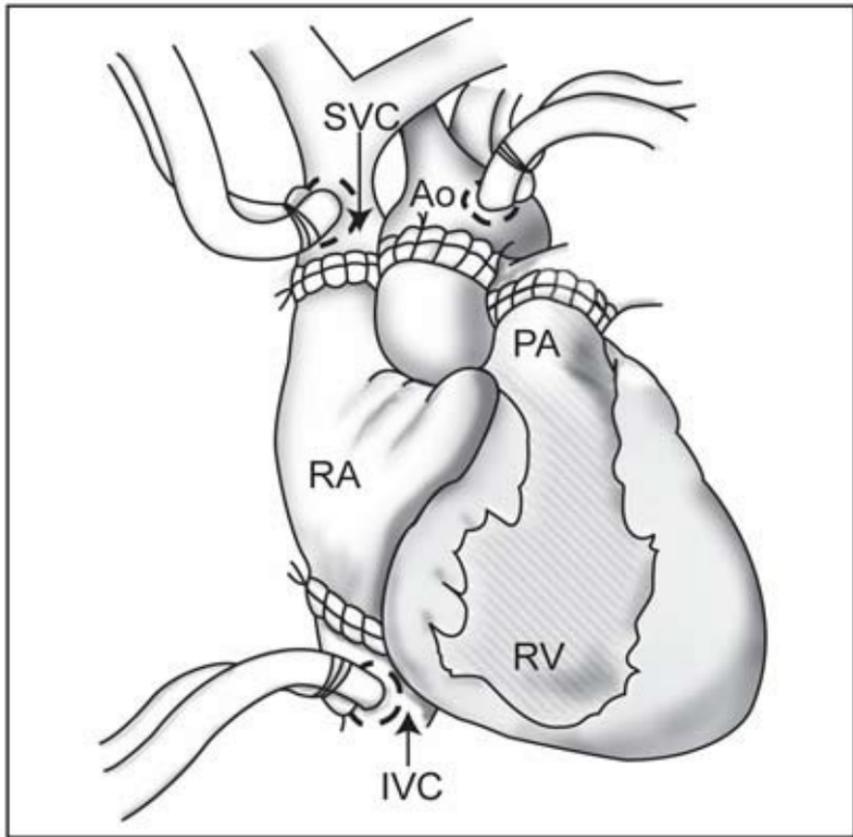
diastolic myocardial performance to identify cardiac allograft rejection. *Am J Cardiol* 2002;90:517-520.

41. Burgess MI, Bright-Thomas RJ, Yonan N et al. Can the index of myocardial performance be used to detect acute cellular rejection after heart transplantation? *Am J Cardiol* 2003;92:308-311.
42. Palka P, Lange A, Galbraith A et al. The role of left and right ventricular early diastolic Doppler tissue echocardiographic indices in the evaluation of acute rejection in orthotopic heart transplant. *J Am Soc Echocardiogr* 2005;18:107-115.
43. Sun JP, Abdalla IA, Asher CR et al. Non-invasive evaluation of orthotopic heart transplant rejection by echocardiography. *J Heart Lung Transplant* 2005;24:160-165.

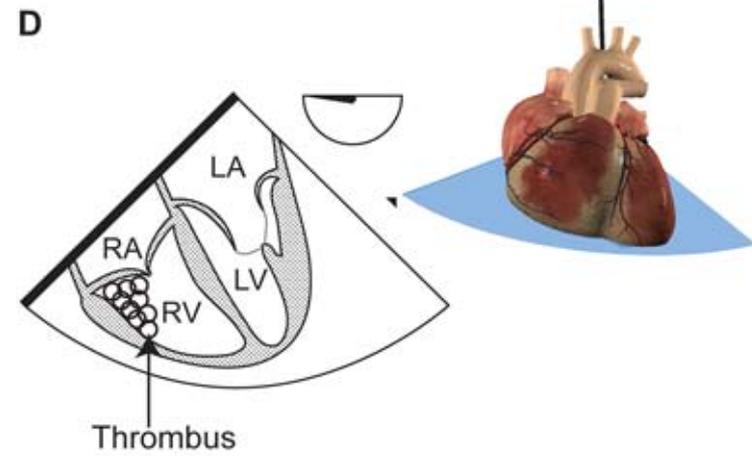
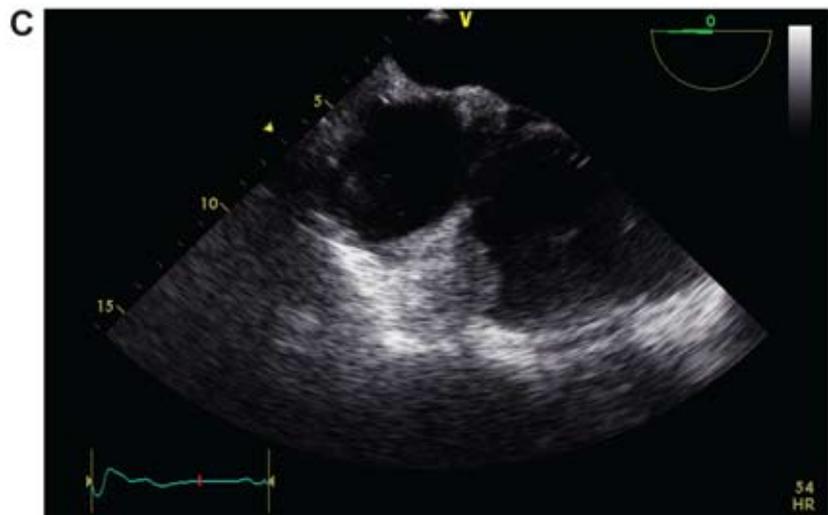
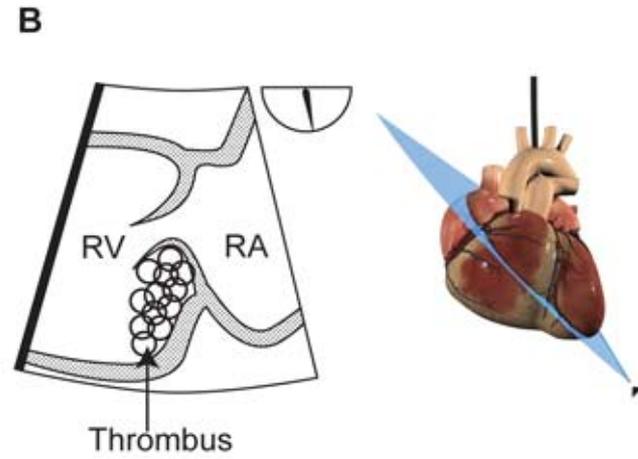


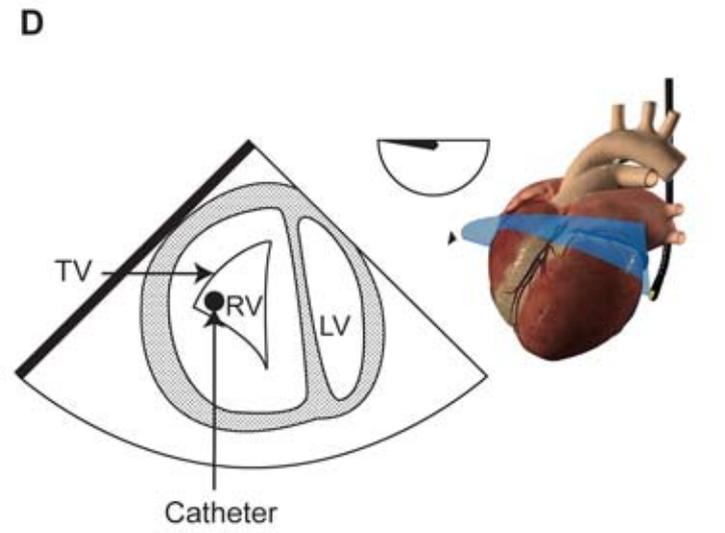
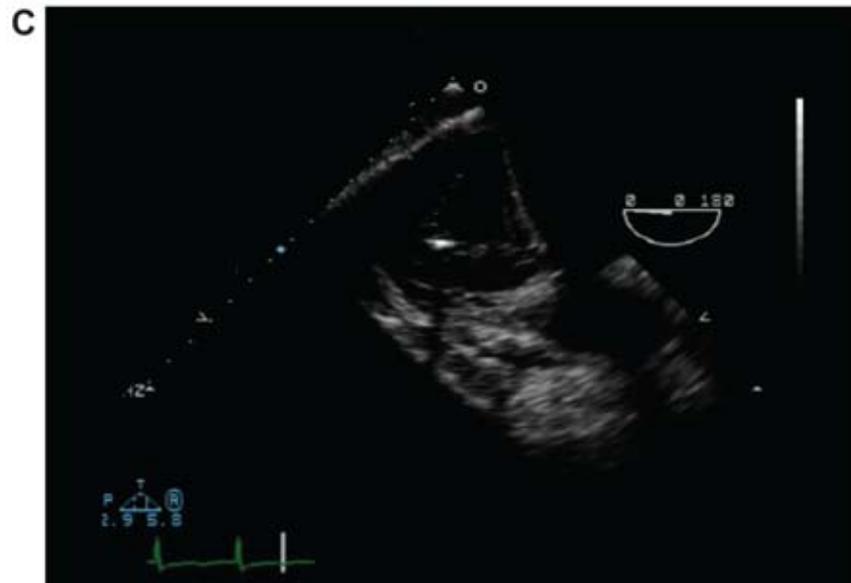
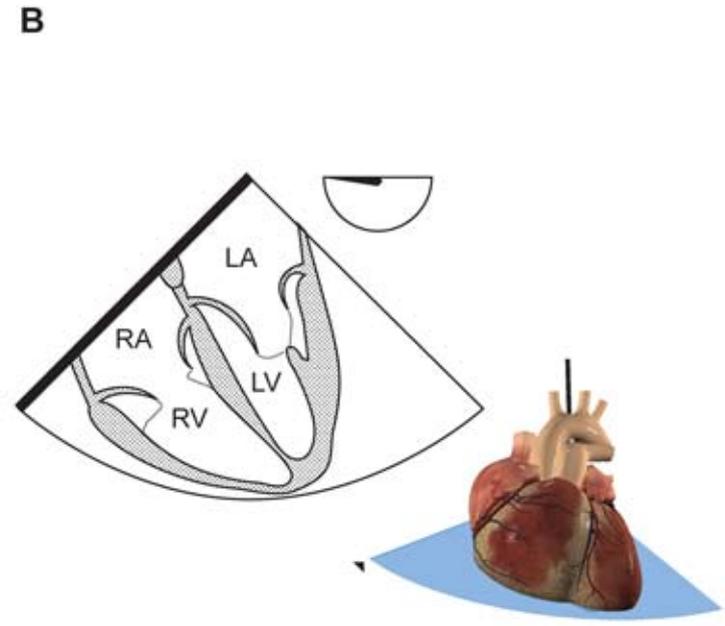
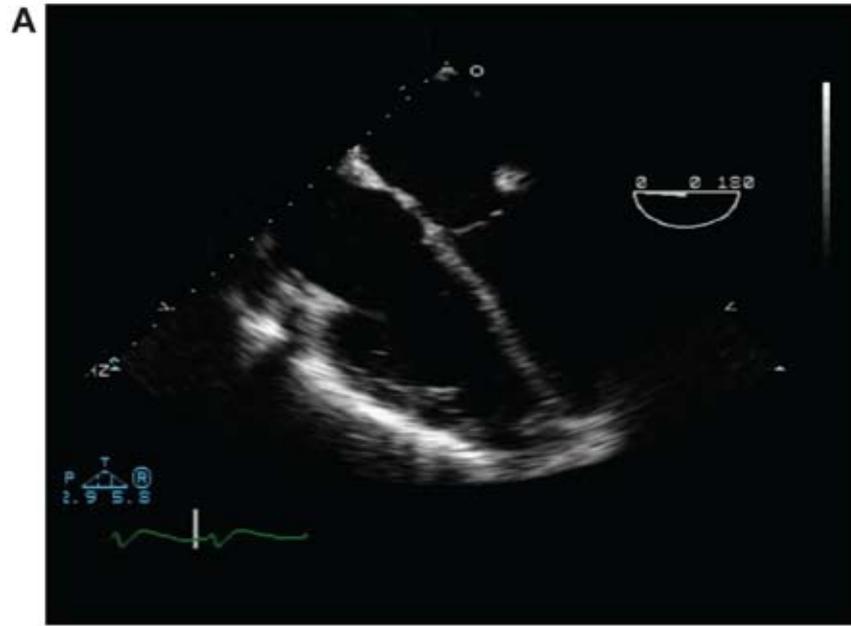
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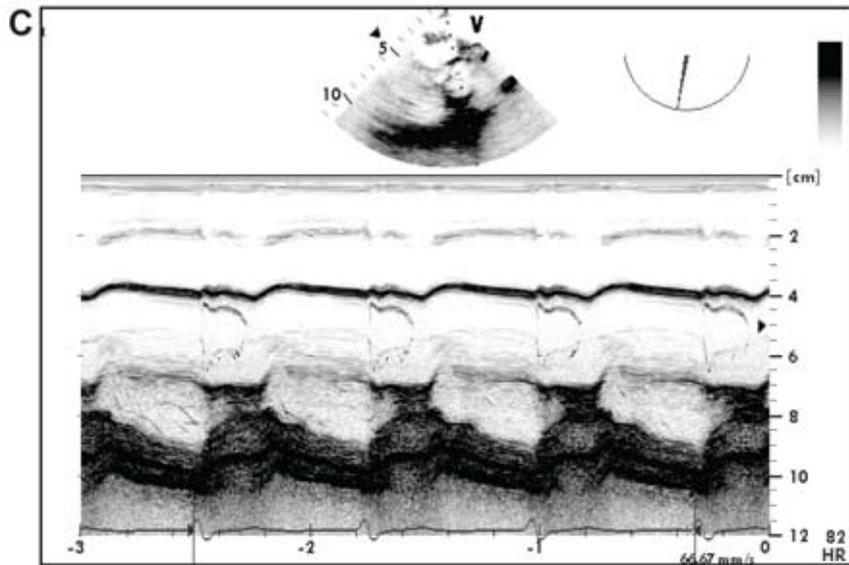
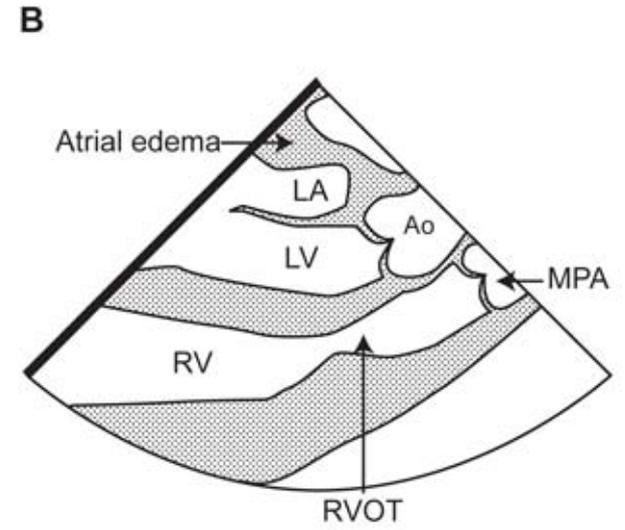
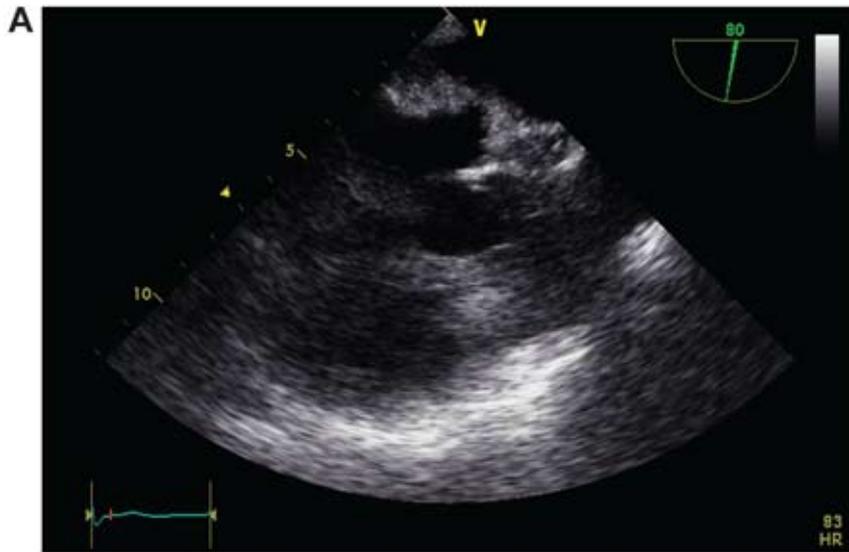


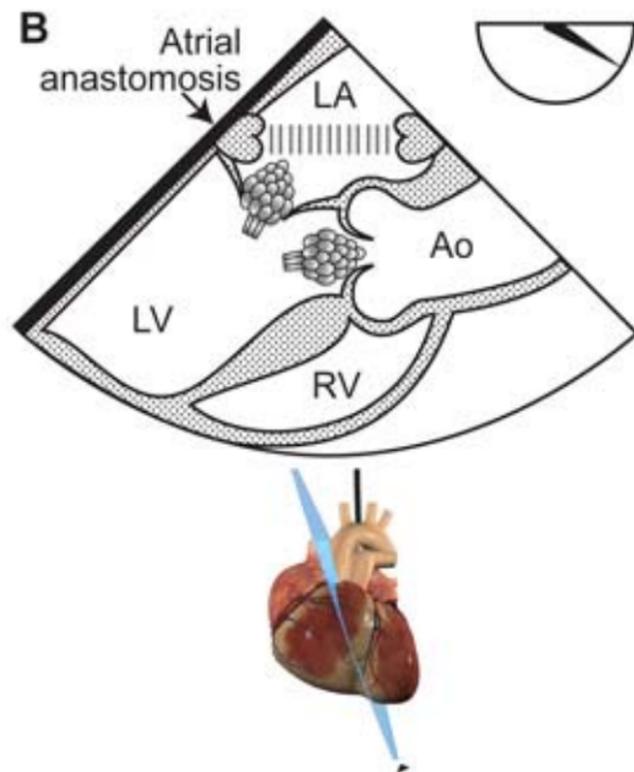
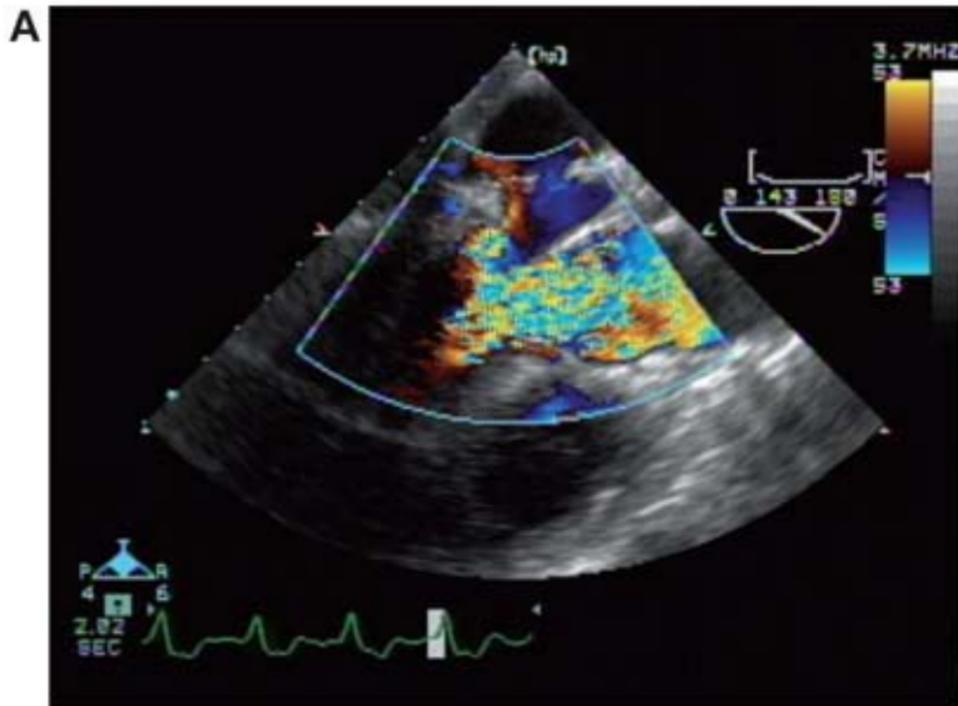


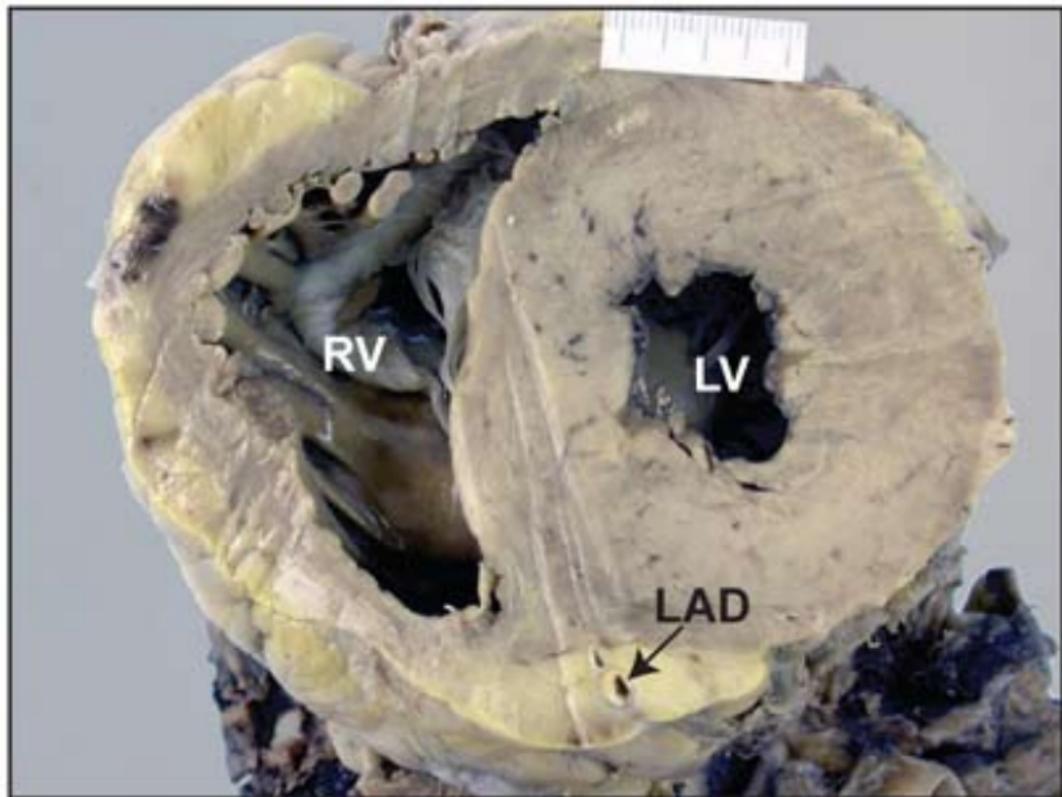
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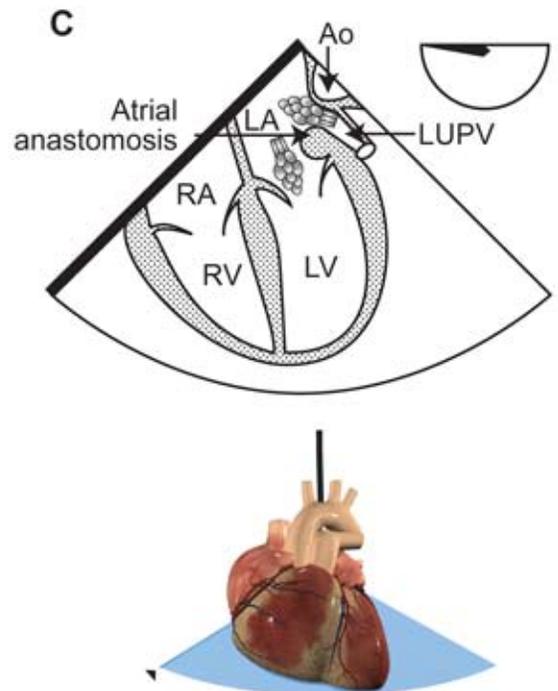
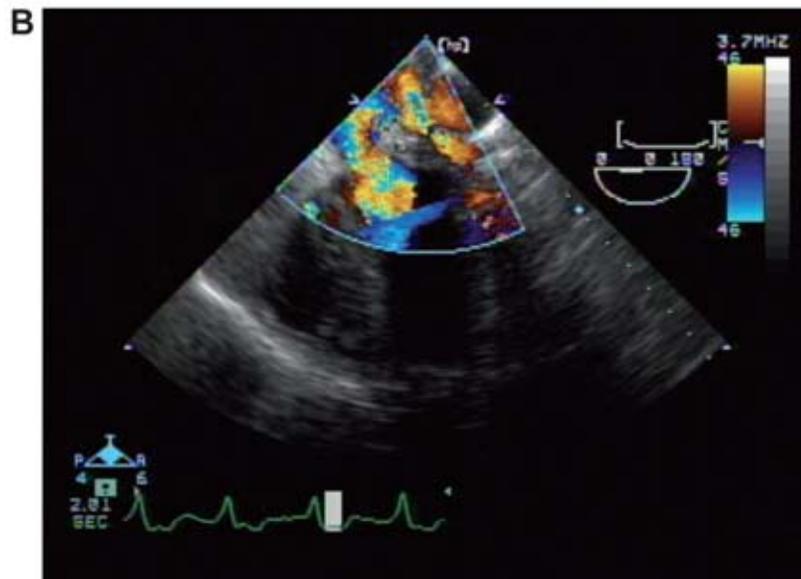
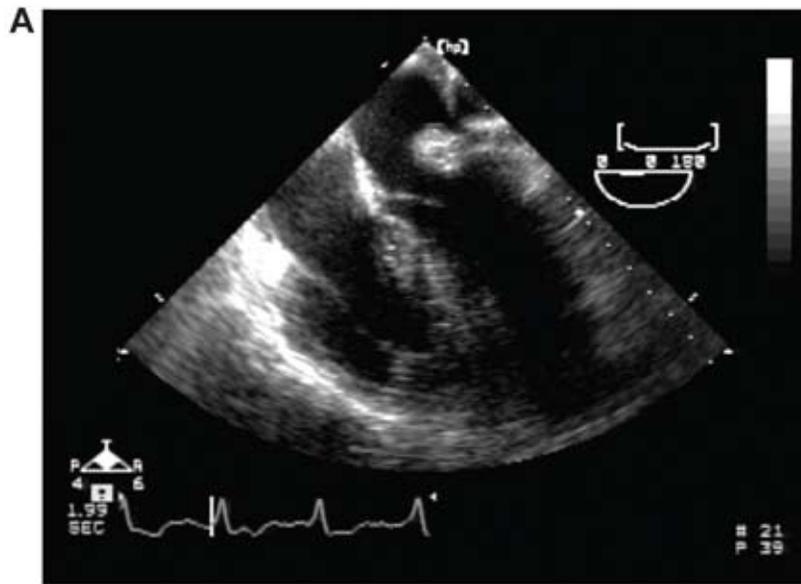


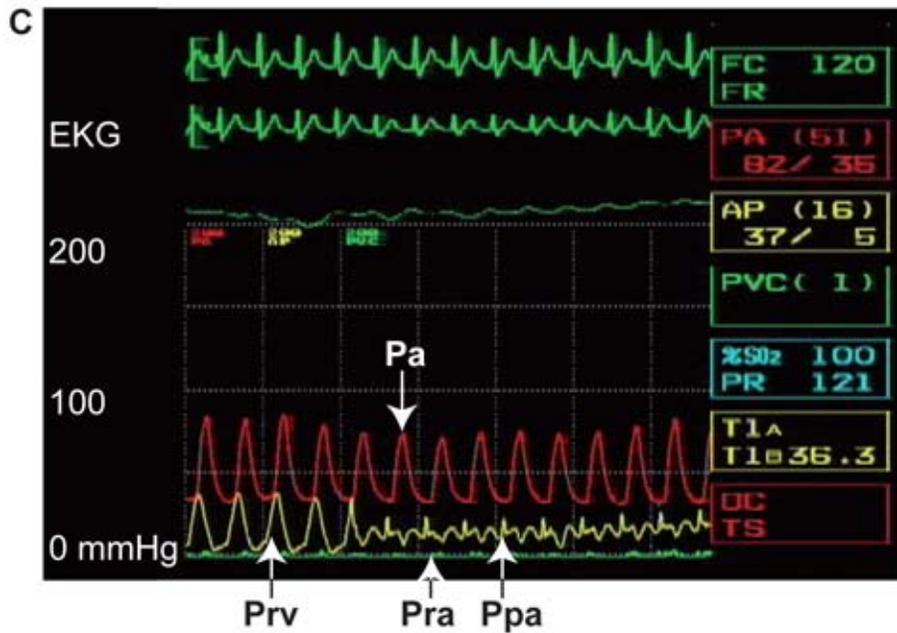
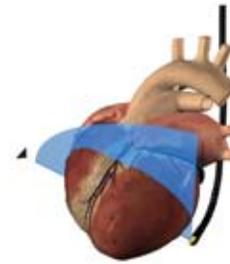
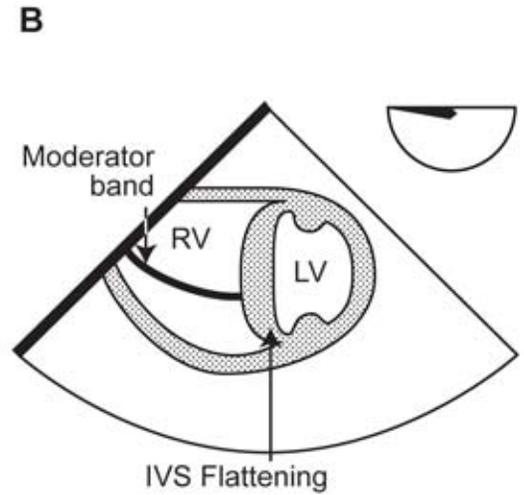
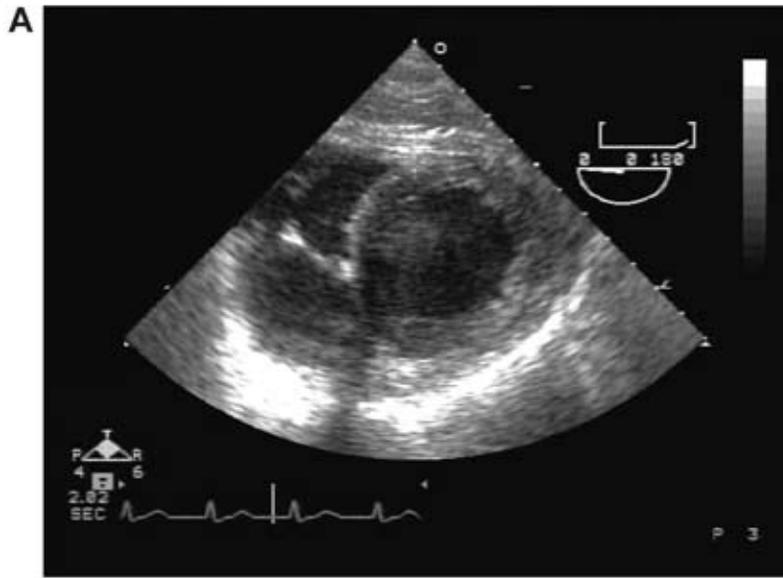




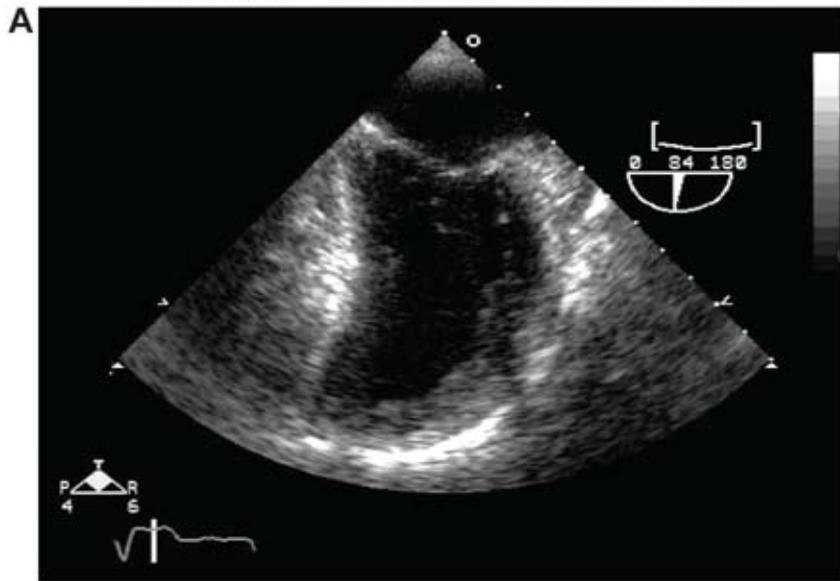


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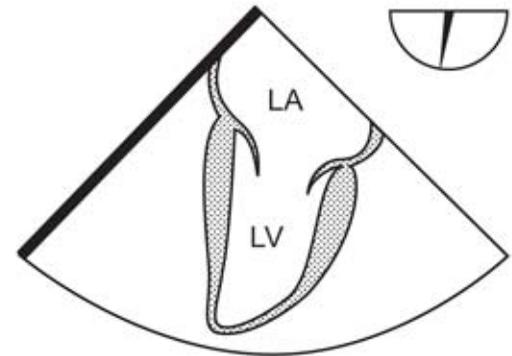




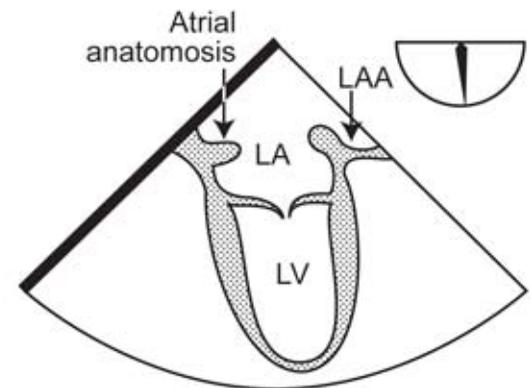
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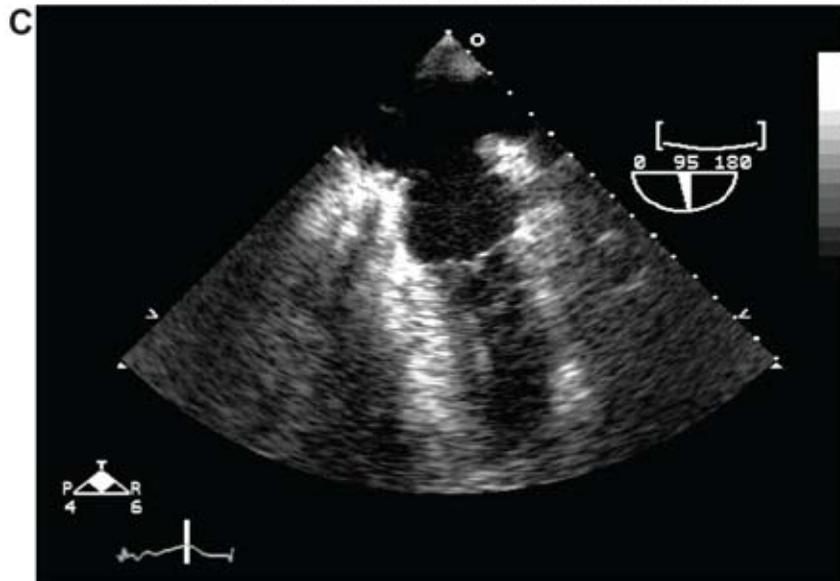
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D



AFTER TRANSPLANTATION



TIME AFTER TRANSPLANTATION

