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Comparison of Transthoracic and Transesophageal Echocardiography in Evaluation of 47 Starr-Edwards Prosthetic Valves

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Objectives. Our objectives were to characterize by transesophageal echocardiography the normal appearance of the Starr-Edwards prosthetic heart valve and to compare the utility of transesophageal and transthoracic echocardiography in detection of valve abnormality.

Background. The Starr-Edwards prosthetic heart valve, the first mechanical valve to be used, has demonstrated excellent durability.

Methods. Fifty transthoracic and transesophageal echocardiographic studies on 37 patients with 47 Starr-Edwards prosthetic valves were analyzed retrospectively. Six cases of surgically confirmed infective endocarditis were studied.

Results. Vegetation or abscess formation, or both, was identified by transesophageal echocardiography in all six cases of infective endocarditis but was found in only one of these cases by transthoracic echocardiography. Thrombus was detected by transesophageal echocardiography in 9 of 11 patients with transient ischemic attacks or stroke and in 2 patients by transthoracic echocardiography with 3 confirmed at surgery. In 26 of the 30 patients with a mitral Starr-Edwards valve, the valve demonstrated a trivial or mild "closing volume" early systolic or holosystolic leak on transesophageal echocardiography alone. Transthoracic evaluation identified significant mitral regurgitation in six of the eight patients who had this finding on transesophageal echocardiography. Serial studies were performed to assess response to treatment or need for surgical intervention in eight patients. Seventeen valves have been implanted for 12 years; six of these had significant leakage without apparent cause, a finding not observed more recently implanted valves.

Conclusions. These observations demonstrated the unique utility of transesophageal echocardiography in patients with Starr-Edwards prosthetic valve dysfunction, endocarditis or thrombus formation, and of the clear superiority of transesophageal echocardiography over transthoracic echocardiography in these situations.

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Starr-Edwards Silastic ball-cage prosthetic valves have been extensively used in clinical practice since 1960 (1). Two-dimensional and Doppler echocardiography have proved useful in the noninvasive assessment of these prostheses; however, transthoracic echocardiographic evaluations are limited by interference with ultrasound waves by the prosthetic poppet, struts and sewing ring. Structures posterior to the mitral valve are obscured, making valvular regurgitation difficult to detect and quantitate. In addition, because of this interference, small or moderate-sized abnormalities such as thrombi or vegetations are hidden from view, so that recognition of any but the most obvious abnormality of the high profile Starr-Edwards mitral valve is problematic for even the experienced echocardiographer. Regurgitation of the Starr-Edwards aortic valve, with its more anterior location in the heart, may be somewhat easier to detect transthoracically than by the transesophageal approach; however, the reverberation and masking may hide small vegetations and thrombi with this valve as well and abscesses of the posterior aortic root may be overshadowed by the prosthesis.

Transesophageal echocardiography would appear to overcome these obstacles by allowing clear visualization of posterior structures, such as the left atrium and aortic root, without interference by the prosthesis; however, investigations of Starr-Edwards valves involving a large number of patients who have undergone transesophageal echocardiography are lacking. The purpose of this study was to identify transesophageal echocardiographic characteristics of normally functioning Starr-Edwards prostheses in the aortic and mitral positions and to compare the utility of transesophageal and transthoracic echocardiography in clinical practice situations (endocarditis, embolic events and regurgitation) common to patients with a prosthetic valve.

Methods

Patient group. Thirty-seven patients with one or more Starr-Edwards prostheses who had undergone transesophageal echocardiography at The Ohio State University Hospitals and Clinics between January 1990 and December 1991

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Table 1. Characteristics of Study Group

					MV Regurgitation			AoV Regurgitation			TV Regurgitation			Endocarditis		Thrombus		
						TEE			TEE			TEE						Method of
Pt No.	Age (yr)/Gender	Indications for Study	Valve Position	Valve Age	TTE	CV	Sig	TTE	CV	Sig	TTE	CV	Sig	TTE	TEE	TTE	TEE	Confirmation
1	62/F	CHF	MV	2	–	+	–							–	–	–	–	
2	38/F	CSE	MV	3	–	+								–	–	–	+	S
3	55/F	PAD	MV	4	–	+	1+ Pv							–	–	–	–	C
4	50/F	IE	MV	5	2+ Pv	–	4+ Pv							–	Veg, Ab	–	–	C,S
5	53/F	EPV	MV	7	–	+	–							–	–	–	–	
6	61/M	CHF	MV	7	–	+	–							–	–	–	–	
7	50/M	CSE	MV	8	–	+	–							–	–	–	–	C
8	32/M	IE	MV	9	–	+	–							Veg	Veg	–	–	S
9	48/F	EPV	MV	9	–	+	–							–	–	–	–	
10	44/F	CSE	MV	9	–	+	–							–	–	–	–	
11	42/M	EPV	MV	10	–	+	–							–	–	–	–	
12	63/F	CSE	MV	13	–	+	–							–	–	+	+	S
13	58/M	EPV	MV	13	3+ Tv	–	3+ Tv							–	–	–	–	
14	58/F	EPV	MV	14	3+ Pv	+	3+ Pv							–	–	–	–	
15	51/F	CSE	MV	14	–	+	–							–	–	+	+	
16	66/F	CHF	MV	15	–	+	–							–	–	–	–	
17	35/F	CSE	MV	16	–	+	–							–	–	–	+	C
18	57/F	EPV	MV	17	–	+	–							–	–	–	–	
19	41/M	CSE	MV	18	–	+	–							–	–	–	+	S
20	64/M	CHF	MV	18	2+ Tv	–	3+ Tv							–	–	–	–	
21	52/F	IE	AoV	2				–	–	–				–	–	–	–	
22	50/F	CSE	AoV	6				–	–	–				–	–	–	+	
23	72/M	IE	AoV	7				–	–	1+ Pv				–	Veg, Ab	–	–	C,S
24	58/M	CSE	AoV	8				1+	–	1+ Pv				–	–	–	–	C
25	67/M	CSE	AoV	8				–	–	–				–	–	–	+	C
26	30/M	EPV	AoV	10				–	–	–				–	–	–	–	
27	52/F	EPV	AoV	21				–	–	1+ Tv				–	–	–	–	
28	31/F	IE	AoV	2,3	–	+	3+ Pv	–	–	–				–	Veg, Ab (MV)	–	–	C,S
29	67/F	IE	MV, AoV	7,7	–	+	–	–	–	–				–	Veg (MV)	–	–	C,S,P
30	65/M	EPV	MV, AoV	11,11	–	+	–	–	–	–				–	–	–	–	
31	32/F	EPV	MV, AoV	11,11	–	+	–	–	–	–				–	–	–	–	
32	66/M	IE	MV, AoV	12,17	2+ Pv	+	3+ Pv	–	–	–				–	Veg (MV)	–	–	C,S
33	62/M	EPV	MV, AoV	14,14	–	–	2+ Tv	–	–	–				–	–	–	–	
34	52/F	EPV	MV, AoV	15,5	–	+	–	–	–	–				–	–	–	–	C
35	66/F	IE	MV, AoV	15,15	–	+	–	1+	–	2+ Tv				–	–	–	–	
36	47/F	CSE	MV, TV	4,4	–	+	–				–	–	–	–	–	–	+(MV)	
37	40/F	CSE	MV, TV	4,4	3+ Pv	+	3+ Pv				–	+	–	–	–	–	+(TV)	

Ab = abscess; AoV = aortic valve; C = cardiac catheterization; CHF = congestive heart failure; CSE = cardiac source of embolus; CV = closing volume; EPV = evaluate prosthetic valve; F = female; IE = infective endocarditis; M = male; MV = mitral valve; P = postmortem study; PAD = possible aortic dissection; Pt = patient; Pv = perivalvular; S = surgery; Sig = significant; TEE = transesophageal echocardiogram; TTE = transthoracic echocardiogram; Tv = transvalvular; TV = tricuspid valve; Veg = vegetation; 1+ to 4+ = grade of regurgitation; – = negative findings; + = positive findings.

were studied in retrospective fashion (Table 1). Subjects ranged in age from 31 to 72 years (mean 53). Twenty patients had only a mitral prosthesis, and seven had only an aortic prosthesis. Eight patients had both mitral and aortic prostheses, and two patients had both tricuspid and mitral prostheses. In all, 47 Starr-Edwards prosthetic valves were evaluated. Because serial studies were performed in several patients, the total number of studies was 50. The tests were performed for the reasons listed in Table 2. Chart review was undertaken to assess the clinical history and the availability of cardiac catheterization and of surgical or autopsy findings for comparison with the echocardiographic results. Patients studied for evaluation of the prosthesis had no significant historical or physical examination findings of congestive heart failure, endocarditis or embolism but were studied because of nonspecific symptoms such as fatigue, dyspnea, chest pain or syncope.

Echocardiographic studies. All patients underwent transthoracic and transesophageal echocardiography; the two studies were performed within several days, (range 0 to 15) and usually within hours of each other. The majority of patients (n = 27) underwent both studies on the same day. All transthoracic studies included two-dimensional, M-mode, Doppler color flow imaging and pulsed and contin-

Table 2. Indications for Study

Fever	8	
Positive findings on blood culture, high clinical suspicion		5
Negative findings on blood culture, high clinical suspicion		1
Negative findings on blood culture, low clinical suspicion		2
TIA/CVA	11	
Evaluate prosthesis, nonspecific symptoms		8
Congestive heart failure		4
Chest pain		3
Other embolic event		1
Low prothrombin time (no embolic event)		1
Rule out aortic dissection		1

CVA = cerebrovascular accident; TIA = transient ischemic attack.

uous wave Doppler modalities. Transesophageal echocardiography was performed after administration of topical anesthesia of the hypopharynx with 10% cetacaine and intravenous sedation with midazolam or meperidine, or both. Antibiotic prophylaxis utilizing 3 g of amoxicillin before the procedure was given in all cases unless the patient was already receiving intravenous antibiotics. A 5-MHz transducer mounted on the tip of a flexible gastroscope (Hewlett-Packard 77020, Sonos 500 and Sonos 1000) was introduced and a complete study was performed. No complications of the procedure occurred in any patient.

Echocardiographic analysis. Studies were interpreted at the time they were performed by an experienced echocardiographer who was aware of the patients' clinical data. An independent echocardiographer subsequently reviewed the studies to verify the initial observations.

The severity of mitral regurgitation was graded by transthoracic echocardiography according to the estimated regurgitant jet area as a percent of left atrial area (2,3), and by transesophageal echocardiography according to the estimated regurgitant jet area (4). Aortic regurgitation was quantitated in both methods by the ratio of regurgitant jet width to left ventricular outflow diameter in the short-axis view (5). Perivalvular jets were defined as eccentric and originating just outside the sewing ring. Transvalvular jets were defined as jets originating between the sewing ring and poppet. The presence of vegetations, abscesses, thrombi or valve dehiscence was also noted. A vegetation was defined as an echogenic mass attached to the valvular or perivalvular surface with independent motion apparent in multiple views. A perivalvular echolucent area was considered as an abscess (6). Thrombi were defined as singular or multiple abnormal masses, linear or globular, located on the valve surface with independent motion. Differentiation between vegetations and thrombus was made on clinical grounds. Valve dehiscence was considered excessive motion of the valve apparatus accompanied by perivalvular regurgitation.

Results

Mitral valves. The time from implantation to examination (age) of the 30 Starr-Edwards valves in the mitral position ranged from 2 to 18 years (mean 10). Thirteen valves had no associated thrombus, endocarditis or significant regurgitation. On transesophageal echocardiography, all of these normal valves had a trivial or mild early systolic transvalvular mitral regurgitation jet demonstrated by Doppler color flow imaging. The jet traveled back centrally toward the posterior wall of the left atrium (Fig. 1). In two of these valves, an identical-appearing jet was holosystolic. All six patients with valve thrombi demonstrated a similar jet, as did four of the five patients with vegetations. Three patients without vegetation or thrombus had closing volume jets along with a significant mitral regurgitant jet. In all, this characteristic leak or "closing volume" was seen in 26 of the 30 patients, 13 of whom had otherwise normal prostheses. In no case was this jet detected by transthoracic echocardiography.

Moderate to severe (≥2+) holosystolic mitral regurgitation was detected in six patients by transthoracic echocardiography and in eight by transesophageal echocardiography. Another patient had 1+ perivalvular regurgitation observed on transesophageal study but not by surface examination. Significant (≥2+) perivalvular mitral insufficiency was identified by the transthoracic study in four of five patients with this finding on transesophageal examination. Four patients with periprosthetic leaks had associated vegetations or abscess formation, or both, and one patient had valve dehiscence.

Five cases of surgically confirmed endocarditis were found by transesophageal echocardiography. Two patients with vegetations had valve dehiscence not identified on transthoracic echocardiography but clearly defined by the transesophageal examination. Two patients with vegetations did not have significant mitral regurgitation. The vegetations or abscess formation, or both, in four of these patients was visible only on transesophageal echocardiography; endocarditis was not identified by transthoracic echocardiography. The sole vegetation identified by transthoracic echocardiography was visualized on the ventricular aspect of the prosthesis in a patient who had large vegetations on either side of the mitral prosthesis.

Thrombus formation was detected in six patients with a Starr-Edwards mitral valve by transesophageal echocardiography, in two patients by both methods. One of these patients was clinically normal but had not complied with warfarin therapy. The other five patients had transient ischemic attacks or cerebrovascular accidents. Thrombus was verified intraoperatively in three of the six patients (Fig. 2).

Aortic valves. Fifteen patients with a Starr-Edwards prosthesis in the aortic position were studied. Duration from the time of implantation to examination ranged from 2 to 21 years (mean 10.3). Nine of these patients had no valve abnormalities on transesophageal echocardiography or transthoracic echocardiography. Mild aortic regurgitation was visualized by transthoracic echocardiography in one of the three patients in whom it was identified by transesophageal

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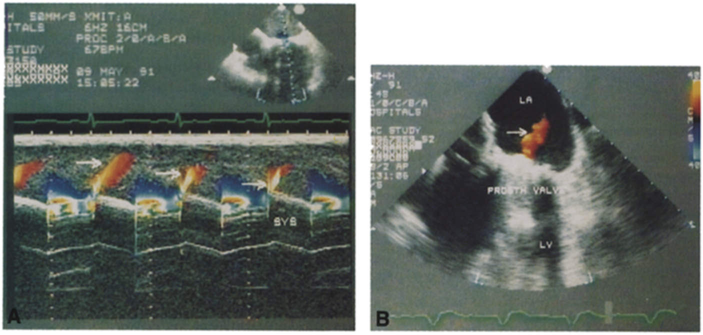


Figure 1. **A,** Color M-mode echocardiogram in transesophageal four-chamber view with the cursor through the Starr-Edwards mitral valve. The early systolic (SYS) jet of closing volume is shown at the arrow. **B,** Two-dimensional Doppler color transesophageal echocardiogram showing typical closing volume mitral regurgitation (arrow) in the central portion of the left atrium (LA). Note the obscuring of the left ventricle (LV) caused by the prosthetic (PROSTH) apparatus.

echocardiography. In another patient, aortic regurgitation was moderate on transesophageal study but only mild on transthoracic echocardiography (Fig. 3). One patient had vegetations (Fig. 4) with an abscess identified by transesophageal echocardiographic findings of a periannular lucency that were not detected by transthoracic echocardiography. These findings were confirmed at operation and at autopsy. In two patients undergoing the study for evaluation of a cerebrovascular accident, thrombi were identified by transesophageal but not by surface echocardiography.

Tricuspid valves. Two patients in this study had a Starr-Edwards valve in the tricuspid position. In one patient who had a subtherapeutic prothrombin time, a small filamentous thrombus was identified by transesophageal echocardiography and not by transthoracic echocardiography. The study was performed to locate a source for splenic infarction.

Aortic and mitral valves. A subset of eight patients had both aortic and mitral Starr-Edwards valves. Two of these three patients with mitral valve endocarditis had a regur-

Figure 2 (left). Patient 12. Transesophageal echocardiogram, four-chamber view, from a 63-year old woman with a left pontine infarction and subsequent transient ischemic attacks. Thrombus (**arrow**), seen attached to the sewing ring, was verified intraoperatively. Ball = ball valve; RA = right atrium; TV = tricuspid valve; other abbreviations as in Figure 1.

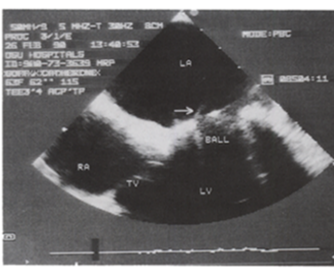
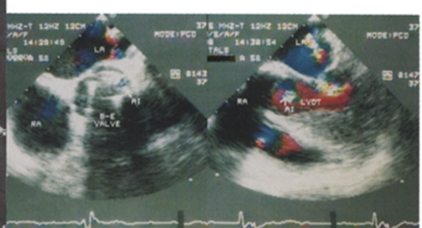


Figure 3 (right). Mild aortic regurgitation (AI) seen on transesophageal echocardiogram in two views. **Left,** Cross-sectional view through a Starr-Edwards (S-E) aortic valve. The **arrow** shows a small periprosthetic leak between the struts and the sewing ring. **Right,** The probe position now is inferior, showing aortic regurgitation in the left ventricular outflow tract (LVOT). Abbreviations as in Figures 1 and 2.



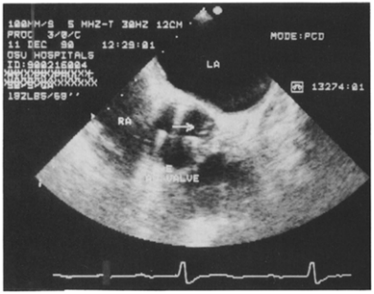


Figure 4. Patient 23. Basal short-axis transesophageal echocardiogram from a 72-year old man with *Streptococcus bovis* endocarditis. Vegetation (arrow) is located at the posterior aspect of the sewing ring. The patient also had an abscess that is not visualized on this frame. AO = aortic valve; other abbreviations as in Figures 1 and 2.

gitant mitral valve but a normal aortic valve, findings that were confirmed at catheterization (Table 3). Three patients had normal surface and transesophageal findings. A seventh patient had mitral regurgitation only (confirmed at catheterization). The eighth patient had moderate aortic insufficiency.

Hemodynamic data. Left and right heart cardiac catheterization data were available in 11 patients with 15 Starr-Edwards valves (Table 3). Eight mitral valves were evaluated. Five of these studies included left ventricular catheterization for assessment of mitral valve insufficiency. Four of the five studies showed excellent correlation with transesophageal results; the remaining study demonstrated no leak on transesophageal study but mild insufficiency at left ventriculography performed 5 days later. The other three patients did not undergo left ventriculography because of the presence of an aortic prosthesis; however, the *v* waves were >50 mm Hg in two, correlating with Doppler findings of moderately severe or severe regurgitation.

Presence or severity of aortic regurgitation on transesophageal Doppler color flow imaging predicted the degree of severity found on aortic root angiography in all seven patients evaluated with both methods.

In five patients surgically confirmed endocarditis was evaluated by both catheterization and echocardiography. In all, abscesses or vegetations were evident by transesophageal echocardiography. Angiography identified an abscess in the one patient with aortic valve endocarditis. In the remaining four patients, with mitral valve endocarditis, abnormal rocking or periannular leakage on catheterization suggested the diagnosis.

Two patients with thrombi identified on transesophageal echocardiography had no abnormalities on catheterization.

Four patients underwent surgery without catheterization. One, Patient 8, a 32-year old black man, had prosthetic valve endocarditis; the remaining three patients had mitral prosthetic valve thrombi by transesophageal echocardiography, confirmed at operation.

Serial transesophageal studies. Serial transesophageal echocardiographic studies were performed on eight patients. In Patient 15, who had had a recent right middle cerebral artery infarction, the study demonstrated prosthetic mitral valve thrombus initially that, after treatment with heparin and coumadin, was diminished in size at 1 month and no longer visible at 4 months. In Patient 12, under evaluation for a transient ischemic attack, serial studies showed no change in thrombus. Conversely, Patients 2 and 19, aged 38 and 41 years, respectively, underwent valve replacement after serial studies performed for continued neurologic events revealed progression in size of thrombi despite medical therapy.

Table 3. Comparisons of Transesophageal Echocardiography (TEE) and Cardiac Catheterization (Cath)

		Mitral Valve		Aortic Valve	
Pt No.	Days*	TEE	Cath	TEE	Cath
3	1	4+ MR, Dehisc	4+ MR, Dehisc	···	···
4	Same day	1+ MR	TR, MR	···	···
7	5	Normal	1 + MR	···	···
17	1	Normal	Normal	···	···
23	2	···	···	1+ AR, Veg, Ab	1+ AR, Ab, Dehisc
24	8	···	···	1+ AR	1+ AR
25	13	···	···	Thrombus	Normal
28†	Same day	3+ MR, Veg, Ab, Dehisc	?Dehisc, *v* = 30	Normal	Normal
29†	5	Veg	*v* = 60	Normal	Normal
32	1	3+ MR, Veg, Ab, Dehisc	Dehisc, *v* = 52	Normal	Normal
34†	Same day	Normal	Normal	Normal	Normal

*Number of days between transesophageal echocardiography and cardiac catheterization. †Patients who did not undergo left ventriculography. Ab = abscess; AR = aortic regurgitation; Dehisc = dehiscence; MR = mitral regurgitation; TR = tricuspid regurgitation; Veg = vegetation(s); *v* = *v* wave on pulmonary capillary wedge tracing; 1+ to 4+ = degree of regurgitation; ··· = not applicable.

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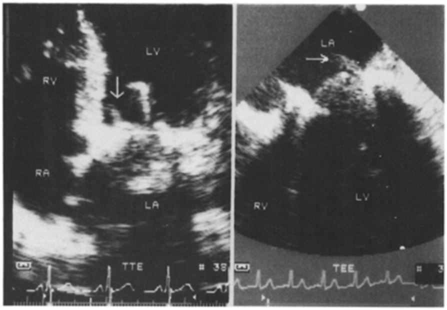

Figure 5. **Left,** Transthoracic (TTE) apical four-chamber view demonstrating a vegetation (arrow) on the left ventricular side of the mitral prosthesis. **Right,** The transesophageal (TEE) four-chamber view shows a vegetation (arrow) at the sewing ring of the valve apparatus protruding in to the left atrium. See text for details. RV = right ventricle; other abbreviations as in Figures 1 and 2.

Patient 23, a 72-year old man with abnormal findings on blood culture, underwent two studies; the first demonstrated a periannular echolucency close to the aortic prosthesis suggestive of an abscess; the second study 1 week later, with the patient receiving appropriate antibiotic therapy, showed enlargement of this area with a new periannular leak more representative of an abscess. These findings were subsequently confirmed at operation. Serial studies in Patient 8, with fever and normal findings on blood culture, initially showed two small masses suggesting an abnormality on either side of the prosthetic valve; 1 week later the masses were smaller and a new one had appeared on a valve strut. These masses were apparent on both surface and transesophageal studies (Fig. 5). Three weeks later the masses were gone. The patient underwent a 6-week course of empiric antibiotic treatment because of his clinical presentation and uncertainty as to whether the findings were vegetation or thrombus. At discharge 4 weeks later, a surface study did not identify any vegetations. Transthoracic and transesophageal studies were obtained after readmission because of hypotension and positive blood cultures for *Klebsiella pneumoniae*. Multiple new masses on the atrial and ventricular sides of the valve were found. The fifth transesophageal [illegible] was performed 10 days after attempted medical management. Rocking motion of the prosthesis as well as new abscess formation in the basal septum near the left ventricular outflow tract were discovered. Three days later the abscess and vegetations were confirmed at operation.

At age 31, Patient 28, with Starr-Edwards mitral and aortic valves and a porcine tricuspid valve, underwent serial studies when she presented with fever and abnormal blood culture findings. Multiple mitral valve vegetations were visible with periannular leakage (Fig. 6). After 3 weeks of antibiotic therapy, the vegetations were gone but the perivalvular leaks persisted. At operation, the vegetations and dehiscence were confirmed. Postoperative study showed less mitral regurgitation and no vegetations. Five months later she had congestive heart failure and fluoroscopy revealed that the new Starr-Edwards mitral valve was rocking severely. Transesophageal echocardiography demonstrated severe mitral regurgitation with periannular leaking and an abscess cavity extending toward the left atrial appendage with fistula formation (Fig. 7). Surgery was believed to be too dangerous in light of her multiple operations, and the patient died suddenly several months later. Patient 4, with a Starr-Edwards mitral valve and Bjork-Shiley aortic valve, underwent serial studies to evaluate lactic acidosis and hemodynamic decompensation. She was found to have a mitral valve vegetation, severe mitral regurgitation and a probable aortic valve abscess. Catheterization showed a rocking mitral valve. She underwent mitral and aortic valve replacements and died shortly thereafter. Transesophageal studies performed 5 months apart in Patient 35, with low grade fever and elevated fungal serologic levels, did not demonstrate signs of infection. Antifungal treatment was discontinued, and the patient has done well.

Valve age >12 years. Seventeen of the Starr-Edwards valves inspected had been implanted for >12 years. Ten valves appeared to be functioning normally with no significant regurgitation. However, in six patients without concurrent endocarditis one aortic and five mitral valves had ≥2+ regurgitation by transesophageal echocardiography. These six patients did not undergo cardiac catheterization or further procedures for confirmatory evidence. It is unknown whether any of these older valves were of the cloth-covered variety. The oldest Starr-Edwards valve had trivial regurgitation after 21 years in the aortic position. No prosthetic valve implanted for <12 years had ≥2+ mitral regurgitation unless concurrent endocarditis was present.

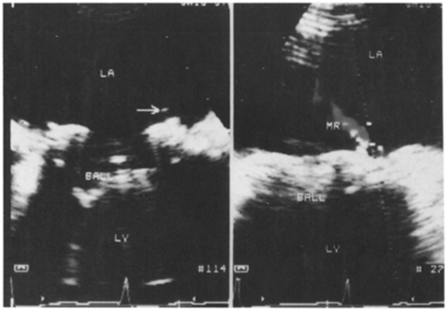

Figure 6. Patient 28. Transesophageal echocardiogram, four-chamber long-axis view, from a 31-year old woman with *Staphylococcus aureus* endocarditis before her fourth open heart operation, during which another Starr-Edwards mitral valve was placed. **Left,** arrow points to a small vegetation. **Right,** When Doppler color flow imaging is added, a perivalvular leak is seen (MR). Abbreviations as in Figure 1.

Discussion

Starr-Edwards prostheses have been in use for the longest period of time and more long-term data are available on these valves than on any other metallic valve (7,8). The earliest valve was made with a stainless steel outflow and cages and contained a silicon rubber poppet. A high rate of thromboembolism and degeneration of the silicon poppet caused by ball variance in the aortic prosthesis resulted in conversion to a metallic hollow poppet and a cloth-covered cage. Because of problems with cloth breakdown leading to hemolysis and tissue ingrowth, the latest design with bare metal struts was introduced in 1966 (9,10).

The present study comprises the largest series to date of transesophageal echocardiographic studies on patients with Starr-Edwards prosthetic valves. The superiority of transesophageal echocardiography over transthoracic echocardiography in this prosthesis is quite clear. Our observations indicate that three clinical situations involving Starr-Edwards valves warrant strong consideration for performance of transesophageal echocardiography in the presence of a negative high quality transthoracic echocardiogram: 1) suspected endocarditis, 2) embolic event, and 3) suspected valve dysfunction.

Endocarditis. The detection rate of endocarditis related to native valves is higher for transesophageal than for transthoracic echocardiography (11,12). The present study confirms and extends previous observations demonstrating the superiority of transesophageal versus transthoracic echocardiography in suspected prosthetic valve endocarditis. Khandheria et al. (13) studied 50 patients with prosthetic valves in the mitral position, including four Starr-Edwards valves affected with surgically confirmed bacterial endocarditis. Abscess or vegetation formation was visible on all four valves by transesophageal study and none by trans-

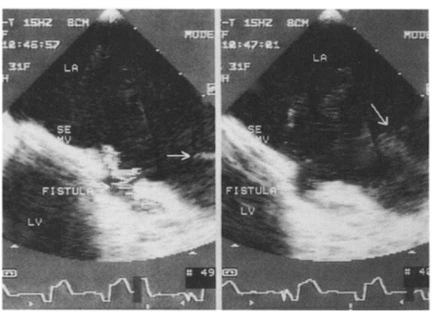

Figure 7. Patient 28 (same patient as in Fig. 6). Five months after mitral valve replacement, a new fistula formation is seen. The arrows point to a large mass in the left atrium (LA), which is probably a vegetation. SEMV = Starr-Edwards mitral valve; other abbreviations as in Figure 1.

thoracic examination. Results of the present investigation are similar in patients with mitral prosthetic valve endocarditis with transesophageal echocardiography demonstrating far superior sensitivity for abscess or vegetation than that of transthoracic echocardiography. In addition, transesophageal echocardiography was superior to catheterization in demonstrating specific lesions (abscess, vegetation) due to endocarditis. Thus, transesophageal echocardiography would appear to be the technique of choice for diagnosing and defining the extent of valvular and perivalvular involvement in Starr-Edwards prosthetic valve endocarditis.

Thrombus. The present investigation also demonstrates the usefulness of transesophageal echocardiography in patients with Starr-Edwards prostheses who have had embolic events. Thrombus was identified in 8 of the 11 patients who had transient ischemic attacks or cerebrovascular events. Surgical confirmation was available in three cases. Only two of the nine patients with positive findings on transesophageal studies had an abnormality on surface study suggestive of thrombus. Before transesophageal echocardiography was available, small, nonobstructive thrombi responsible for cerebral ischemic events could not be detected. With this technique, these thrombi can be readily detected and treatment modified accordingly. Serial studies have allowed determination of the response to modified therapy.

Physiologic regurgitation. From the present observations, a "normal" pattern of Starr-Edwards regurgitation can be defined. Previous transesophageal echocardiographic studies (14) included only small numbers of Starr-Edwards valves with differing characteristics. Doppler evidence of mild regurgitation has been a frequent finding in normal aortic and mitral valve replacement with other metallic valves (15). A previous transesophageal study that included five Starr-Edwards mitral valves described a color flow jet consisting of two confluent jets 2 cm long that were observed only in early systole (16). In 14 patients with a Starr-Edwards mitral valve, Khandheria et al. (13) found 7 with minimal regurgitation due to valve closure. In the present study, the closing volume jet was observed by transesophageal echocardiography in 26 (87%) of 30 patients with a mitral Starr-Edwards prosthesis. This regurgitation is an early systolic transvalvular leak with central flow of trivial or mild severity, not seen on transthoracic evaluation. All of the remaining patients had pathologic regurgitation. Such jets were not noted on the aortic prostheses, a finding that is probably related more to limitations of transesophageal echocardiography in visualizing the left ventricular outflow tract than to design differences between aortic and mitral valves.

Pathologic regurgitation. In comparison with transesophageal echocardiography, transthoracic echocardiography either underestimated the severity or missed completely five of eight cases of significant (≥2+) mitral regurgitation (Table 2). This result confirms previous observations (13–15) that results of transthoracic echocardiography can be normal in patients with severe dysfunction of a mechanical mitral prostheses.

The sample size of seven patients with an aortic prosthesis alone is too small to make definitive statements comparing transthoracic and transesophageal studies. However, there was a good correlation of transesophageal findings with aortic root angiography (Table 3) in seven patients, two with an aortic valve prosthesis alone, and four with mitral and aortic Starr-Edwards valves.

The transesophageal echocardiographic assessments of severity of valve regurgitation of Starr-Edwards valves correlate with those of angiography in most cases. The transesophageal study also outlines abscess and vegetation formation when, as in our patients, angiography generally identifies only the results of the inflammatory response—namely, valve dehiscence and regurgitation. The transesophageal study was especially invaluable in three of the patients who had prosthetic aortic and mitral valves by making transseptal or left ventricular puncture unnecessary.

Eight patients with both aortic and mitral Starr-Edwards valves constituted a small subset. Interference of visualization of the aortic valve by the reverberations of the mitral valve may occur with transesophageal echocardiography. Our sample size is too small to provide definitive answers; however, a good correlation was found between transesophageal echocardiography and catheterization data in the four patients in whom it was obtained.

The present study also illustrates the longevity of these valves. The oldest valve, implanted in the aortic position for 21 years, shows normal function and mild regurgitation. The durability of Starr-Edwards valves has been discussed in several review articles (7,8). McGoon and coworkers (7) found only three instances of primary valve malfunction in 336 patients with a mean valve duration of 15 years from the time of implantation to the time of study. In the Mayo Clinic study (13), one of four Starr-Edwards mitral valves implanted for >12 years manifested dehiscence and severe regurgitation. In our study, 38% of the valves implanted >12 years previously demonstrated significant regurgitation without underlying endocarditis. The valves in the present study should not have a tendency to develop ball variance. The more sensitive method of transesophageal echocardiography may enable clinicians to provide early detection of future valve problems.

Limitations of present study. There have been no transesophageal studies quantifying prosthetic valve mitral or aortic regurgitation and only limited transesophageal studies quantifying native valve mitral or aortic regurgitation. Extrapolating these data to determine the extent of prosthetic valve regurgitation in the present study may therefore prove misleading.

Use of a single-plane transducer may have limited the quantification of aortic regurgitant flow and prevented identification of a "closing volume" of the Starr-Edwards valve in this position. Also, in quantifying mitral regurgitation, one recent study (4) showed that the best correlation with angiography was obtained when the greater of the two jet areas found with a biplane transducer (longitudinal vs. transverse) was used.

Because transthoracic echocardiography was performed first in all cases, there is a bias against this method inherent in the study design. The small sample size and small numbers of patients with findings confirmed anatomically makes determining sensitivity and specificity with accuracy impossible.

The present investigation includes catheterization data. Comparing these tests is problematic because the studies were not performed simultaneously or even on the same day in many instances. Clearly, variations in loading conditions could alter findings, especially in quantifying the severity of valve regurgitation. Grayburn et al. (17) found that day to day within-subject variation of maximal color jet area of mitral regurgitation on surface echocardiography was not significant when patients were receiving stable doses of diuretic agents and were not receiving antihypertensive agents or vasodilators. Also several of the catheterizations did not involve a left ventricular angiogram, and estimation of mitral regurgitation was based on v wave data. Because most of the two types of echocardiographic studies were performed consecutively within minutes of each other, these uncontrolled variables should be less important. Another limitation is the lack of confirmation of findings in patients with regurgitation not due to endocarditis. However, several studies (2,3,18) have shown an excellent correlation between severity of mitral regurgitation by Doppler color flow imaging using the transthoracic approach and angiography. Transesophageal Doppler color flow imaging has also been shown to provide reliable estimates of mitral regurgitation in comparison with catheterization (19).

Conclusions. Transesophageal echocardiography is a valuable technique for assessing prosthetic valves. Because of the lack of acoustic shadowing by the prosthetic valve, the transducer's proximity to posterior cardiac structures, the lack of bone or lung artifact as well as the clarity of the pictures, it has a distinct advantage over transthoracic echocardiography. A trivial early systolic "closing volume" is commonly observed on transesophageal studies and is not significant. Older valves may exhibit an increase in mitral insufficiency, which may be of little concern. In this investigation, transesophageal echocardiography was an important adjunctive tool to transthoracic studies in identifying and following up patients with endocarditis and thrombus on Starr-Edwards valves in the mitral and aortic positions. It appeared to have the greatest merit in detecting mitral regurgitation when the surface study was inadequate.

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References

1. Sprecher DI, Adamick R, Adams D, Kissilo J. In vitro color flow pulsed and continuous wave Doppler ultrasound masking of flow by prosthetic valves. J Am Coll Cardiol 1987;9:1306–10.
2. Helmcke R, Nanda NC, Hsiung MC, et al. Color Doppler assessment of mitral regurgitation with orthogonal planes. Circulation 1987;75:175–83.
3. Spain MG, Smith MD, Grayburn PA, Harlamert EA, DeMaria AN. Quantitative assessment of mitral regurgitation by Doppler color flow imaging: angiographic and hemodynamic correlations. J Am Coll Cardiol 1989;13:585–90.
4. Yoshida K, Yoshikawa J, Yamaura Y, Hozumi T, Akasaka T, Fukaya T. Assessment of mitral regurgitation by biplane transesophageal color Doppler flow mapping. Circulation 1990;82:1121–6.
5. Castello R, Fagan L, Lenzen P, Pearson AC, Labovitz AJ. Comparison of transthoracic and transesophageal echocardiography for assessment of left-sided valvular regurgitation. Am J Cardiol 1991;68:1677–80.
6. Jaffe WM, Morgan DE, Pearlman AS, Otto CM. Infective endocarditis, 1983–1988: echocardiographic finding influencing morbidity and mortality. J Am Coll Cardiol 1990;15:1227–33.
7. McGoon MD, Fuster V, McGoon DC, Pumphry CV, Pluth JR, Elueback LR. Aortic and mitral valve incompetence: long-term follow-up (10 to 19 years) of patients treated with the Starr-Edwards prosthesis. J Am Coll Cardiol 1984;3:930–8.
8. Best JF, Hassanein KM, Pugh DM, Dunn M. Starr-Edwards aortic prosthesis: a 20-year retrospective study. Am Heart J 1986;111:136–42.
9. Silverman NA, Levitsky S. Current choices for prosthetic valve replacement. Mod Concepts Cardiovasc Dis 1983;52:35.
10. Kotler MN, Mintz GS, Panidis I, Morganroth J, Segal BL, Ross J. Noninvasive evaluation of normal and abnormal prosthetic valve function. J Am Coll Cardiol 1983;2:151–73.
11. Mugge A, Daniel WG, Frank G. Echocardiography in infective endocarditis: reassessment of prognostic implications of vegetation size determined by the transthoracic and transesophageal approach. J Am Coll Cardiol 1989;14:631–8.
12. Shively BK, Gurule FT, Roldan CA, Leggett JH, Schiller NB. Diagnostic value of transesophageal compared with transthoracic echocardiography in infective endocarditis. J Am Coll Cardiol 1991;18:391–7.
13. Khandheria BK, Seward JB, Oh JK, et al. Value and limitations of transesophageal echocardiography in assessment of mitral valve prostheses. Circulation 1991;83:1956–68.
14. Chaudhry FA, Herrera C, DeFrino PF, Mehlman DJ, Zabalgoitia O. Pathologic and angiographic correlations of transesophageal echocardiography in prosthetic heart valve dysfunction. Am Heart J 1991;122:1057–64.
15. Cooper DM, Stewart WJ, Schiavone WA, et al. Evaluation of normal prosthetic valve function by Doppler echocardiography 1987;114:576–82.
16. Van den Brink RBA, Visser CA, Basart DCG, Duren DR, de Jong AP, Dunning AJ. Comparison of transthoracic and transesophageal color Doppler Flow imaging in patients with mechanical prostheses in the mitral valve position. Am J Cardiol 1989;63:1471–4.
17. Grayburn PA, Pryor SL, Levine BD, Klein MN, Taylor AL. Day to day variability of Doppler color flow jets in mitral regurgitation. J Am Coll Cardiol 1989;14:936–40.
18. Miyatake K, Shiro I, Okamoto M, et al. Semiquantitative grading of severity of mitral regurgitation real-time two-dimensional Doppler flow imaging technique. J Am Coll Cardiol 1986;7:82–8.
19. Nellessen U, Schnittger I, Appleton CP, et al. Transesophageal two-dimensional echocardiography and color flow velocity mapping in the evaluation of cardiac valve prostheses. Circulation 1988;78:848–55.