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Contrast echocardiographic shunts may persist after atrial septal defect repair

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We performed contrast echocardiography on 19 subjects who were asymptomatic in the postoperative period after surgical repair of atrial septal defects. Eighteen of these subjects had adequate right heart echocardiographic contrast to assess the presence or absence of right-to-left shunting. Multiple M-mode and two-dimensional echocardiographic views were studied during several contrast injections with and without the Valsalva manoeuvre. Six patients had postoperative shunts and 12 patients had no postoperative shunts. The age of the six patients with postoperative shunts was 26 ± 10 years (mean ± s.d.) and that of the 12 patients without postoperative shunts was 39 ± 14 years.

Four out of six of the postoperative shunt group were males and of these three had patch repairs compared with two males out of 12 with patch repair in the no shunt group. There were no definite differences between the two groups in the following variables: type of atrial septal defect (primum v. secundum), pre-operative shunt size, pre-operative peak right ventricular pressure, pre-operative New York Heart Association functional class, pre- or postoperative right ventricular or left ventricular dimensions, aortic and left atrial dimensions. Four of the six patients with postoperative contrast echo shunting underwent cardiac catheterization, showing no significant step-up in oxygen saturation in three, and a significant shunt in one patient who had patch dehiscence at re-operation. We conclude that right-to-left shunts as demonstrated by contrast echocardiography are common in the late postoperative period after atrial septal defect repair. They need not indicate unsuccessful repair or a haemodynamically important residual shunt.

Contrast echocardiography (CE) is a sensitive method for the detection of atrial septal defects (ASD). A small right-to-left shunt is always present in patients with uncomplicated ASD. Even in the absence of oximetric evidence, these shunts are frequently demonstrated by CE[1–7]. Since it is non-invasive, simple and safe when properly performed, CE is an attractive and practical method for the study of patients with known or suspected ASD.

Persistent shunts have been demonstrated by CE during the first three to five days after surgical correction of ASD[8]. It is also known that M-mode echocardiographic abnormalities indicating right ventricular volume overload do not always resolve after ASD closure[9–13]. Recently we studied two asymptomatic patients who demonstrated residual right-to-left shunting by CE long after operative closure of their ASD (the first patient was referred to us because of clinical findings suggesting the presence of a residual ASD and the second patient underwent CE study as part of an unrelated research protocol). We were unsure whether this shunting implied an unsuccessful operative result, and thus decided prospectively to explore the prevalence of residual shunting in the late postoperative period after ASD closure.

Patients

The study consisted of 19 patients who had undergone surgical repair of an ASD. Patients 1 and 2 were the index cases. Seventeen patients were studied prospectively. Since an adequate CE study

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Table 1 Clinical and haemodynamic data

Patient No.	Age/sex	Type of ASD	Pre-op. NYHA class	Peak RVSP (mm Hg)	Pre-op. aortic sat.(%)	Type of repair	OP-CE time
1	23 F	II	I	25	97	pr	11 years
2	25 M	I	I	32	98	patch	2 months
3	43 M	II	II	49	98	pr + CABG	$1\frac{1}{2}$ years
4	17 M	II	I	28	95	patch	7 years
5	31 F	II + PAPVD + LSVC	I	35	97	patch	$1\frac{1}{4}$ years
6	17 M	II	I	28	98	pr	$1\frac{1}{4}$ years
7	31 F	II	I	30	97	pr	4 months
8	29 F	II	I	24	97	pr	5 days
9	48 F	I	II	20	96	patch	5 months
10	47 F	II	I	30	98	pr	4 months
11	21 F	II	I	39	97	pr	1 month
12	48 F	II	I	32	96	pr	$2\frac{3}{4}$ years
13	54 M	II	II	33	97	pr	10 months
14	22 F	II+ PAPVD	I	47	98	pr	11 months
15	42 F	II	I	28	96	pr	4 years
16	48 F	II	II	39	95	pr	1 month
17	16 M	II	I	50	99	pr	8 years
18	58 F	II	II	40	95	pr	11 months

Abbreviations: type of ASD I = primum; II = secundum; NYHA = New York Heart Association classification; Qp/Qs = pulmonary to systemic flow ratio; RVSP = right ventricular systolic pressure; sat. = saturation; OP–CE time = interval between ASD closure and postoperative contrast echo study; F = female; M = male; pr = primary suture; CABG = coronary artery bypass surgery; PAPVD = partial anomalous pulmonary venous drainage; LSVC = left superior vena cava.

could not be obtained in one patient, he was excluded from further analysis. Of the remaining 18 patients, six were male and 12 were female (Table 1). Their ages ranged from 17 to 58 years (mean 34). All patients had ASD diagnosed at pre-operative cardiac catheterization and confirmed at surgery. Two patients had an ASD of the primum type and 16 had an ostium secundum ASD. Two patients had associated anomalous pulmonary venous drainage and one of these had persistence of a left superior vena cava draining into the coronary sinus. No other congenital abnormalities were present. One patient had single-vessel coronary disease. Pre-operative shunt size was $3{\cdot}5 \pm 1{\cdot}6$ (pulmonary to systemic flow ratio).

The peak right ventricular systolic pressure ranged from 20 to 50 mm HG. Twelve patients were in New York Heart Association class I and six were in class II. The defect was closed with primary suture in 13 patients and patch graft in five patients (Table 1).

The time between ASD repair and CE was more than one year in eight patients, between one month to one year in nine patients and one patient was studied five days postoperatively.

Methods

M-mode echocardiograms were obtained with an EchocardioVisor SE (Organon Teknika) and recorded on light sensitive paper with a Honeywell LS6 recorder. Two-dimensional echocardiograms were made with a Toshiba SSH–10A phased array sector scanner or an Organon Teknika Echo-cardio-Visor 03 linear array instrument. Images were recorded on videotape for subsequent analysis. Stop frame images were obtained by Polaroid photography.

All CE examinations were performed with the patient in the left lateral decubitus position. Echocardiographic contrast was produced by a forceful hand injection of 5 to 10 ml of 5% dextrose in a water solution through a 16 or 18-gauge Teflon venous cannula placed in an antecubital vein. At least 10 injections were performed in each patient.

During recording of M-mode echocardiograms, CE was performed in two sound beam directions: (1) right ventricular outflow tract — aortic — left atrial level, and (2) mitral valve level. The projections employed for CE with two-dimensional echocardiography were the (1) parasternal long axis view, (2) parasternal short axis view at the level of aortic valve, (3) apical four-chamber view, (4) apical long axis view, and if possible (5) the subcostal short axis and (6) right parasternal views[14]. Attention was focused on the interatrial septum in each view (except the parasternal long axis view).

In 14 patients CE was also performed during the Valsalva manoeuvre to increase the amount of right-to-left shunting. This manoeuvre was done by blowing with an open glottis in a mouthpiece connected to a mercury manometer and holding the pressure above 30 mm Hg for about 10 s. Careful patient instruction was necessary to prevent the patient from taking a deep breath on release, obscuring the echocardiogram just at the moment when shunting is likely to be present during the CE study.

The pre-operative M-mode tracings were available in 14 patients and analysed in the same manner as the postoperative tracings (see below).

Data analysis

Each M-mode and two-dimensional study was assessed for the presence of right-to-left shunting. Two-dimensional studies were also assessed for the presence of left-to-right shunting (on the basis of negative contrast effect)[15]. Right-to-left shunting was considered present when contrast echoes appeared in one or more of the following areas: left atrium, mitral orifice, left ventricular outflow tract or aorta. To avoid false positive interpretation as a result of overload effects, care was taken to use gain

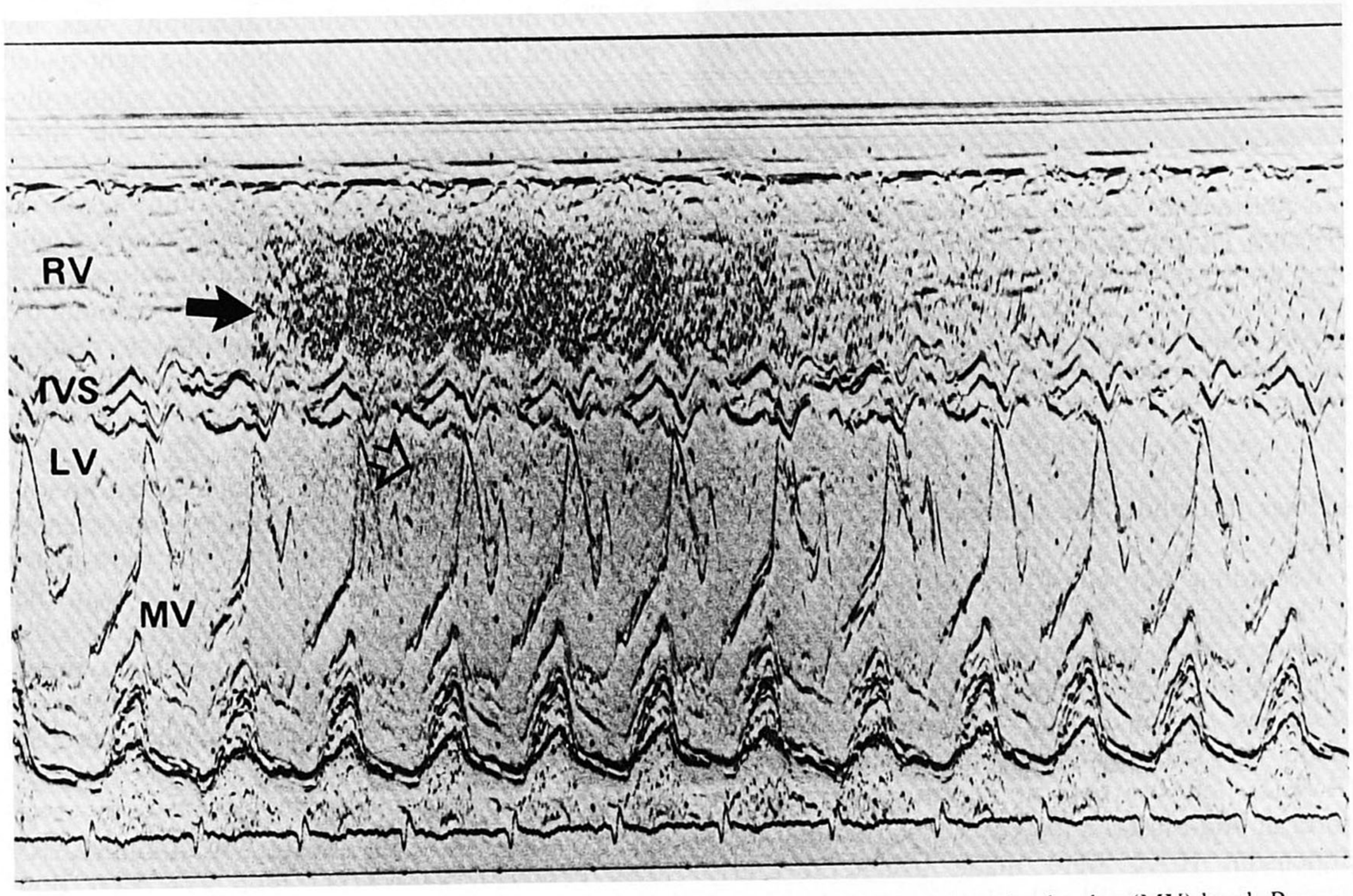

Figure 1 Postoperative M-mode contrast echocardiogram from patient 4 at the mitral valve (MV) level. Peripheral venous injection of 5% dextrose solution performed before the start of this tracing. Note presence of contrast in the right ventricle (RV) (closed arrow) and left ventricle (LV) (open arrow), indicating an intracardiac shunt. IVS = interventricular septum.

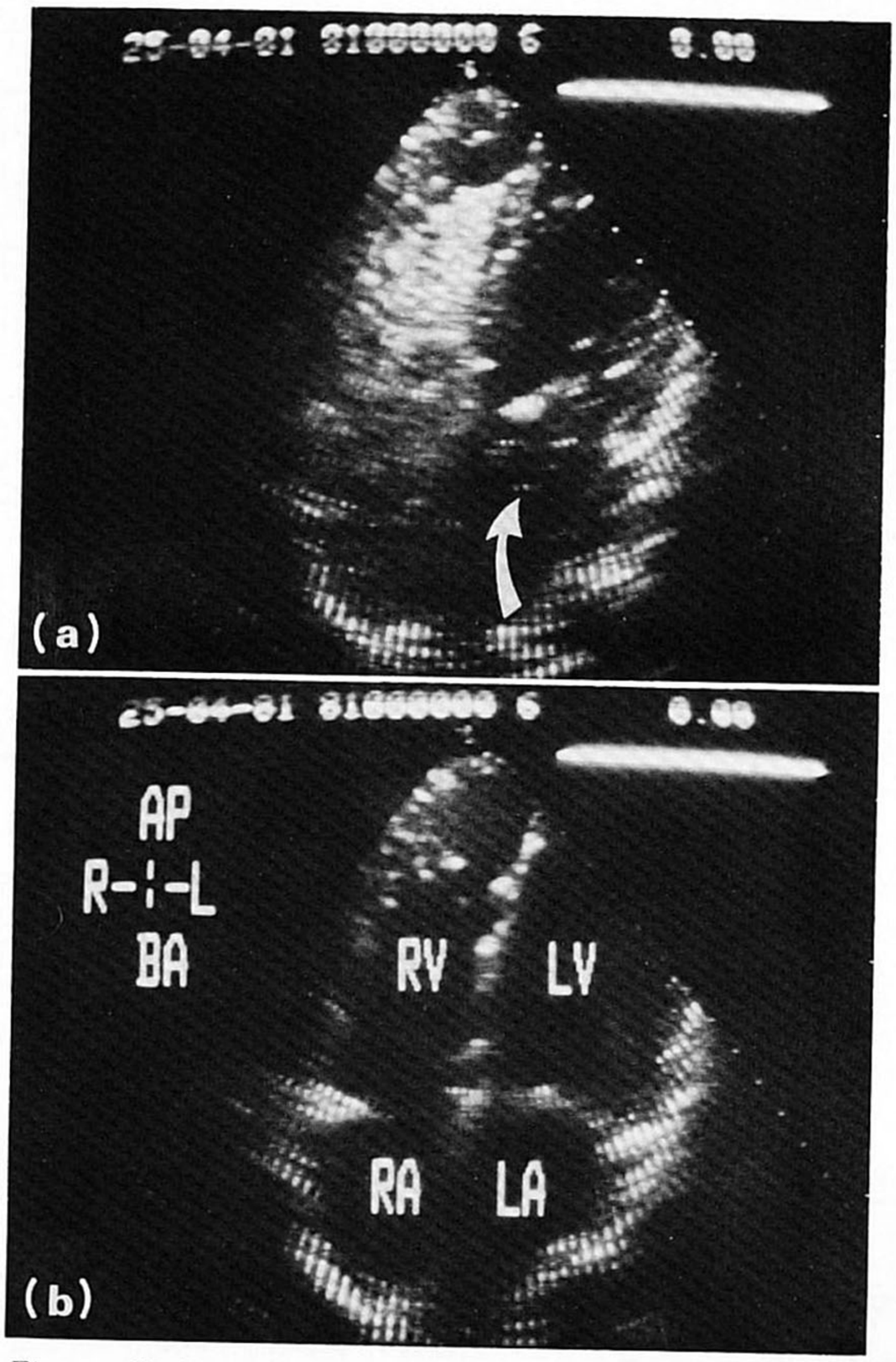

Figure 2 Stop-frame Polaroid photograph from the two-dimensional contrast echocardiographic study of patient 2. (a) Just before contrast injection, (b) 10 s later. Note dense contrast in the right atrium (RA) and right ventricle (RV), and less dense contrast in the left atrium (arrow) again indicating intracardiac shunt. AP = apical; BA = basal; R = right; L = left; LA = left atrium; LV = left ventricle.

settings just under the threshold for intracavitary noise.

Recordings were considered adequate for analysis if the right-sided heart chambers were densely opacified with contrast echoes (Figs 1 and 2). Interpretations were made by two independent observers. M-mode echocardiographic measurements of the right ventricle at end-diastolic (RVED), left ventricle at end-diastolic (LVED), aorta at end-diastolic (Ao) and maximal left atrial dimension (LA), were made using previously described methods[16]. The interventricular septal (IVS) motion on M-mode echocardiogram was classified as normal, intermediate, or paradoxical. Left-to-right shunting was diagnosed by the presence of a negative contrast effect along the right margin of the interatrial septum.

Clinical (age, sex, pre-operative shunt size, pre-operative peak right ventricular systolic pressure, pre-operative New York Heart Association functional class, type of ASD, patch or suture closure) and echocardiographic (RVED, LVED, Ao, LA, type of IVS motion) data for the patients with post-operative shunts were compared to those of patients without postoperative shunts using Student's unpaired t-tests or the chi-square test. Pre-and post-operative changes in echocardiographic measurements were compared using the paired Student's t-test.

Results

PRESENCE OF SHUNTS

Six of the 18 patients had right-to-left shunts post-operatively (patients 1 to 6). These included the two index patients and four of the prospectively studied 16 patients with adequate CE. Examples of studies with residual shunts are shown in Figs 1 and 2. Two-dimensional echocardiography was not performed in patient 1, in whom the right-to-left shunt was demonstrated by M-mode echocardiography alone. Patient 3 had no detectable shunt during resting M-mode and two-dimensional CE, but showed repeated right-to-left shunting during the strain phase of the Valsalva maneouvre. Right-to-left shunting was demonstrated in patients 2, 4, 5 and 6 on both M-mode and two-dimensional CE without Valsalva. Twelve patients had no residual shunting by either M-mode or two-dimensional CE despite Valsalva manoeuvres during several of the contrast injections.

Three subjects (patients 1, 2 and 4) had no oximetric evidence of a residual postoperative shunt by heart catheterization shortly after right-to-left shunts were demonstrated on their CE. One further subject (patient 5) had a large step-up in right-sided oxygen saturations. This patient became symptomatic again shortly after her positive postoperative contrast echo study. At re-operation the interatrial patch was loose.

Right-to-left shunts were detected by two-dimensional CE in the apical four-chamber view (five patients), parasternal long axis view (four patients) and parasternal short axis view (three patients) of the five patients showing right-to-left shunt on two-dimensional CE. Two of the five patients with positive CE in the apical fourchamber

view had echo discontinuity of the interatrial septum. In one of these the discontinuity was also seen in the parasternal short axis view at the level of the aortic cusps. Right-to-left shunting was detected in the other three patients in the absence of an echocardiographic discontinuity in the interatrial septum. Three of the 12 patients without demonstrable shunt had echocardiographic discontinuity of their interatrial septum in the apical four-chamber view. In none of the 18 patients studied was a definite negative contrast effect seen in the right atrium.

CLINICAL DIFFERENCES BETWEEN PATIENTS WITH AND WITHOUT SHUNTS (TABLE 1)

The six patients with residual shunts (patients 1 to 6) did not differ from the 12 patients without shunts (patients 7 to 18) in the following parameters: type of ASD (five secundum, one primum *v.* 11 secundum, one primum), pre-operative shunt size (Qp/Qs = 2·8 ± 1·0 *v.* 3·8 ± 1·8, mean ± s.d.), pre-operative peak right ventricular systolic pressure (22 ± 9 *v.* 34 ± 8 mm Hg), pre-operative New York Heart Association Classification (five class I, one class II *v.* eight class I, four class II), age (26 ± 10 *v.* 39 ± 14 years), sex (4/6 males *v.* 2/12 females), or proportion of the patients with patch as opposed to primary suture closure (3/6 *v.* 1/12). Though these differences did not reach statistical significance, it is possible that some tendencies were masked by the small number of patients. All patients were asymptomatic after surgery and all except patient no. 5 (see above) remained so.

The time betwen ASD repair and CE study was 44 ± 52 months (mean ± s.d.) in patients with postoperative shunts and 19 ± 28 months in patients without shunts. In five of the six patients with shunts, CE was performed more than one year after surgery as compared to three of the 12 patients without shunts.

ECHOCARDIOGRAPHIC DIFFERENCES BETWEEN PATIENTS WITH AND WITHOUT SHUNTS (TABLE 2)

There was no difference between patients with and without postoperative shunts in the following pre-operative echocardiographic parameters: right ventricular dimension (44 ± 22 *v.* 46 ± 10 mm), left ventricular end-diastolic dimension (43 ± 5 *v.* 38 ± 15 mm), left atrial dimension (35 ± 10 *v.*

Table 2 Echocardiographic findings

Patient no.	Pre-operative						Postoperative							
	RV (mm)	LVED (mm)	Ao (mm)	LA (mm)	IVS	CE	RV (mm)	LVED (mm)	Ao (mm)	LA (mm)	IVS	CE	CE+V	IAS
1	ND						45	40	25	33	P	+	ND	ND
2	30	38	28	34	P	+	22	48	30	32	P	+	ND	ED
3	55	45	28	48	P	–	32	50	35	41	N	–	+*	C
4	ND						20	44	33	33	I	+	+	ED
5	70	50	30	48	P	ND	10	57	27	31	P	+	+	C
6	22	40	28	28	N	–	17	51	34	40	N	+	ND	C
7	48	38	24	44	P	+	32	45	28	38	I	–	–	ED
8	42	42	23	32	P	+	37	45	21	28	N	–	ND	C,IE
9	40	38	28	38	P	+	23	40	30	40	P	–	–	ED
10	45	30	35	28	P	+	41	34	34	40	I	–	–	C
11	48	40	28	32	P	ND	21	46	30	30	I	–	–	C
12	25	52	32	45	N	ND	21	50	28	48	N	–	–	C
13	65	50	40	50	P	ND	38	49	37	43	I	–	–	C
14	40	40	30	30	P	ND	24	40	28	28	N	–	–	ED
15	53	41	40	45	P	ND	36	50	39	41	N	–	–	C
16	ND						40	50	32	43	I	–	–	C
17	ND						25	46	29	28	I	–	–	C
18	50	50	28	45	P	ND	20	38	27	31	I	–	–	C

Abbreviations: RV = right ventricle; LVED = left ventricular end-diastolic dimension; Ao = aortic root diameter; LA = left atrial dimension; IVS = interventricular septal motion; CE = contrast echocardiography; V = Valsalva; IAS = interatrial septal appearance on 2D echo; ND = not done; * = two-dimensional echocardiogram; P = paradoxical; I = intermediate; N = normal; ED = echodiscontinuity; C = continuous; IE = increased echoes from area of IAS on 2D echo.

39 ± 8 mm), aortic root diameter (29 ± 1 *v.* 30 ± 7 mm) and prevalence of abnormal (paradoxical or intermediate) interventricular septal motion (3/4 *v.* 9/10).

There was also no difference between the patients with and without shunts in the following postoperative echocardiographic parameters: right ventricular dimension (24 ± 12 *v.* 29 ± 8 mm), left ventricular end-diastolic dimension (48 ± 6 *v.* 44 ± 5 mm), left atrial dimension (35 ± 4 *v.* 37 ± 7 mm), aortic root diameter (31 ± 4 *v.* 30 ± 5 mm), abnormal interventricular septal motion (4/6 *v.* 8/12), discontinuity of the interatrial septum by two-dimensional echocardiographic (2/5 *v.* 3/12).

No echocardiographic finding could differentiate a primary suture closure of the defect from a patch closure. One patient (no. 8) whose ASD was repaired with a primary suture closure had a highly reflective and thickened midportion of the interatrial septum. None of the remaining 11 patients without echo discontinuity in the interatrial septum or the five patients with such discontinuity present showed any abnormal echoes or thickening of the septum (Table 2).

COMPARISON BETWEEN PRE-OPERATIVE AND POSTOPERATIVE M-MODE ECHOCARDIOGRAPHIC FINDINGS

Four of the six patients with residual postoperative shunting and 10 of the 12 patients without postoperative shunting had pre-operative M-mode tracings available for analysis.

The only echocardiographic parameter which showed a statistically significant difference before and after surgery was the right ventricular dimension (Table 2). In all patients with pre-operative echocardiograms available for comparison, the right ventricular dimension decreased after surgery (Fig. 3). It was 45 ± 14 mm (mean ± s.d.) pre-operatively and became 29 ± 9 mm (mean ± s.d.) postoperatively ($P < 0{\cdot}001$). The decrease in right ventricular dimension was similar in patients with or without postoperative shunts (Table 2, Fig. 3).

Postoperative right ventricular dilatation was found in two patients with postoperative shunts detected by CE. One of these (patient 1) was the patient whose postoperative catheterization revealed no oximetric evidence of shunting, and the other patient showed contrast shunting only during Valsalva manoeuvre. On the other hand, six of the 12 patients without CE evidence of shunting still had right ventricular dilatation. There was no significant correlation between age at operation and right ventricular dimension on the postoperative M-mode echocardiogram.

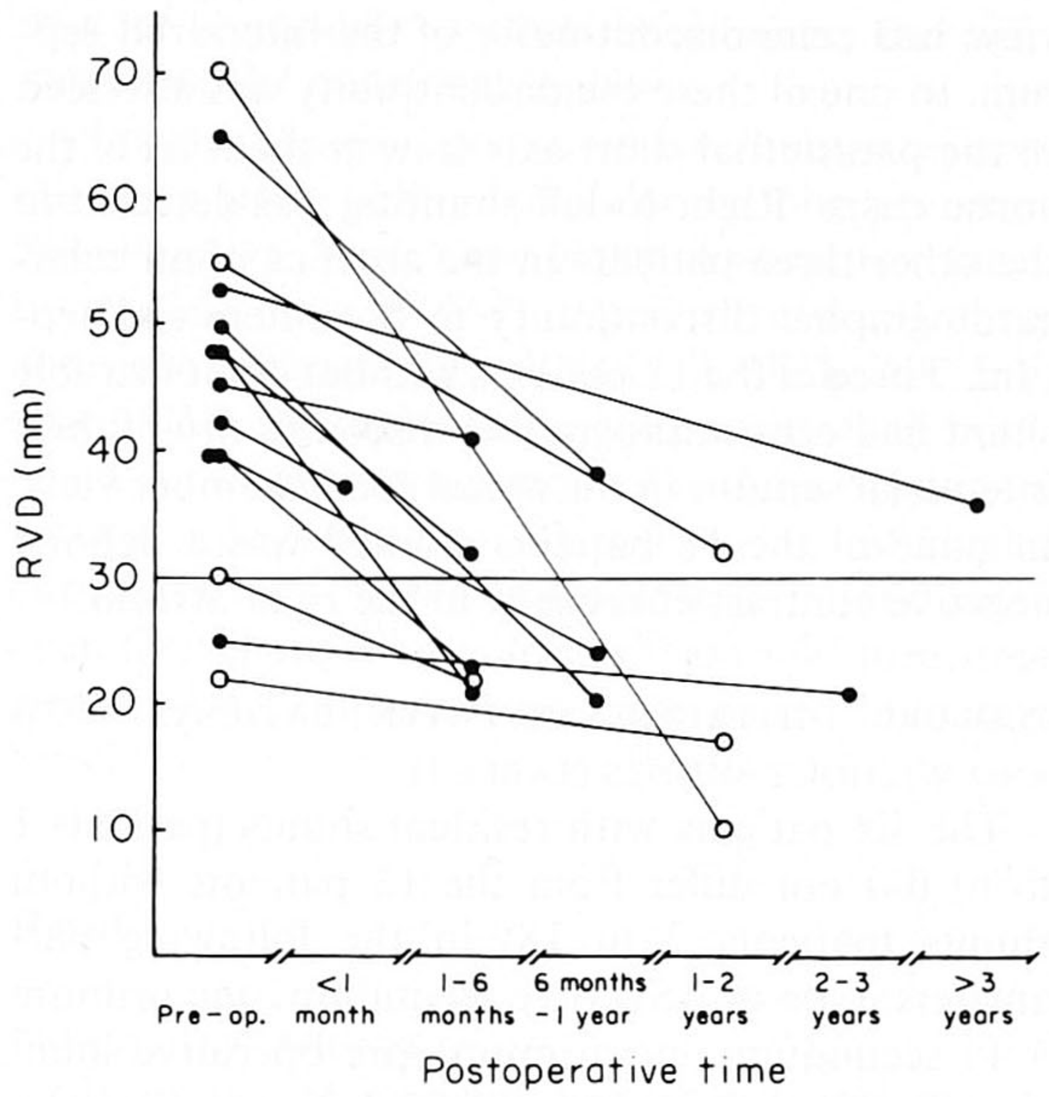

Figure 3 Right ventricular dimension (RVD) is displayed on the ordinate (in mm) pre-operatively (left) and postoperatively (right). Solid lines connect the pre-operative and postoperative studies of each individual patient. ○ = Patients with residual postoperative shunting by contrast echo; ● = patients without residual shunting. Note that there is no definite correlation between RVD and the interval between operation and postoperative echo (x axis). Line through 30 mm represents upper limit of normal.

Discussion

CONTRAST ECHOCARDIOGRAPHY FOR ASD DETECTION

Contrast echocardiography is a sensitive and specific technique for the detection of right-to-left intracardiac shunts[1–7,17]. Various series report sensitivity in detecting ASD at 75 to 100%, even in the absence of demonstrable arterial desaturation[3,5–7,17]. Technique variation with respect to the cross-sectional views employed, performance of Valsalva manoeuvre and insistence on adequate right heart opacification before judging a study to be negative probably explain the different reported sensitivities. The sensitivity of CE has been reported to be higher than oximetry[6,17]. This is not particularly surprising, since oximetry is known to lack sensitivity and small shunts with a pulmonary : systemic flow ratio of less than 2 : 1 are not consistently detected by oximetry[18].

Though uncomplicated ASDs have predominately left-to-right shunts, detailed studies have also consistently shown small amounts of right-to-left shunting[19–21]. This is the reason for the sensitivity of peripheral CE in detecting uncomplicated ASD. Since Valsalva manoeuvre increases the proportion of right-to-left shunting[5,22], it should increase the sensitivity of CE in patients with ASD. It is possible that a Valsalva manoeuvre may cause a 'false positive' right-to-left shunt in a patient with a patent foramen ovale. We have seen one such cause (unpublished data) and Kronik *et al.* have recently reported that three out of five patients with patient foramen ovale and normal right-sided pressure had right-to-left shunt on peripheral CE[22]. There is a report of two cases with paradoxical embolism where ascorbate dye dilution curves showed an interatrial shunt only upon Valsalva manoeuvre[23]. Thus CE may be 'overly sensitive' to interatrial communications — i.e. it can pick up clinically insignificant shunts as well as more major shunts, especially during Valsalva manoeuvre. We suspect that the right-to-left pressure gradient seen in early systole in patients with uncomplicated ASD may partly persist after operation in some patients, and may even be present in some normals, though mean left atrial pressure is higher than right atrial pressure.

CLINICAL AND ECHOCARDIOGRAPHIC STUDIES AFTER SURGICAL ASD REPAIR

Studies of patients who have undergone re-catheterization after surgical closure of ASD suggest that residual defects may be found in as many as 36% of the cases[24,25]. Fortunately, in most of these the shunt size is small (Qp/Qs is less than 1·5/1). These residual postoperative defects may be unsuspected clinically because auscultatory findings may decrease or disappear, heart size may decrease and the electrocardiographic manifestations of right ventricular overload may normalize[26].

Postoperative M-mode echocardiographic studies may also be misleading, since a sizeable number of patients have persistence of right ventricular dilatation and abnormal interventricular septal motion despite no demonstrable shunt at post-operative catheterization[13,24].

Valdes-Cruz *et al.*[8] studied 26 patients with complex congenital heart disease by CE through central venous and left atrial lines in the first 3–5 days after surgical closure of atrial or ventricular septal defects. Using CE they found that residual left-to-right and right-to-left shunts were common. They concluded that 'positive studies in the first day after surgery may represent either temporary flow through the newly implanted patch or shunting across a true residual defect'. They suggested that persistent shunting beyond the early post-operative period would imply a true residual defect. However, none of their patients had only isolated ASD and late follow-up studies were not reported. Therefore the significance of persistent post-operative shunting in an uncomplicated group of patients remained to be determined.

SIGNIFICANCE OF SHUNT DETECTION BY CE IN THE LATE POSTOPERATIVE PERIOD

Of course, a postoperative right-to-left shunt by CE may indicate an unsuccessful operative result, as was the case in patient 5. However, an important finding of this study answers the question posed by our two index cases: that a positive postoperative CE study need not imply an unsuccessful operative result. In fact, this finding is not uncommon.

Of interest is a possible trend toward younger age (26 ± 10 *v.* 39 ± 14 years) and higher proportion undergoing patch closure (3/6 *v.* 1/12) in the post-operative shunt group. The younger age is not due to this group being symptomatic earlier on the basis of larger shunts, since they were generally asymptomatic and did not have larger pre-operative pulmonary : systemic flow ratios compared to the patients without postoperative CE shunts. It is possible that late postoperative CE shunting is facilitated by patch closures via the following mechanism: incompletely *endothelialised* patches or small folds of tissue around the sutures may allow contrast shunting in the absence of a clinically significant shunt. The data in the present series are too limited, though, to elucidate the mechanism further.

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