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Contrast bidimensional echocardiography in the morphologic and functional postoperative evaluation of the Senning technique for complete transposition of the great vessels

Contrast bidimensional echocardiographic (2DE) studies were performed in eight patients with d-transposition of the great vessels in the postoperative period of the Senning technique. Contrast was injected into a peripheral vein of all patients, and into the arterial atrium in five in the postoperative period. The 2DE projections used were the four-chamber apical view and four-chamber subcostal view. In all patients it was possible to see and identify the new atrial cavities which greatly resembled the actual anatomy. Early postoperative alternating injections of contrast in both new atria not only achieved the main purpose of delineating the real anatomy, but also permitted more definitive identification of residual shunts. (AM HEART J 108:110, 1984.)

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While significant interest appears in the arterial switch operation for complete transposition (TGV) which leads to a more anatomic correction,[1-6] there are continued concerns about potential complications of that operation and many surgeons continue to perform physiologic atrial baffling procedures.[7] Of these procedures, the Mustard[8,9] and Senning[10] are the most widely used. The latter, although described in 1959, did not become common practice until 1976,[11,12] 12 years after the Mustard procedure. However, to the best of our knowledge, the real-time two-dimensional (2DE) echocardiographic features of patients with d-TGV operated on with the Senning technique have not yet been described. The purpose of the present article is to report the 2DE studies of eight patients with d-TGV anatomically and functionally evaluated in the immediate postoperative period following the Senning procedure.

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METHODS

Patients. 2DE examination was performed in eight patients, ranging from 4 months to 4 years of age, with d-TGV surgically corrected with the Senning technique. Six had intact interventricular septum and two had

ventricular septal defect—all of them with mild pulmonic stenosis.

Echocardiography. The patients were examined in the supine position using the subcostal and apical view; a detailed description of these anatomic planes is well provided in previous articles.[13, 14, 16-19] We performed contrast 2DE by injecting a bolus of dextrose 5%, 2 to 5 cc, into a peripheral vein or into the new right arterial atrium (NRAA), as previously described.[15] The 2DE was obtained using a real-time mechanical sector scanner with a digital scan converter with transducers set between 3.5 and 5 MHz.

RESULTS

For comparison of preoperative anatomy to the postoperative anatomy, the preoperative image of a patient after balloon septostomy is shown in Fig. 1. The four cardiac chambers can be seen as well as the interatrial and interventricular septa. The atrioventricular valves are also identifiable.

Echocardiographic findings.

Four-chamber subcostal plane. In the four-chamber subcostal view (Fig. 2), the new left venous atrium (NLVA) was recorded as a small cavity which shows a finger-shape morphology, obliquely invaginated into a bigger cavity with a virgule shape which is the NRAA. The NLVA opens into the left ventricle through the mitral valve, and the NRAA connects with the right ventricle through the tricuspid valve; both atrioventricular valves are shown in this particular projection.

Four-chamber apical plane. In the four-chamber apical view (Fig. 3), the NLVA shows a less round aspect, with an arrowhead-shape due to the different angle of the exploration plane; its size is still smaller than that of the NRAA. In this view, the NLVA is surrounded by the NRAA which shows a similar morphology to that observed in the subcostal view.

Anatomic-echocardiographic correlations.

NLVA. The wall of the NVLA is formed by four segments of different origin. Segment 1 is the anterior part of the former left atrial free wall. Its limit is defined by the insertion of segment 2. Segment 2 is the fleshy tissue of the interatrial septum which, once sectioned, is directed to the primitive left atrial free wall, disconecting the inlet of the pulmonary veins from the mitral valve. Segment 3 is created by the part of the right atrial free wall delimited by interatrial sulcus and the vertical incision performed in the right atrium just between both caval veins. Segment 4 originated from the remnant of the anterior part of the interatrial septum and, once attached to the border of segment 3, completes the closing of the NLVA.

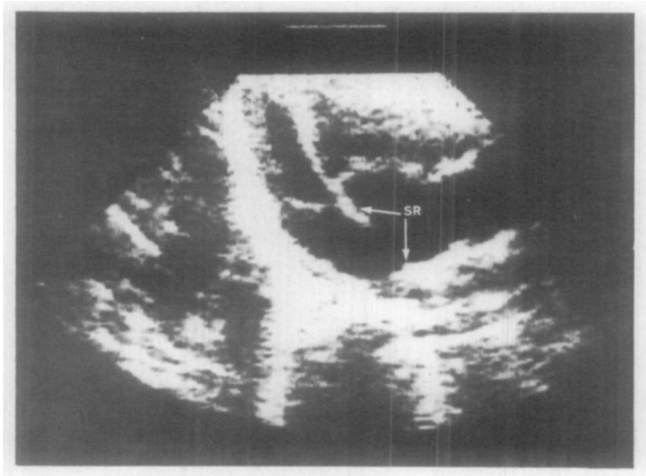

Fig. 1. Four-chamber apical view of a patient with d-TGV after balloon atrioseptostomy. This projection shows the cardiac apex placed on the upper and left side, and the atria on the right of the figure and below. Note the two remnants of the interatrial septum after atrioseptostomy (*SR* and *arrows*). Sometimes there is a false image in the four-chamber apical position showing a false lack of the medial and upper portions of the interatrial septum. *SR* = septum remnants.

NRAA. The external wall of the NRAA is created by two segments. Segment 5 is formed by the primitive left atrial wall including pulmonary venous conections. Segment 6 originates from the rest of the right atrial free wall.

Demonstration of atrial identity. The alternating injections of echocardiographic contrast in both new atria support the echocardiographic-anatomic correlations described herein. Surgical implantation of a catheter in the NRAA allows contrast echocardiographic studies of the arterial cavities during the postoperative period. In Fig. 4, alternating opacification of both atrial chambers of a patient are compared. These images are not only a good demonstration of the echocardiographic-anatomic correlations but also an excellent method for the early detection of postoperative residual shunts and, as a result, permit a good evaluation of the short-term surgical results.

Postoperative shunt detection. Fig. 5 shows the echocardiographic demonstration of the only postoperative leak. Note the contrast in the NLVA (after injection in a peripheral vein) and the opacification of right arterial cavities through the new interatrial septum. The shunt can be clearly seen between segments 3 and 4.

Postoperative obstructions. Our results were very good in this respect as we observed only one case with narrowing of the passage from the pulmonary veins to the right ventricle between segments 3 and

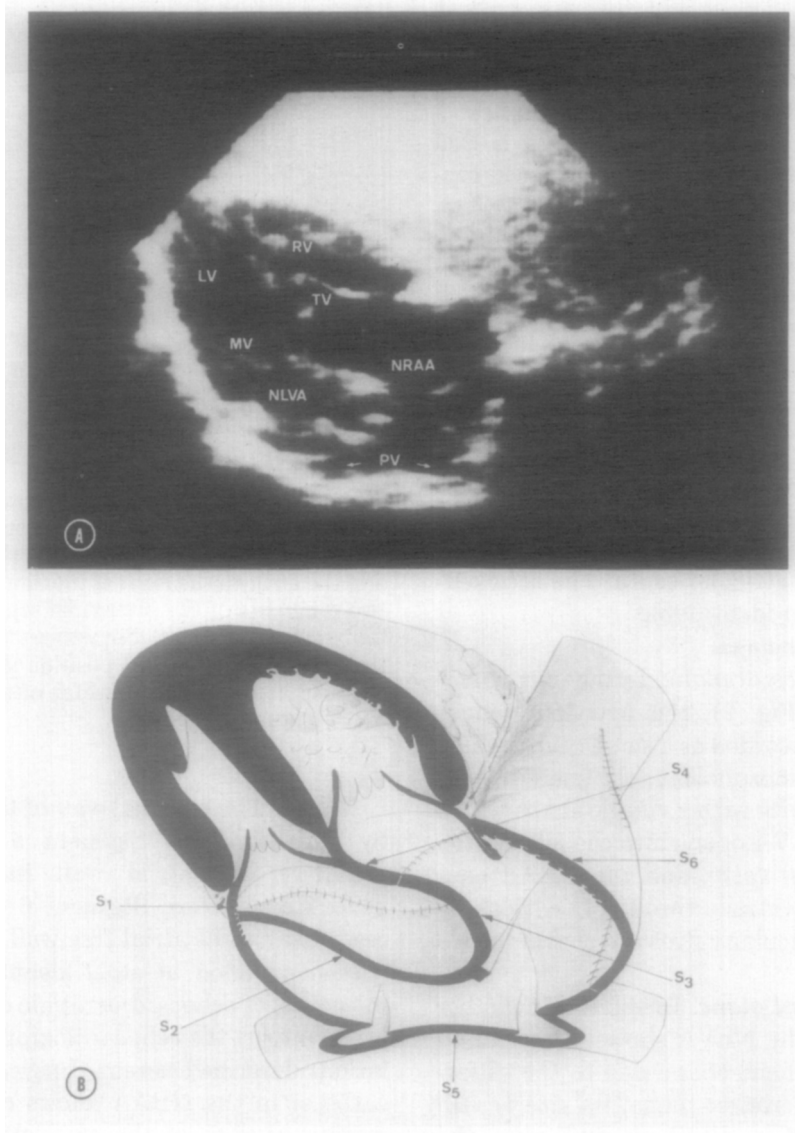

Fig. 2. Four-chamber subcostal view of a patient with d-TGV corrected by the Senning technique. *Panel A,* the ultrasonic image *(top)* shows the new atrial anatomy; clearly defined is a small "finger-shaped" NLVA with the four segments that form its wall. The NRAA, which surrounds the former atrium, shows the pulmonary venous connections in the middle of segment 5. The atrioventricular valves are clearly identified. *Panel B,* The exact situation of the different segments that constitute the new atrial walls are explained in the anatomic schematic figure *(bottom). NLVA* = new left venous atrium; *NRAA* = new right arterial atrium; *LV* = left ventricle; *RV* = right ventricle; *MV* = mitral valve; *TV* = tricuspid valve; *PV* = pulmonary veins; *S* = segment.

5. In this case, the contrast injection was done using the catheter implanted in the NRAA during the surgical procedure. In Fig. 6 we can see that the contrast bolus does not permeate the proximal part of the chamber but remains, for more cycles than in the other cases, within the injection site. This is a crucial area due to the closeness of segments 3 and 5 (and sometimes 6) after surgery. An excessively large segment 3 or an excessively short segment 5 or 6 or both conditions together, could result in partial obstruction of blood flow from the pulmonary veins to the right ventricle.

Reproducibility of 2DE images. We observed the easy reproducibility of these images in all our patients. Interestingly, we found that when we obtained an excellent image of the four-chamber subcostal view, the apical view was difficult to obtain, and vice versa. However, we were always able to obtain an excellent four-chamber image, whether apical or subcostal.

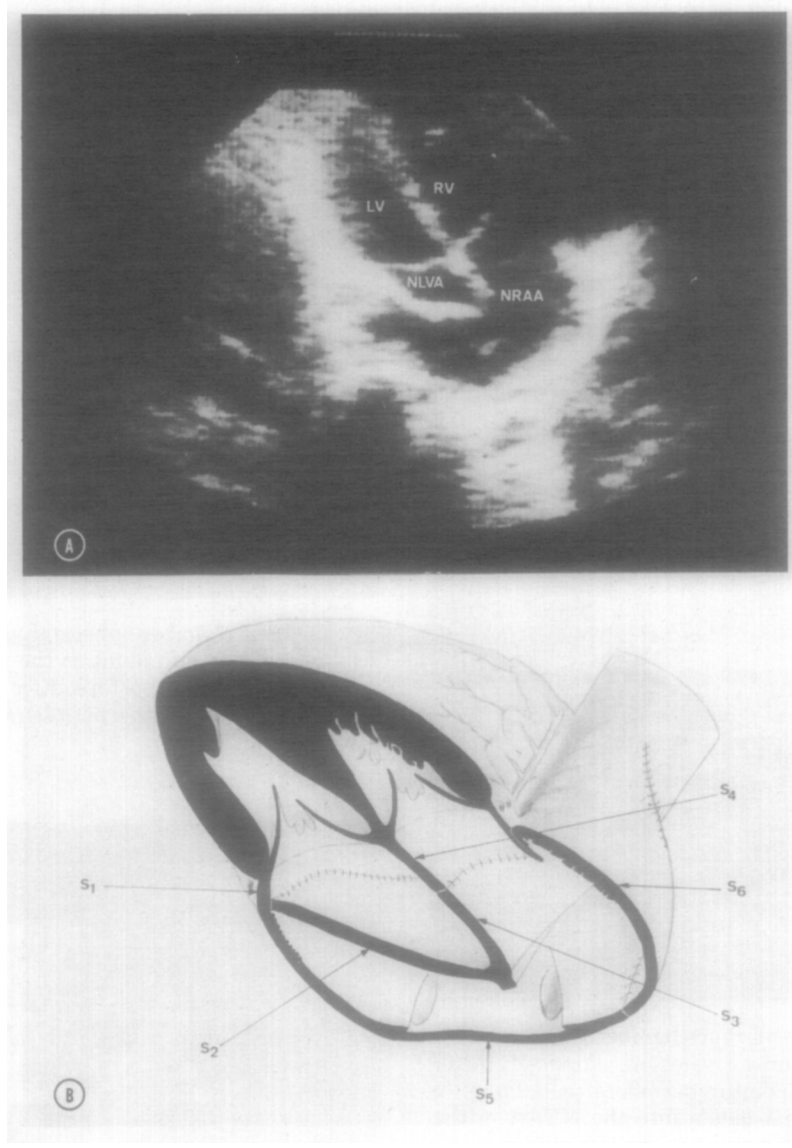

Fig. 3. Four-chamber apical view in the same patient as in Fig. 2. *Panel A*, The NLVA shows an "arrowhead" morphology; its apex is segment 3 (right atrial flap) and its size is very reduced due to specific angulation of the ultrasonic beam. Segment 4 (remnant of the interatrial septum) remains elongated and straightened when compared with this segment in Fig. 2 (see text). *Panel B*, The anatomic schematic image can be seen at the *bottom* of the figure. Abbreviations same as in Fig. 2.

DISCUSSION

As demonstrated in the present article, it is possible to record and explain the echocardiographic images obtained from patients following surgery for d-TGV with the Senning technique.

Echocardiographic description. The echocardiographic image in the four-chamber subcostal view is a well documented real-time image of the anatomy surgically created, showing perfectly differentiated (Fig. 2) the four segments that constitute the NLVA wall. The external wall of the NRAA in this plane allows identification of both segments, because the visualization of the pulmonary veins identifies segment 5.

In the four-chamber apical view, the real morphology of the new atrial cavities appears slightly distorted due to the angle of the ultrasonic beam (Fig. 3). Segment 4 appears more expanded and straightened than in the subcostal projection. The identification of segment 3 is difficult in the apical view.

Functional evaluation of surgery. As reported in the Results section, we have detected only one case with narrowing of the passage from the pulmonary veins

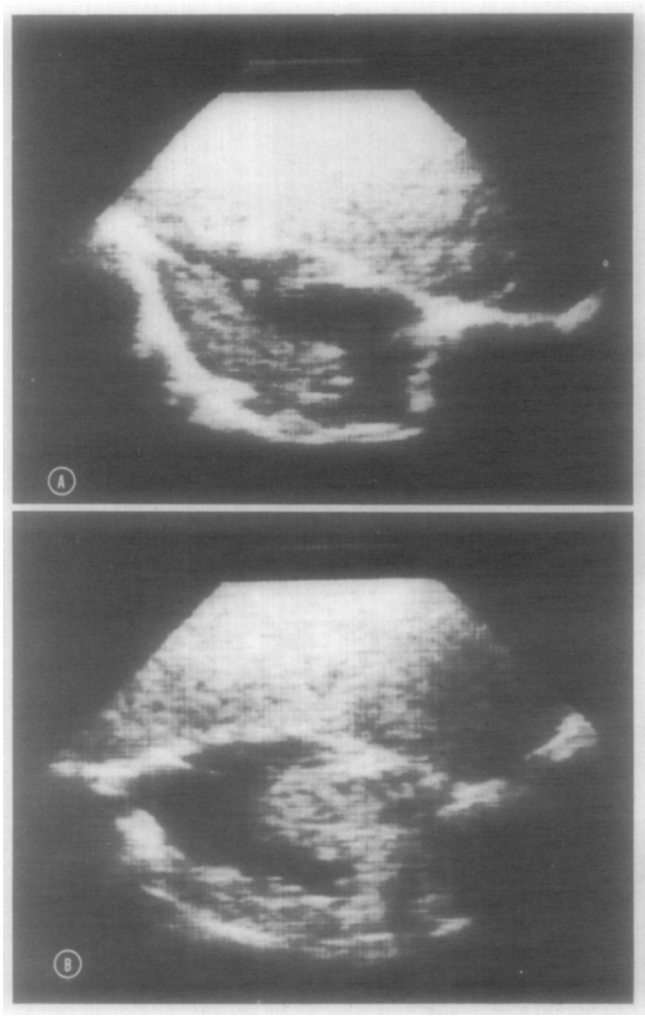

Fig. 4. This figure shows a four-chamber subcostal view of a patient after Senning operation. *Panel A,* After injection of contrast media into a peripheral vein. *Panel B,* After injection of contrast media into the NRAA in the postoperative period by means of a catheter placed in the systemic atrium. The absence of contrast passage in either direction clearly indicates that the wall was intact after surgical correction. Abbreviations same as in previous figures.

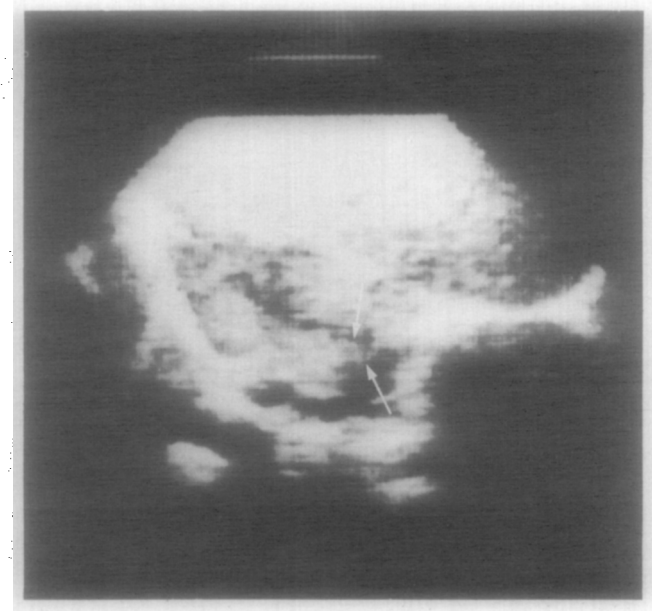

Fig. 5. Four-chamber subcostal view of a patient with a residual right-to-left shunt at the junction of segments 3 and 4 in the early postoperative period. The contrast injection was made into a peripheral vein. *Arrows* indicate site of shunt.

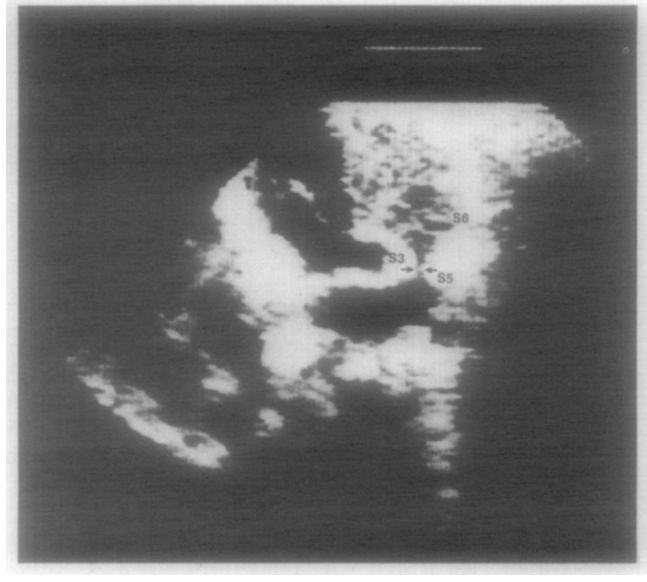

Fig. 6. Four-chamber subcostal view of a patient with moderate obstruction between the posterior (proximal) and anterior (distal) portion of the NRAA detected in the early postoperative period. Injection was made in the distal portion of the NRAA (see text).

to the right ventricle between segments 3 and 5. We believe that this is a crucial area in the surgical procedure and that 2DE can play a major role in early postoperative obstruction detection.

The size of NRAA in all of our echocardiograms was bigger than the size of the NLVA, which is in agreement with the hemodynamic and anatomic observations of others.[20] Our present work centers on observing the atrial echocardiographic area with a view of observing a pattern of development in this type of patient, and establishing the relationship between changes in anatomy such as narrowing and growth and possible future complications such as heart failure, restricted venous return, and obstructions.

Considering the detection of residual shunts, we have to emphasize the great value of injection of

ultrasonic contrast material, alternatively performed in both new atria during the early postoperative period. Fig. 5 shows an example of the echocardiographic image of a patient with an angiographically confirmed postoperative right-to-left residual shunt.

Clinical implications. Contrast 2DE is a useful method in the morphologic and functional evaluation of the Senning operation in patients with d-TGV. The clearness and easy reproduction of the images allowed us to use this technique as a valid alternative, not only in patients with indications for postoperative cardiac catheterization, but also as a routine method for evaluation of all patients following the Senning operation. Further studies will clarify the value of this technique in the long-term follow-up of these patients.

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