RADIOISOTOPIC ANGIOCARDIOGRAPHY: FINDINGS
IN CONGENITAL HEART DISEASE

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The employment of video recording devices in conjunction with the scintillation camera and the concomitant use of short-lived pharmaceuticals have enabled a number of groups of investigators to develop techniques of performing radioisotopic angiocardiography (1–6). Although very good results may be achieved by administering the radiopharmaceutical via an intracardiac catheter (1), considerable emphasis has been given in other reports to develop an intravenous technique which would be suitably accurate for diagnostic screening of patients suspected of having disease of the heart or great vessels. In a series of reports from our laboratories the use of the variable time-lapse videoscintiscope (7) in performing intravenous radioisotopic angiography has been described for a variety of cardiac and/or vascular disorders (3,4,8–13). From experience gained over the past 2 years we have defined criteria for the diagnosis of a number of specific entities and have outlined our views concerning the general indications, limitations, and potential of the radioisotopic method (12). We have been favorably impressed with its accuracy, speed, simplicity, and safety and believe that its wider use and further development should be encouraged. During the current phase of development of this new tool there is a need to formulate and test the diagnostic criteria used to evaluate specific lesions. The purpose of this report is to describe our findings in a group of 30 patients with congenital heart disease.

PATIENTS AND METHODS

From January 1, 1969, to December 31, 1970, radioisotopic angiocardiography has been performed on 145 patients of whom 30 had congenital heart lesions. Table 1 lists the disease categories and frequency with which specific lesions were found in these 30 subjects. Patient selection was arbitrary and was based on such factors as age, lesion of interest at any given time period, and accessibility of patient veins.

The clinical diagnoses were in all instances established or confirmed by other diagnostic procedures including phonocardiography, echocardiography, cardiac catheterization, roentgenography, and contrast ciné-angiocardiography. In addition, direct confirmation of the diagnosis was made by visual and manual inspection at the time of open heart surgery in many of the patients. Six of the group with congenital heart disease were studied by radioisotopic angiocardiography both pre- and postoperatively. The interval between operation and the postoperative study varied from 3 days to 3 months.

The scintillation camera with our accessory variable time-lapse recording, display, and scintiphotography system (VTV) has been described previously (1). The system allows for the recording, display, replay, and photography of dynamic events for selected time periods and also permits the enhancement, suppression, or deletion of any portion of the record. Adults were usually studied while seated. The positioning technique for performing studies in the anterior and modified left anterior oblique views were those reported by Matin and Kriss (4). The intravenous bolus-injection technique (4) recently has been modified to advantage by employing a specially prepared two-compartment syringe* which upon pushing the plunger fully forward results in the injection first of the radioactive bolus, followed immediately thereafter by a saline wash and pusher bolus of up to 2 ml. The radiopharmaceutical employed was ^{99m}Tc-pertechnetate, given in

TABLE 1. LESIONS PRESENT IN GROUP OF 30 PATIENTS WITH CONGENITAL HEART DISEASE

Lesions	No. of patients
Atrial septal defect	11
Ventricular septal defect	3
Tetralogy of Fallot	5
Pulmonic stenosis	5
Aorto-pulmonary window	1
Complete transposition of great vessels	2
Corrected transposition	2
Idiopathic hypertrophic subaortic stenosis	1
Aneurysm sinus of Valsalva	1
Post-valvular aortic stenosis	1
Coarctation of aorta	3
Left superior vena cava	1

a volume of 0.5–3.0 ml. The usual adult dose was 10 mCi; that for children was 0.1 mCi/kg. The radiation hazard is regarded to be very low (0.06–0.16 rads/dose) (4). The times selected for exposing scintiphotographs varied widely from case to case, and even in the same case, and were determined on an individual basis dependent on the rate of passage of the bolus and the particular lesion one wished best to demonstrate; indeed, this option for time-interval selectivity is an essential unique feature of the VTV. Double exposures superimposing different cardiac phases on the same scintiphoto (3,4, 11–13) were made routinely. In most instances, a high-contrast setting on the television monitor was employed; this, plus the employment of a defocused light dot mode, tends to result in a diminished photographic representation of pulmonary radioactivity and a relative enhancement of activity in the heart and great vessels.

Infants and very young children were usually studied in the supine rather than the seated position, and the injection was made with the arm abducted. Special problems exist with young children. Venepuncture is more difficult. Crying is inevitable in the unsedated child, and the resulting involuntary Valsalva maneuver may interfere with bolus transit. The circulation times tend to be very rapid, and the size of the heart and the resulting scintiphoto image are very small. It is important, particularly in the assessment of septal defects (see below), that the bolus enters the heart over a 1–2-sec interval. The prior injection of a sedative, use of small injection volume (with two-compartment syringe), and "milking" the brachial vein immediately after injection are useful maneuvers to ensure prompt entry of the bolus. Scintiphoto image size in very young children or infants may be increased by substituting a pinhole collimator for the multichannel collimator

usually employed and positioning it close over the precordial area.

RESULTS

General comment. The procedure was easy to perform, was accomplished with minimal discomfort and inconvenience, required the presence of the patient in the Nuclear Medicine unit for a short period of time (10–30 min), and was not accompanied by any discernible immediate or delayed toxic reactions. Occasionally, partial extravasation of a bolus occurred. If so, the injection site was massaged gently and compressed, and a different vein was chosen for a second attempt. Under these circumstances, the radiation dose at the injection site and to the whole body are increased, but because of the rapid absorption of pertechnetate from soft tissues, the radiation hazard to the subject was still judged to be acceptably low.

Atrial septal defect (ASD). This lesion was observed in 11 patients, and the scintiphotographic pattern in each was similar; a characteristic set of abnormalities was identified which provides the basis for an accurate diagnosis.

The scintiphotographic criteria of left-to-right intracardiac shunt at the atrial level stem from the fact that the radioactive blood, once it enters the left atrium on its first pass through the heart, in part is diverted through the septal defect and reappears in the right atrium, thereby initiating a continuous, recycling process. Thus in atrial septal defect all four heart chambers and the lungs are concomitantly visualized. In order to make certain that the right atrium is clearly identified, the angiography study should be performed in both anterior and oblique positions. A typical study is presented in Fig. 1 (see footnote p. 33). In ASD the following scintiphotographic findings may be noted:
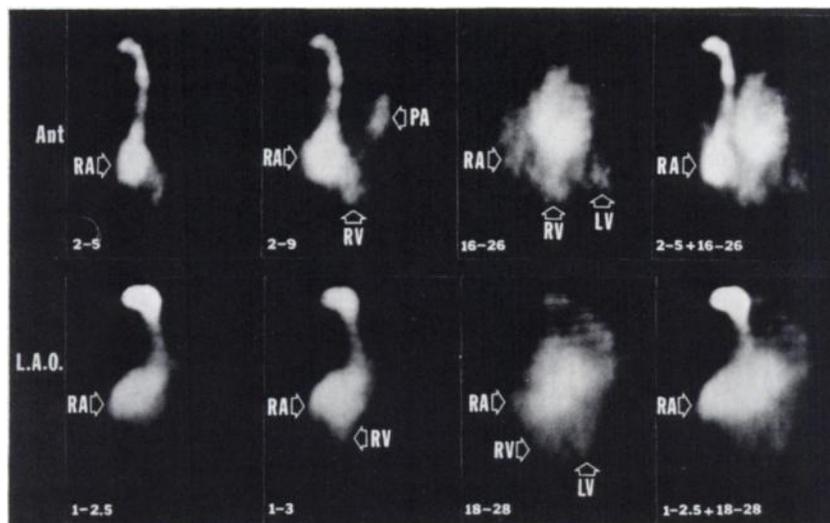
FIG. 1. Atrial septal defect, anterior and oblique positions. Note prominence of RA, "smudge" pattern in later phases (frames 3) with activity present in RA (proved by double exposures, frames 4) and the other three heart chambers, failure to isolate an LV-aortic pattern, prolonged visualization of intracardiac activity. Pulmonary-systemic flow ratio was 1.6.
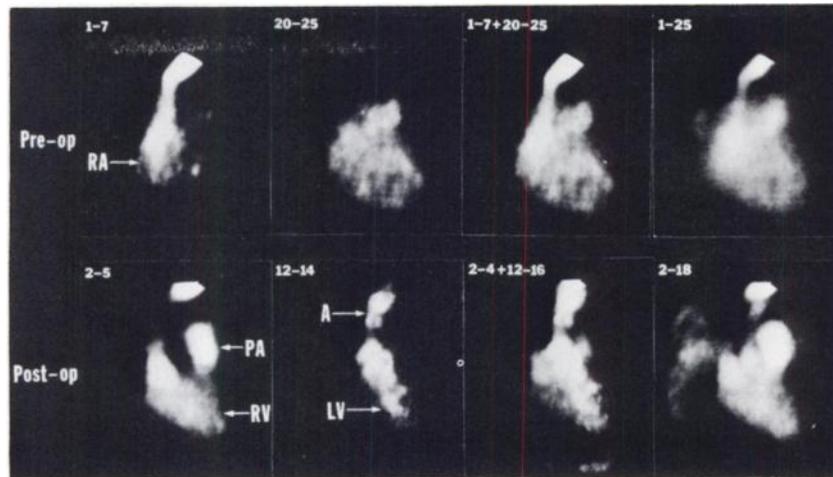
FIG. 2. Atrial septal defect, anterior position, pre- and postoperatively (3 days). Preoperatively note prominent RA (frame 1) "smudge" pattern in later phases (frame 2) with activity present in RA (proved by double exposure, frame 3, and long exposure frame 4). Postoperatively note normal left-sided phase (frame 2), smaller heart (frame 4) but prominent PA (frames 1 and 4).
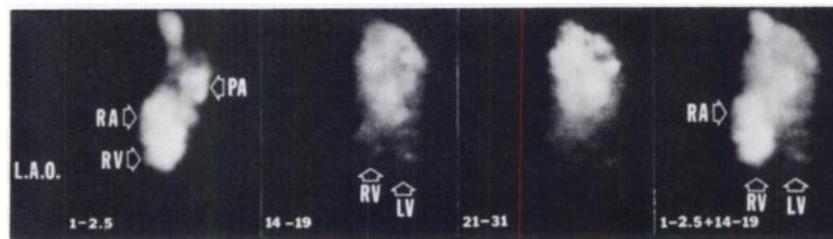
FIG. 3. Ventricular septal defect, oblique position. Note "smudge" patterns in late phases (frames 2 and 3), late visualization of RV and L, but not RA (compare frames 2 and 4), and prolonged visualization of cardiopulmonary activity. Pulmonic/systemic flow ratio was 1.2.

1. Enlargement of the right atrium.
2. Loss of apparent intensity of bolus during initial cardiac filling phase as it passes from right atrium to right ventricle. (This sign is especially noted in the presence of large shunts and is probably due to dilution of the bolus by unlabeled blood entering the atrium across the septal defect.)
3. Enlargement of the pulmonary conus.
4. Persistent visualization of activity in all four cardiac chambers and lungs after first passage of bolus into lungs, tending to produce a long-lasting "smudge" pattern. This is the most characteristic and universal diagnostic angiographic feature of this lesion. It is important to document that the right atrium specifically contains radioactivity at all time phases of the study.
5. Relatively poor delineation of the aorta due to activity simultaneously present in the lungs.

The outstanding diagnostic angiographic features in the successfully operated patient are the prompt disappearance of the "smudge" pattern, normal right atrial emptying, and the ready visualization of an isolated left ventricular-aortic phase with a normal circulation time (Fig. 2). However, right atrial enlargement and prominence of the pulmonary conus region may persist, at least for several weeks.

Our results indicate a high sensitivity of the method with respect to shunt magnitude. No failures of angiographic diagnosis have been observed in proven cases. The smallest visualized left-to-right shunt in the series studied was not demonstrable by O_2 saturation changes but was detectable by hydrogen electrode studies performed during cardiac catheterization. Shunts associated with a calculated pulmonary/systemic flow ratio of only 1.2:1 have been readily visualized. The largest shunt was associated with a pulmonary/systemic flow ratio of 3:1.

Ventricular septal defect (VSD). The recycling of blood from left ventricle back into right ventricle following initial filling of the former chamber results in a characteristic abnormal angiographic pattern resembling, but not identical, to that of atrial septal defect (Fig. 3). The noteworthy diagnostic features of VSD are:

1. Persistent visualization of the right ventricle, lungs, left atrium, and left ventricle, but not the right atrium after first passage of the bolus through the right heart and lungs.
2. Relatively poor delineation of the aorta due to activity simultaneously present in the lungs.

The demonstration that, during recycling, the right atrium is not refilling serves to distinguish VSD
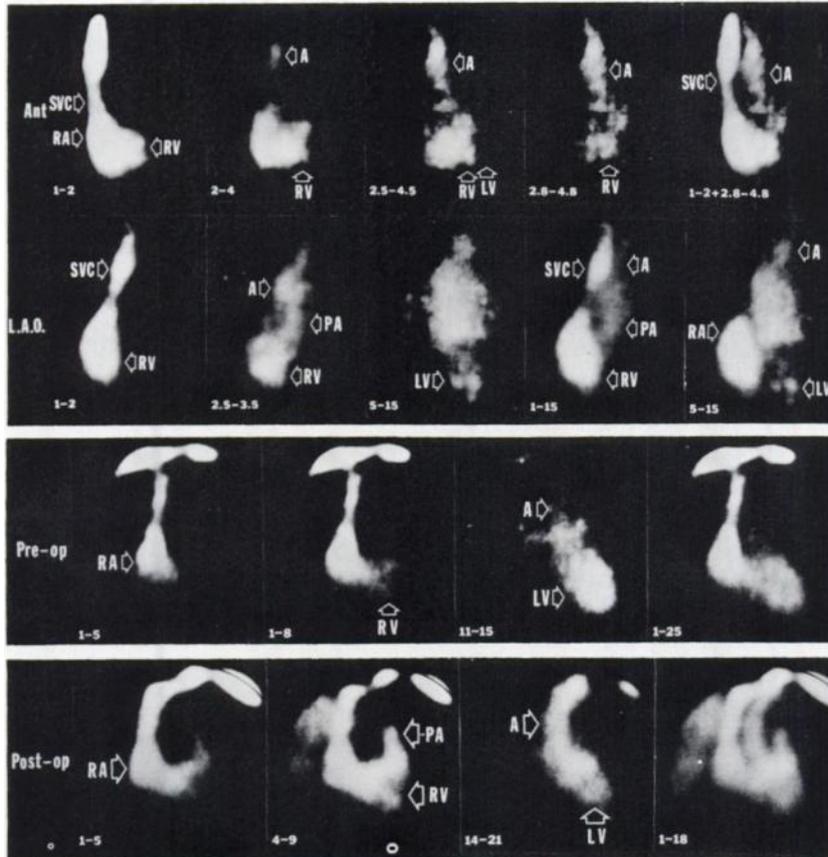
FIG. 4. Tetralogy of Fallot, anterior position (top row) and oblique position (bottom row). In anterior note very early filling of aorta (A), frames 2–4, directly from RV (frame 4) but no visualization of pulmonic outflow tract. LV also was faintly visualized early in original scintiphoto (frame 3). In oblique study both PA and A are visualized early (frame 2), and LV was not seen until later (frame 3). Intense activity above LV (frame 3) was due to abnormal bronchial arterial channels, demonstrated more definitively by roentgenographic studies.

FIG. 5. Tetralogy of Fallot with Pott's anastomosis, anterior position, pre- and postoperatively (9 days). Preoperatively note prominent RA, reflux into left innominate vein (frames 1, 2, 4), poor and delayed filling of RV (frame 2), no pulmonary artery initially, dilated LV, poorly visualized aorta (A) and late PA branch filling. Postoperatively note improved filling of RV and clear demonstration of PA (frames 1 and 2), smaller LV, improved delineation of aorta (A). See text for fuller explanation of procedure.

from ASD. The smallest ventricular shunt demonstrated by the radioisotopic test was associated with a pulmonary/systemic flow ratio of 1.2:1.

Tetralogy of Fallot. In patients with tetralogy of Fallot, we have demonstrated a variety of abnormalities, depending to some extent on the age of the patient and whether or not previous cardiac surgery had been performed. Figure 4 demonstrates the following findings in a previously untreated adult:

1. Markedly diminished caliber of pulmonary outflow tract and main pulmonary arterial branches due to pulmonary artery atresia.
2. Early appearance of activity in left ventricle immediately after right ventricular filling due to right-to-left shunt across a ventricular septal defect.
3. Early filling of the aorta immediately after right ventricular filling due to right over-riding of the aorta on the right ventricular chamber.

Unusual findings have been found in several patients with tetralogy who had undergone previous palliative surgery to increase pulmonary blood flow. For example, Figs. 5 and 6 demonstrate pre- and postoperative findings in a rather complicated clinical situation, i.e., tetralogy of Fallot with a malfunctioning Pott's anastomosis. A Pott's anastomosis creates a shunt between the descending aorta and the

left pulmonary artery. In this 18-year-old male, this procedure had been done at an earlier age. His current findings included cyanosis and signs of right-sided failure. At operation, a 4-mm atretic segment of the pulmonary artery was found, and the Pott's anastomosis was patent. The Pott's anastomosis was closed and a plastic procedure was done on the pulmonary artery. One week later, the radioisotopic angiocardiogram showed evidence of marked improvement (Figs. 5 and 6). In another case, bizarre findings in a patient with the tetralogy were observed because of the presence of an anomalous left superior cava entering the heart presumably via the coronary sinus and filling both right atrium and right ventricle, and also because of retrograde filling of the pulmonary artery via a previously made Blalock anastomosis (Fig. 7).

Aorta-pulmonary window. A variable right-to-left shunt between the main pulmonary artery and the ascending aorta was demonstrated in one patient who developed striking cyanosis and poor exercise tolerance on slight exertion but who was minimally cyanotic at rest. Radioisotopic angiocardiography was performed before and after exercise. Both studies were abnormal (Fig. 8). The scintigraphic study was unique and revealed the following findings:
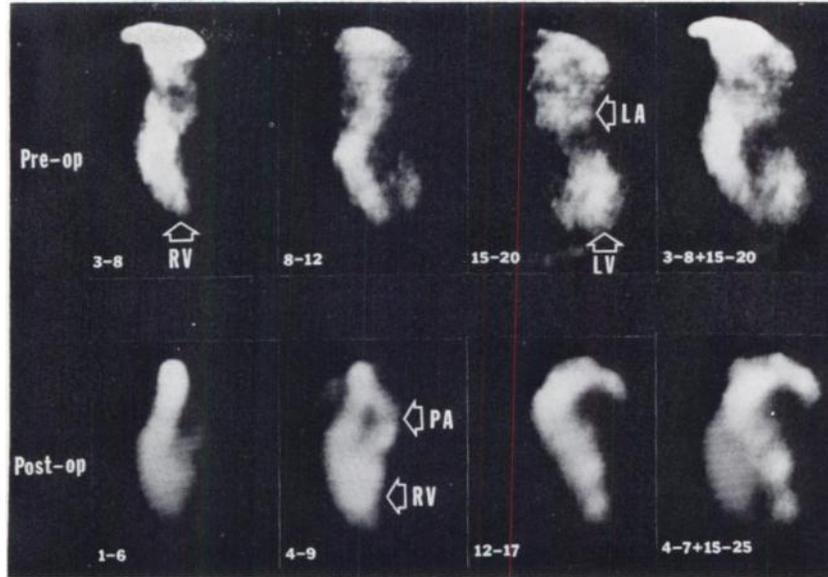
FIG. 6. Tetralogy of Fallot with Pott's anastomosis, left anterior oblique position, pre- and postoperatively (9 days). Preoperatively note poor delineation of PA (frame 1), LV dilation and late visualization of LV and LA (? superimposed PA activity also) (frame 3), the latter presumably filling after blood has re-entered left heart via Pott's anastomosis. Postoperatively note improved delineation of PA, clear delineation of right- and left-sided cardiac phases (frames 2 and 3, respectively), smaller LV and good filling of aorta (frame 3).
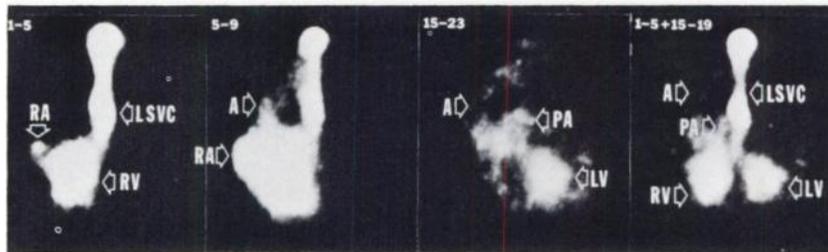
FIG. 7. Tetralogy of Fallot, left superior vena cava, anterior position, with Blalock anastomosis. Note persistent left superior vena cava (LSVC) filling RA and RV (frame 1), early filling of aorta (A) in frame 2, but no associated early demonstration of pulmonary artery. PA fills only in late phase by retrograde flow via Blalock anastomosis (frame 3).
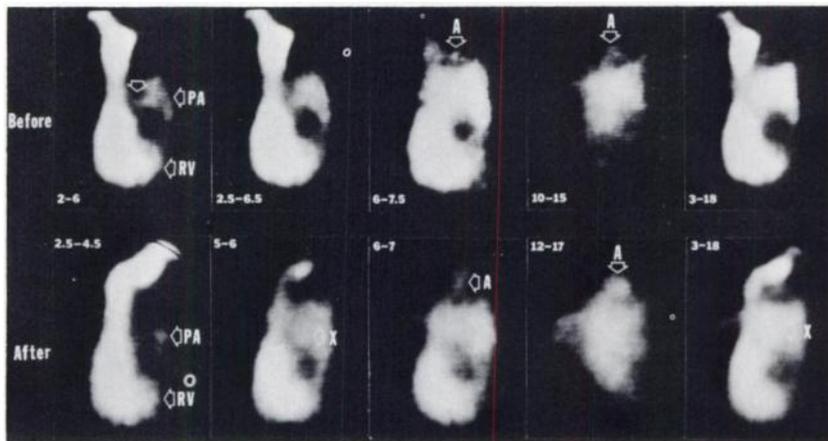
FIG. 8. Aorto-pulmonary window anterior position, before and after brief walking exercise. Note asymmetry of PA to right, with tract filling ascending aortic area (frames 1 and 2, top arrow), early aortic activity (frames 3), and relatively increased prominence of ascending aortic region after exercise (compare X, frames 5 before and after exercise).

1. Asymmetrical main pulmonary trunk, with anomalous right-sided tract leading to the region of the ascending aorta.
2. Demonstration of activity in ascending aorta and arch nearly synchronous with presence of maximal pulmonary artery activity, and before delineation of left ventricle.
3. Rapid loss of radioactivity from the heart immediately after delineating the right-sided cardiac phase.

The findings are similar to those expected in patent ductus arteriosus with Eisenmenger physiology ex-

cept that in the latter the descending rather than the ascending aorta would be visualized, and a ductus involving the right side of the pulmonary trunk would be unusual.

Pulmonic stenosis. Figure 9 shows the marked abnormalities seen in one patient with severe pulmonic valvular stenosis:

1. Prolonged residence of the bolus in the right side of the heart.
2. Persistent and striking narrowing of the pulmonic valve area.
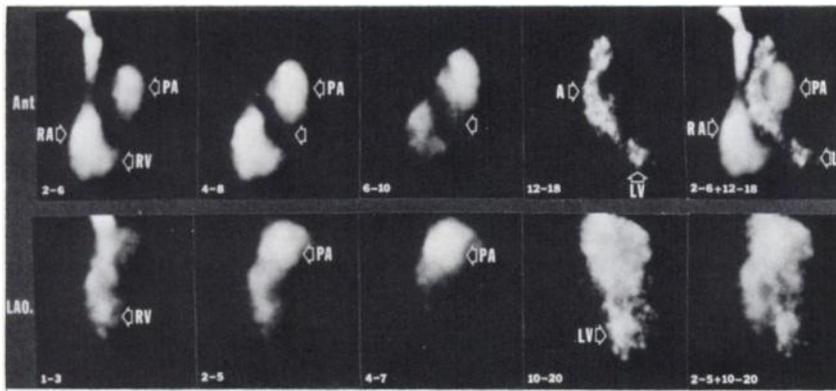
FIG. 9. Pulmonic stenosis, anterior and oblique positions. Anteriorly note relatively small-sized cavity of RV (frames 1 and 2), persistent narrowing in right ventricular outflow tract due to hypertrophied infundibulum (arrow, frames 2, 3), persistent filling of dilated main pulmonary artery (PA) just beyond narrowing, and delayed filling of LV and aorta. In oblique position, note RV cavity is relatively small, PA is dilated and retains activity over long interval (frames 2, 3).
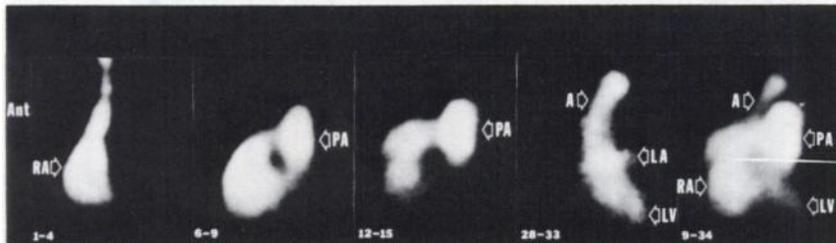

FIG. 10. Corrected atrial septal defect, 6 years following surgical closure of defect, anterior position. Note prominent RA (frame 1), relatively small sized cavity of right ventricle (frame 2), dilated main pulmonary artery (PA, frames 2, 3), prolonged circulation time through both right and left heart (frames 3, 4), and striking prominence of PA on composite view (frame 5), findings attributed to residual pulmonary hypertension.
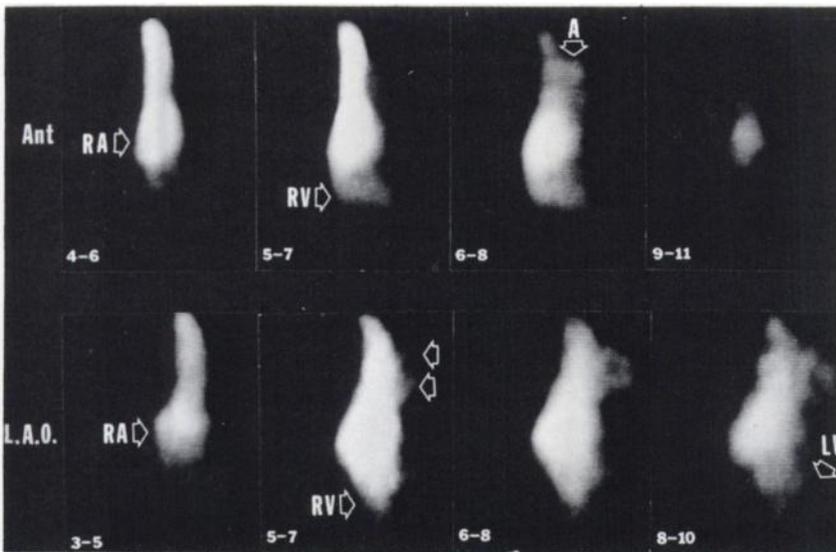
FIG. 11. Transposition of great vessels, anterior and oblique positions. Anteriorly note very early filling of aorta A (frames 2, 3), rapid disappearance of cardiac activity (frame 4), failure to visualize left ventricle or pulmonary artery. In oblique position note filling of two outflow tracts after RV filling (arrows, frame 2, frame 3) corresponding to aorta and pulmonary artery joined by Blalock anastomosis (frame 3), LV is only faintly visualized (frame 4).
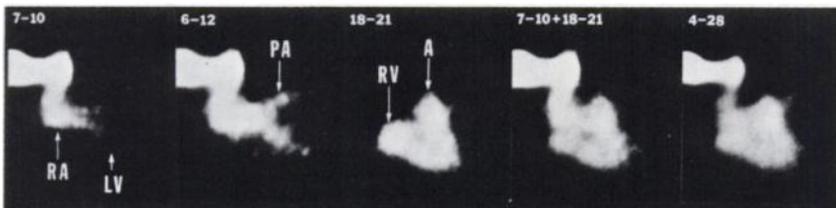

FIG. 12. Transposition of great vessels, anterior position, 1 week postoperatively (Mustard procedure). Note filling of LV from upper part of RA (frame 1), subsequent filling of PA (frame 2), later filling of RV and A (frame 3). Identity of chambers is proven by comparing composite (frame 4) with previous frames.
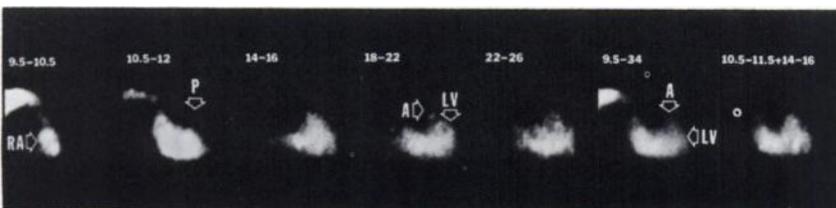
FIG. 13. Corrected transposition with VSD, anterior position. Note failure to visualize normal pulmonary outflow tract at P (frame 2), abnormal position of aorta (frames 4, 6, 7), "smudge" patterns in later phases (frames 3–5) with persistent visualization of both RV and LV and "U-shaped" configuration of heart and great vessels.

FIG. 14. Idiopathic hypertrophic subaortic stenosis (with mitral insufficiency), anterior and oblique positions. Anteriorly note displacement of RV cavity of right (frame 1) due to thickening of interventricular septum, large LA (frame 3), small LV (frames 4 and 5), and wide space between RV and LV cavities representing interventricular system. In oblique view note large LA (frames 2–5), small, wedge-shaped LV (frames 2–5), and wide separation between RV and LV cavities (frames 4, 5) representing thickened interventricular septum. Aorta is well visualized in both positions. Dotted lines on last frames indicate estimated outer limit of LV wall.
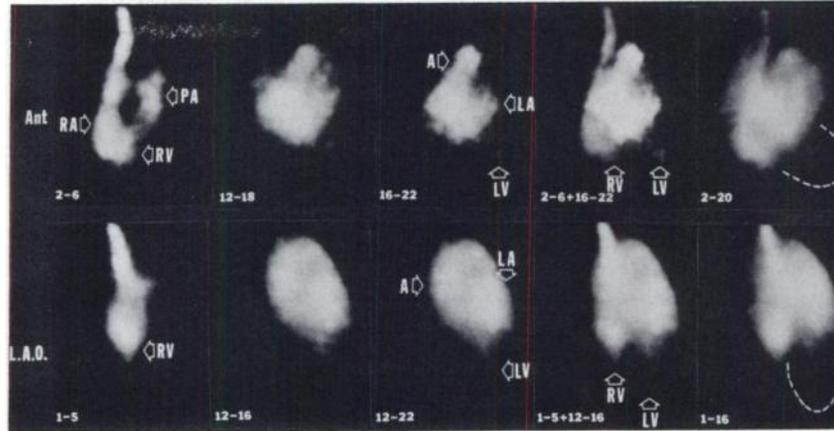
3. Marked post-stenotic dilation of the pulmonary trunk.

4. Relatively small-size cavity of the right ventricle due to right ventricular hypertrophy.

In two additional proven cases in children, we were unable to discern any definite abnormalities on radioisotopic study. In another case, findings somewhat similar to those described above were seen in a patient who had marked right-sided congestive heart failure for a number of years following repair of an atrial septal defect (Fig. 10). In the latter case, however, filling of the pulmonic valvular area did occur, and the abnormalities were believed to be due to long-standing pulmonary hypertension.

Transposition of the great vessels. Figure 11 shows strikingly abnormal findings in an adult patient with transposition of the great vessels and pulmonic stenosis:

1. Early filling of aorta immediately after filling of right ventricle.

2. Early marked loss of cardiac activity.

3. Very faint visualization of left ventricle and pulmonary artery, so that right heart and aorta were the only portions of the heart well seen.

4. Visualization of a small, poorly functioning Blalock anastomosis which had been made earlier.

The findings bear some resemblance to those seen in tetralogy of Fallot (see above), as might be expected since the physiology of transposition with pulmonic stenosis is similar to that of tetralogy.

Figure 12 shows a postoperative scintiphotographic sequence in a cyanotic 13-year-old child who had undergone a successful Mustard procedure for transposition of the great arteries 1 week earlier. As a consequence of her malformation, unoxygenated blood entered the aorta from the right ventricle while blood exited the left ventricle via the pulmonary artery; a large ventricular septal defect was present also. The surgical procedure involved closure of the

ventricular defects, diversion of right atrial blood to left ventricle (Fig. 12), and left atrial blood to right ventricle, thereby establishing a physiologically normal circulation.

Corrected transposition. In corrected transposition, the anatomic position of the ventricles is reversed, but pulmonic and systemic flow are physiologically normal, and there is usually a ventricular septal defect. These abnormalities result in the angiographic pattern seen in a child in Fig. 13 which shows:

1. Displacement of normal pulmonic outflow tract to the right (from anatomic left ventricle).

2. Displacement of aortic outflow to the right (from anatomic right ventricle).

3. Persistent dual visualization of left ventricle and right ventricle (and lungs).

4. The above abnormalities create an overall U-shaped heart activity pattern.

Idiopathic hypertrophic subaortic stenosis. Figure 14 documents the findings observed in an adult patient with idiopathic hypertrophic subaortic stenosis (associated with mitral insufficiency):

1. Displacement of the right ventricular cavity to the right due to hypertrophy of the interventricular septum.

2. Marked muscular hypertrophy of the left ventricle, causing diminished chamber size and wide separation between right and left ventricular cavities. The left ventricular cavity is wedge-shaped with the apex of the wedge pointed toward the anatomic apex of the left ventricle.

3. Left atrial enlargement and prolonged visualization of that chamber.

4. Prolonged and good visualization of the aorta.

The findings indicated above resemble, but are not identical to, those previously described for mitral stenosis (5). In the latter, the left ventricular cavity
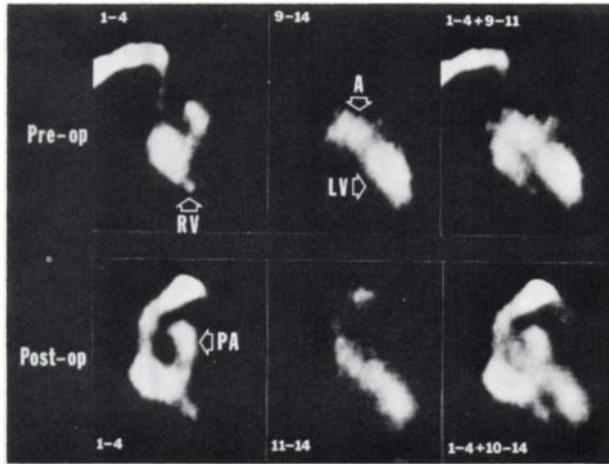
FIG. 15. Supra-valvular aortic stenosis, anterior position, pre- and postoperatively (1 week). Preoperatively note sharp cut-off of activity just above aortic root (A) at point of stenosis and failure to visualize ascending aorta (frame 2), LV dilation. Postoperatively note normal aortic filling (frame 2), slightly smaller LV.

is normal or small, but the configuration is not wedge-shaped, the signs of left ventricular hypertrophy (8) are absent, and aortic activity tends to be much less prominent.

Supra-valvular aortic stenosis. Unusual findings were demonstrated in an 11-year-old boy with a murmur suggesting aortic stenosis (Fig. 15). However, other diagnostic tests, as well as radioisotopic angiocardiography, indicated that the stenosis of the aorta was supra-valvular. One week after surgical correction of the lesion, radioisotopic angiography demonstrated marked improvement in aortic filling.

Aneurysm of the sinus of Valsalva. The successful demonstration of an aneurysm of the sinus of Valsalva, with postoperative assessment of its repair,

has been documented in a separate report (6); the scintiphotographic findings were striking and are shown in Fig. 16.

Coarctation of aorta. Lesions of the arch or descending aorta are usually best studied in the left anterior oblique position (12). The demonstration of aortic narrowing at the site of a coarctation is shown in Fig. 17. The authors urge caution in interpretation of narrowing of the descending aorta, however, since the descending aorta normally may appear to diminish in caliber just beyond the arch. This finding is partly due to anatomic change in caliber of the aorta and partly due to the greater distance (and diminished scintigraphic intensity) of the lower aorta from the detector. It is essential that an abrupt change in aorta size and contour be demonstrated before a diagnosis of coarctation can be made.

DISCUSSION

Our results of intravenous radioisotopic angiocardiography demonstrate that markedly abnormal and distinguishable scintiphotographic patterns are obtained in a variety of specific cardiovascular diseases. The conditions include congenital and acquired heart disease, involving both right- and left-sided lesions, and diseases of the great vessels and pericardium. The scintiphotographic criteria that are being applied currently in our laboratory for diagnostic purposes in evaluating some of these conditions have been described, particular emphasis being given in this report to patients with congenital heart disease. In many respects intravenous radioisotopic angiocardiography resembles forward angiography performed by intravenous injection of contrast material. Advances in our knowledge of congenital heart
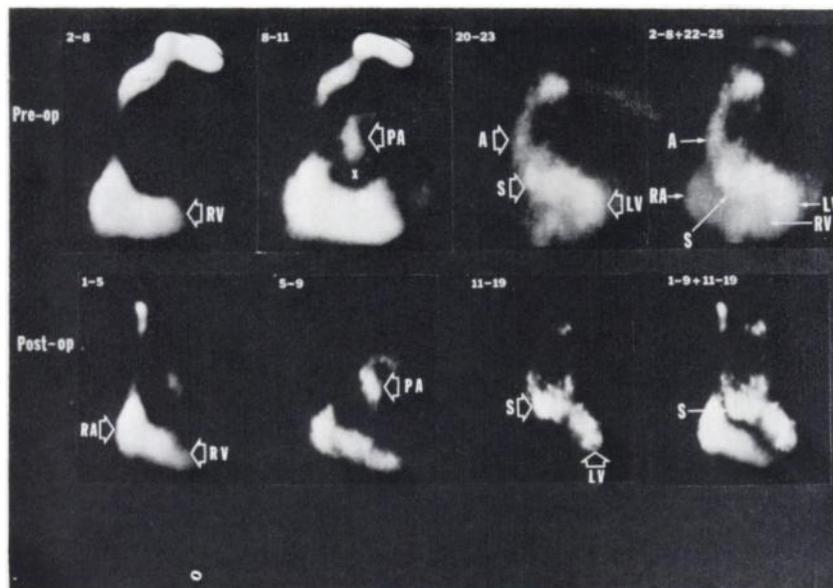
FIG. 16. Aneurysm of sinus of Valsalva producing right ventricular obstruction, anterior position, pre- and postoperatively (4 months). Preoperatively note very large RA and RV (frames 1 and 2), region of obstruction (X) to RV outflow (frame 2), delayed right heart emptying, aneurysmal dilatation near aortic root with increased density at its lower portion (S) in frame 3. Composite view (frame 4) shows that S lies in region corresponding to RV outflow obstruction (X, frame 2). Postoperatively note greatly decreased size of right heart (frame 1), diminished size of sinus of Valsalva aneurysm (S) which no longer obstructed RV output, shorter circulation time.
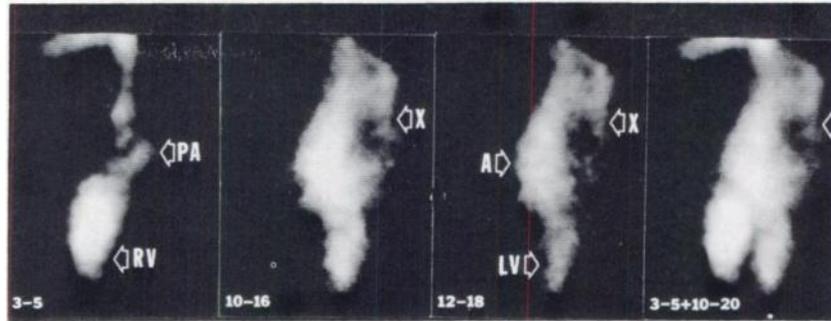
FIG. 17. Coarctation of aorta, oblique position. Note tapered narrowing of descending aorta at X (frames 2–4). Cardiac chambers are normal.

disease permit us to interpret the dynamic scintiphotographs as representations of normal or deranged physiologic events. Combined with an understanding of pathologic congenital cardiac anatomy, this relatively simple, noninvasive, speedy, and safe technique becomes an attractive and useful clinical procedure with wide applicabiilty.

The findings we have enumerated for specific lesions have been a reasonably good guide to diagnosis. With experience, we have come to recognize that each pattern represents a physiological circumstance, e.g., left-to-right shunt or obstruction to pulmonary flow, which, when correlated with the apparent anatomy suggests a given cardiac lesion. We recognize that different anatomic abnormalities may give similar physiologic syndromes and may be very difficult to distinguish by this technique. For example, tetralogy of Fallot, double outlet right ventricle, transposition of the great vessels with pulmonic stenosis, and ventricular septal defect with pulmonary hypertension form an incomplete list of lesions which might be expected to give similar photoscintigrams with the intravenous technique we have described. Nevertheless, as a screening procedure and for serial study of the effects of medical or surgical intervention, the intravenous radioisotopic angiocardiogram provides physiologic and anatomic information not readily obtainable by other noninvasive techniques.

The atraumatic nature of this examination deserves special emphasis in the pediatric age group (6,14–16). This procedure can easily be performed on an outpatient, and therefore removes from the physician the psychological burdens associated with hospitalization of a child who is otherwise doing well for followup data.

In general, we recommend that radioisotopic angiocardiography be performed as a screening procedure prior to cardiac catheterization or selective contrast angiography. Specifically, we suggest that the radioisotopic procedure be considered under any of the following circumstances:

1. As a screening test in ambulatory or hospitalized patients with suspected congenital or acquired heart disease, caval obstruction, pericardial effusion, and thoracic aortic aneurysm.
2. In patients sensitive to radiographic contrast agents.
3. In patients too ill to undergo heart catheterization or contrast angiography.
4. Serially, as a guide to the effectiveness of medical therapy.
5. Serially, as a guide to the progression of disease in patients who are being followed expectantly.
6. Pre- and postoperatively to document effects of specific operative interventions.

SUMMARY

Intravenous radioisotopic angiocardiography with ^{99m}Tc-pertechnetate has been performed on 30 patients with congenital heart disease using the scintillation camera and the variable time-lapse videoscintiscope. Seven patients were studied before and after surgical treatment. The following different lesions were encountered: atrial septal defect, ventricular septal defect, tetralogy of Fallot, pulmonic stenosis, aorto-pulmonary window, complete transposition of the great vessels, corrected transposition, idiopathic hypertrophic subaortic stenosis, aneurysm of the sinus of Valsalva, post-valvular aortic stenosis, coaraction of aorta, and left superior vena cava. Abnormal and distinguishable scintiphotographic patterns were obtained in nearly all of the patients studied. The sensitivity of the method, especially in the assessment of septal defects, was excellent; e.g., capable of indicating the presence of left-to-right shunts associated with a pulmonary artery-to-systemic flow ratio of only 1.2. The procedure has been espe-

cially helpful in ruling out recurrence of shunts in surgically treated patients with persistent or developing cardiac murmurs. Because of its simplicity, speed, safety, and immediate clinical relevance of the data, we recommend that the test be performed as a screening procedure before cardiac catheterization or selective contrast angiography.

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