Postoperative thallium-201 myocardial images

Evidence of regression of right ventricular hypertrophy in man

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SUMMARY Thallium-201 myocardial scintigraphic studies were performed on 24 patients with chronic right ventricular overload before and after surgical correction of haemodynamic overload. The ages of the patients ranged from 20 to 65 years (mean 39 years) at operation. The degree of right ventricular visualisation remained essentially unchanged in an early postoperative study (four to 60 days), though a decrease in right ventricular cavity size was noted in patients with right ventricular volume overload. On later follow-up (18 to 36 months), thallium uptake in the right ventricle was definitely less than before operation in all 13 patients studied at this time.

Because thallium-201 radioactivity reflects myocardial blood flow and mass, our study indicates that right ventricular hypertrophy is largely reversible. Thus, thallium-201 myocardial scintigraphy can be used to assess non-invasively regression of right ventricular hypertrophy in patients with right ventricular overload.

Hypertrophy is a basic response of the heart to increased stress imposed by chronic pressure and volume overload. Morphological and metabolic changes associated with cardiac hypertrophy have been investigated extensively.^{1,2} The response to removal of haemodynamic overload, however, is not well known.³⁻⁵ Non-invasive methods for determining regression of hypertrophy are of considerable importance.

Thallium-201 (²⁰¹Tl) myocardial imaging has been used to show the presence of right ventricular overload in adults with chronic heart disease.⁶⁻⁸ The uptake of ²⁰¹Tl by the right ventricular free wall is proportional to right ventricular free wall mass.^{9,10} The present report describes our observation by ²⁰¹Tl of myocardial imaging of regression of right ventricular hypertrophy after surgical correction of haemodynamic overload.

Subjects and methods

Our study group consisted of 24 patients with chronic right ventricular overload who were referred to our department for evaluation and surgical treatment of

cardiac disease. All the patients underwent cardiac catheterisation preoperatively and were categorised into two clinical groups: (1) 11 patients with right ventricular pressure overload; (2) 13 patients with right ventricular volume overload (Table). Corrective surgery had been performed on patients with congenital heart disease, and either commissurotomy or valve replacement had been performed on patients with acquired valvular heart disease. Both mitral and tricuspid valve replacements were performed in three cases. All the patients showed a stable or improving clinical course after operation. Postoperative cardiac catheterisation performed in eight of the 24 patients showed a haemodynamic improvement of right ventricular overload. The mean age at operation was 39 years (range 20 to 65).

Both preoperative and postoperative myocardial imagings were made using the Toshiba GCA-202 scintillation camera with low energy, high resolution, parallel-hole collimator. The method of myocardial imaging has been described previously.^{7,11} Briefly, images were taken 10 minutes after the intravenous injection of 2 mCi of ²⁰¹Tl. Scintigrams were taken from the anterior view, left anterior oblique views at 30°, 45°, and 60°, and left lateral view. The energy and

Table Material

	No of patients
Right ventricular pressure overload	11
Mitral stenosis	6
Mitral stenosis with tricuspid regurgitation	3
Tetralogy of Fallot	1
Pulmonary stenosis	1
Right ventricular volume overload	13
Atrial septal defect	13
Total	24

window width was set at 500 000 counts. Analogue images were obtained with Polaroid films and a microdot imager without additional contrast enhancement or computer processing. Any case with a heart rate greater than 100 beats/min was excluded.

Visualisation of the right ventricular free wall was evaluated in accordance with Cohen *et al.*'s criteria,⁶ as shown previously^{7 11}; the radioisotope activity visible in the right ventricular free wall was compared with that of the left ventricular free wall on the basis of myocardial imaging from 45°. A minus sign (−) indicated that visualisation of the right ventricular free wall was not clear. Intensity 1+ was assigned for activity less than that of the left ventricular free wall, 2+ for activity equal to that of the left ventricular free wall, and 3+ for activity greater than that of the left ventricular free wall. In addition, for comparison of the postoperative and the preoperative imagings, half points (±) in the grading system were used when observers thought that the intensity decreased and was intermediate between 1+ and (−). Unprocessed photocopies were interpreted by three independent observers who had no knowledge of the patients' status and were graded by consensus of at least two of them in each case. The right ventricular volume was assessed in accordance with the technique of Bulkley *et al.*¹² Preoperative and early postoperative scintigraphic studies were made in all 24 cases, and 13 cases were studied again at 18 to 36 months after operation. In addition to myocardial imaging, M-mode echocardiograms and 12 lead electrocardiograms obtained within 24 hours after myocardial imaging were interpreted.

Results

PREOPERATIVE AND EARLY POSTOPERATIVE ^{201}Tl MYOCARDIAL SCINTIGRAPHY

Among the 11 preoperative patients with right ventricular pressure overload, the right ventricular free wall was visualised at grade 1+ in five, 2+ in five, and 3+ in one. Good visualisation of the right ventricular free wall was achieved in cases with abnormally high right ventricular systolic pressure or in cases with combined tricuspid regurgitation (Fig. 1, left). In cases

Fig. 1 (a) Relation between right ventricular systolic pressure and right ventricular radioisotope (RI) activity. MS, mitral stenosis; TR, tricuspid regurgitation; T/F, tetralogy of Fallot; PS, pulmonary stenosis. (b) Relation between pulmonary-to-systemic flow ratio (Q_p/Q_s) and right ventricular radioisotope (RI) activity in patients with atrial septal defect.

with right ventricular volume overload caused by atrial septal defect, the 2+ group tended to have a higher pulmonary-to-systemic flow ratio than that of the 1+ group (Fig. 1, right). The right ventricular systolic pressure ranged between 23 and 70 mmHg in the cases with atrial septal defect.

Fig. 2a shows changes in right ventricular free wall visualisation from preoperative to early postoperative (mean 31 days, range four to 60 days) ^{201}Tl scintigraphy in these 24 cases; with two exceptions, no changes appeared though conspicuous reduction in right ventricular cavity was noted in the cases with atrial septal defect (Fig. 3). In a case with Fallot's tetralogy,

Fig. 2 (a) Grading of right ventricular free wall visualisation before operation and early after operation. (b) Grading of right ventricular free wall visualisation before operation and late after operation.

Fig. 3 Myocardial images in the 45° left anterior oblique projection of a patient with atrial septal defect. (a) Preoperative, right ventricular (RV) free wall visualised at grade 2+ with dilated right ventricle. (b) Early postoperative (32 days), right ventricular free wall remained visualised at grade 2+, with a smaller cavity than the preoperative one. (c) Late postoperative (22 months), right ventricular free wall visualisation less than the former one.

the right ventricular systolic pressure was 94 mmHg preoperatively to 38 mmHg in an early postoperative study. The degree of right ventricular free wall visualisation, however, remained unchanged, being grade 2+ 60 days after operation.

²⁰¹Tl MYOCARDIAL SCINTIGRAPHY 18 TO 36 MONTHS AFTER OPERATION

Fig. 3 illustrates a typical ²⁰¹Tl image in a patient who had corrective surgery for an isolated atrial septal defect. The early postoperative images disclosed that the right ventricular free wall visualised at grade 2+, similar to that found before operation, with the right ventricular cavity appearing to be smaller than before. Note that in this case the right ventricular free wall visualisation was definitely less than in the preoperative one though minimal uptake of thallium in the right ventricular free wall remains apparent. In all 13, definite reduction in right ventricular free wall visualisation was present in late postoperative studies (Fig. 2b and Fig. 4). At this stage, there was no relation between the degree of reduction in right ventricular free wall visualisation and the postoperative interval.

OTHER NON-INVASIVE STUDIES

The early postoperative electrocardiograms were essentially unchanged in all the 24 cases. In five of the eight patients with atrial septal defect whose preoperative electrocardiogram showed incomplete right bundle-branch block, diminution of r' in V1 was shown in the late postoperative studies. In the other three with atrial septal defect, however, who had complete right bundle-branch block and in five patients with right ventricular pressure overload, the late postoperative study showed no significant changes in the electrocardiogram.

Fig. 5 and 6 show preoperative and postoperative echocardiographic measurements of the internal diameter of the right ventricle at end-diastole in the cases with atrial septal defect. The right ventricular diameter decreased in all the cases in the early postoperative studies. No further tendency to a continued reduction in the right ventricular diameter, however, was present 18 to 36 months after operation. In all the cases of right ventricular pressure overload, little change appeared in the right ventricular diameter from the pre- to early or late postoperative echocardiograms.

Fig. 4 Myocardial images in the 45° left anterior oblique projection of a patient with mitral stenosis and tricuspid regurgitation. (a) Before operation, showing right ventricular (RV) free wall visualised at grade 1+. (b) 20 months after operation, right ventricular free wall visualisation was less than the preoperative picture.

Fig. 5 Pre- and early postoperative echocardiographic right ventricular studies in the same patient as in Fig. 3. There was a 15 mm reduction in right ventricular diameter at end-diastole in an early postoperative study (one month).

Fig. 6 Serial echocardiographic studies of right ventricular (RV) diameter in patients with atrial septal defect. There was a reduction in right ventricular diameter in an early postoperative study. No further tendency to a continued reduction was noted in a late postoperative study (mean 24 months).

No echocardiographic data were available for evaluation of changes in right ventricular free wall thickness.

Discussion

^{201}Tl MYOCARDIAL SCINTIGRAPHY FOR EVALUATION OF CHRONIC RIGHT VENTRICULAR OVERLOAD

Myocardial imaging with ^{201}Tl has been found to be widely applicable in the clinical evaluation of patients with both ischaemic and non-ischaemic cardiac disease. Upon intravenous injection, this nuclide is taken up by the myocardium, and subsequent imaging reflects myocardial perfusion and mass.^{13 14} Though the right ventricle is not visualised on the resting ^{201}Tl myocardial image,^{13 14} it is easily seen under conditions

that increase the total right ventricular myocardial blood flow, such as increased pressure or volume work leading to right ventricular hypertrophy.^{6 11} Recent studies in animals with chronic right ventricular overload showed that left ventricular and right ventricular mass ratios correlated well with ^{201}Tl radioactivity ratios.^{9 10} These studies suggest that right ventricular visualisation in right ventricular hypertrophy may be the result of increased right ventricular mass, not of relative increase in coronary blood flow, since ^{201}Tl radioactivity and myocardial blood flow per 1 g of right ventricular mass were normal.¹⁰ Clinically, we have shown that the degree of right ventricular visualisation correlated well with haemodynamic indices of right ventricular overload in cases of chronic heart disease.^{7 11} As yet, little information has been available on the effect of removal of haemodynamic overload.

In the present study, ^{201}Tl imaging obtained within two months after operation showed no remarkable change in right ventricular visualisation, compared with preoperative ^{201}Tl imaging. Right ventricular visualisation diminished, but the right ventricle could still be seen faintly in most cases 18 to 36 months after operation. This diminution of the uptake of ^{201}Tl in the right ventricle may be because of a decrease of right ventricular mass or a diminution of coronary blood flow, or both.

REGRESSION OF RIGHT VENTRICULAR HYPERTROPHY AFTER REMOVAL OF HAEMODYNAMIC OVERLOAD

Previous studies in animals have shown that there is almost complete regression of the increased heart weight, ventricular mass, and volume after removal of a stimulus to hypertrophy.^{4 15} Complete reversal of structural and metabolic changes in the muscle associated with hypertrophy has also occurred.¹⁶ Documentation of morphological or metabolic regression of myocardial hypertrophy is, however, difficult in humans because of methodological limitations. Diminution of electrocardiographic voltage and radiological demonstration of decreases in the size of the cardiac silhouette disclose only indirect evidence of regression of chronic changes. Echocardiography allows direct assessment of the cavity dimension, but difficulties exist in the evaluation of ventricular mass, especially in the right ventricle. Angiographic studies of regression of left ventricular hypertrophy have been disparate. Some reduction has been reported in the left ventricular volume and mass after homograft aortic valve replacement⁵ or surgical correction of ventricular septal defect.¹⁷ Another study, however, showed little regression of left ventricular hypertrophy in patients who had aortic or mitral valve replacement.³ The conflicting results of previous studies may be attributed

Fig. 7 Myocardial images in the 45° left anterior oblique projection of a patient with chronic recurrent pulmonary embolism. In a period of 30 months, the right ventricular systolic pressure increased from 42 to 96 mmHg and the right ventricular free wall visualisation also increased from grade 1+ to grade 2+.

in part to technical limitations. This study has provided unique documentation of the decrement of mass and coronary blood flow in the right ventricle 18 to 36 months after removal of haemodynamic overload in adult patients.

To evaluate further the use of this approach, we performed serial studies on one patient with worsening haemodynamics caused by chronic recurrent pulmonary embolism. Increase in right ventricular free wall visualisation and right ventricular overload appeared coincidentally in a late follow-up study (Fig. 7).

Recently, quantitative evaluation of right ventricular hypertrophy using right ventricular and left ventricular count ratios has been developed.¹⁸ The ultimate usefulness of the quantitative, instead of qualitative, evaluation merits further investigation.

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