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Right ventricular failure after heart transplantation: relationship with preoperative haemodynamic parameters

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Abstract. The prevalence of right ventricular failure after orthotopic heart transplantation, evaluated in 196 patients, was 11.7%, as assessed by the presence during the first postoperative month of right atrial pressure >10 mm Hg. Two deaths, related to refractory right ventricular failure, were observed within the first month, both in subjects with preoperative pulmonary arteriolar resistances >5 Wood Units. The haemodynamic profile after heart transplantation showed a significant decrease ($P < 0.01$) and an early normalization of pulmonary arterial pressure, pulmonary wedge pressure and pulmonary arteriolar resistances, while right atrial pressure slowly decreased until the third month. In a long-term analysis of survival (death within 1 year) the probability of death was significantly related to the values of right atrial pressure and cardiac index during the first month after heart transplantation. Otherwise, the presence of elevated values of right atrial pressure did not show a significant correlation with the echocardiographic right ventricular end-diastolic diameter nor with the presence of right bundle branch block. The careful selection of patients referred for the cardiac transplantation (mean value of pulmonary arteriolar resistances in the evaluated subjects was 2.5 ± 1.5 Wood Units) improves the probability of avoiding the appearance of severe right ventricular failure in the postoperative period in most cases. The best predictor of right ventricular failure remains to be clearly identified.

Key words: Right ventricular failure – Pulmonary hypertension – Pulmonary vascular resistances – Heart transplantation

The development of secondary pulmonary hypertension is a frequent finding in patients with advanced cardiac failure referred for heart transplantation. The evaluation of the degree of pulmonary hypertension and pulmonary vascular resistances is a critical issue in defining the indication for orthotopic cardiac transplantation. Previous experience in transplantation of patients with high pulmonary resistances has resulted in donor right heart failure generally in the early postoperative period.

It is still unclear which among the various preoperative haemodynamic parameters indicative of pulmonary hypertension is a good predictor of the clinical and haemodynamic evolution after cardiac transplantation.

The purposes of this study were to verify the prevalence of right ventricular failure after cardiac transplantation, to characterize the potential predictors of right ventricular failure after cardiac transplantation, and to evaluate the short-term (1 and 3 months) and long-term (1 year) mortality after heart transplantation in relation to the haemodynamic parameters before and after the cardiac transplant.

Methods

Between November 1985 and April 1991, 196 orthotopic cardiac transplants were performed at the IRCCS Policlinico S. Matteo of Pavia, according to the criteria of the clinical programme of heart transplantation.

The patients ranged from 9 to 67 years of age (mean age 43.2); 176 were males and 20 were females. All patients showed advanced cardiac failure and were ascribed to III or IV NYHA functional class. The indications for heart transplantation were dilated cardiomyopathy in 96 patients, ischaemic cardiac disease in 85, valvular heart disease in 13, and hypertrophic cardiomyopathy in 2 cases.

The preoperative cardiac catheterization data were available for all 196 patients. The death of 13 patients occurred within the first month, 6 between the first and the third month and 15 three months later after heart transplantation. The postoperative catheterization data were completely lacking in 13 cases and 6 other cases had only one evaluation after cardiac transplant, because the patients died.

The haemodynamic data were derived from right heart catheterization by the Swan-Ganz thermodilution technique. The systolic, diastolic and mean pulmonary arterial pressures, the mean right atrial and pulmonary capillary wedge pressures, the cardiac output, and pulmonary vascular resistances expressed in Wood Units, were recorded before transplantation and at the first and third month after surgery. If preoperative pulmonary vascular resistances were >5 Wood Units, the pretransplant haemodynamic evaluation

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was also carried out after the administration of vasodilators (nitroprusside graded infusion at a starting dose of 0.2 μg/kg per min).

In the analysis of the post-transplant data, the presence or the absence of right bundle branch disturbances in the 12-lead surface ECG was considered, according to the hypothesis that this finding could be related to right ventricular distension.

In a limited group of patients (64 patients, mean age 42 years) it was possible to analyse the echocardiographic parameters; two-dimensional and Doppler echocardiograms in the parasternal short and long axis, and apical two- and four-chamber views were obtained, respectively, at the first and third month after cardiac transplantation. The echocardiographic images were analysed to assess right ventricular size (right ventricular diastolic diameter).

Statistics

The results are presented as mean ± standard deviation. Means were compared using the non-paired Student's *t*-test; statistical significance was defined as $P < 0.05$.

A survival analysis was performed using a logic-linear model, considering nine different variables and various associations between them.

Results

Two deaths because of refractory right ventricular failure in the early postoperative period were observed, both in patients with preoperative pulmonary arteriolar resistances > 5 Wood Units.

The prevalence of right ventricular failure in the whole population was 11.7%, considering that 23 patients showed, at the first month evaluation, a right atrial pressure > 10 mm Hg (mean 13.17 ± 2.39 mm Hg (range 11–20 mm Hg).

The haemodynamic profile was characterized by an early normalization of pulmonary artery pressure (PAP) (pretransplant systolic PAP 48.6 ± 18.3 mm Hg; mean PAP 33.1 ± 12.9 mm Hg; diastolic PAP 23.4 ± 10.9 mm Hg; first month systolic PAP 28.3 ± 8.3 mm Hg; first month mean PAP 18.1 ± 6.07 mm Hg; first month diastolic PAP 10.8 ± 5.3 mm Hg; third month systolic PAP 28.3 ± 8.6 mm Hg; third month mean PAP 18.2 ± 6.4 mm Hg; third month diastolic PAP 11.7 ± 5.8 mm Hg), pulmonary wedge pressure (PWP) pretransplant PWP 23.5 ± 11.2 mm Hg; first month PWP 9.3 ± 5.3 mm Hg; third month PWP 9 ± 5.2 mm Hg) and pulmonary arteriolar resistances (PAR) (pretransplant PAR 2.5 ± 1.5 W.U., first month PAR 1.5 ± 0.8 W.U., third month PAR 1.5 ± 0.9 W.U.).

Right atrial pressure (RAP) showed a slow decrease until the third month (pretransplant RAP 7.9 ± 6 mm Hg; first month RAP 5.5 ± 3.9 mm Hg; third month RAP 4.9 ± 3.3 mm Hg).

The values of cardiac output and cardiac index before transplantation were, respectively, 4.0 ± 1.2 l/min and 2.2 ± 0.6 l/min per m^2. After heart transplant surgery, the related values of cardiac output and cardiac index were: first month, 5.7 ± 1.1 l/min and 3.3 ± 0.7 l/min per m^2; third month 5.8 ± 1.2 l/min and 3.3 ± 0.7 l/min per m^2.

In the short-term survival analysis none of the eight pretransplant haemodynamic variables provided a significant predictive capacity. In the long-term evaluation, in contrast, the nine post-transplant variables supplied a predictive survival power, but only considering the values related to the first month, according to the formula:

$$P(\text{death within one year}) = \frac{e^{3.7 - 0.14 \times ADI - 1.8 \times CII}}{1 + e^{3.7 - 0.14 \times ADI - 1.8 \times CII}}$$

Then the values of right atrial pressure and cardiac index for first month after cardiac transplantation showed a significant predictive capacity.

On the other hand, the pretransplant and 3 months post-transplant parameters did not supply statistical predictivity. In relation to two different subgroups with right atrial pressure for the first month after heart transplantation > or ⩽ 10 mm Hg, the preoperative haemodynamic patterns did not show statistically significant differences.

The evaluation of the echocardiographic parameters showed mean values of right ventricular end-diastolic diameter (RVEDD) of 27.9 ± 5.1 mm for the first month and 26.4 ± 5.02 mm for the third month (NS). If they were related to the right atrial pressure, in the presence of right atrial pressure > 10 mm Hg, RVEDD was 28.6 ± 5.3 mm for the first month and 25.2 ± 5.8 mm for the third month. In the presence of right atrial pressure < 10 mm Hg RVEDD was 27.4 ± 4.9 mm for the first month and 27.1 ± 4.3 mm for the third month, without significant differences among the groups.

The prevalence of right bundle branch disturbances (complete or incomplete block) after cardiac transplantation was 43% (84/196 patients). In the subgroup of patients with right atrial pressure > 10 mm Hg, the prevalence of right bundle branch block was 56% (13/23 patients), without significant differences compared with all transplant recipients.

Discussion

Pulmonary hypertension is observed in most patients affected by advanced cardiac failure referred for heart transplantation. Generally the subjects who show pulmonary hypertension and high pulmonary vascular resistances are not good candidates for orthotopic heart transplantation, because of the presence of severe risk of acute perioperative right ventricular failure. The subjects with pulmonary vascular resistances > 5 or 6 Wood Units are usually not admitted to the cardiac transplant programme, even if there has not been a wide agreement on this subject.

The Wood Unit has traditionally been used to measure pulmonary vascular resistance, but according to certain authors [1], the pulmonary vascular resistance index unit (PVRI) identifies better the subjects at higher risk for right ventricular failure after cardiac transplantation.

The transpulmonary pressure gradient (TPG = PAPm-PWP) also seems to be a good marker of level of pulmonary hypertension to define the contraindications to orthotopic heart transplant and to show a different early and late risk of death [3].

According to other studies [2], the increased risk of death imposed by high pulmonary vascular resistances is

continuously variable and it is not correct to identify a cut-off level.

An accurate selection of patients referred for cardiac transplantation according to pulmonary hypertension and pulmonary vascular resistances is an important condition to avoid the development of right ventricular failure. According to these criteria, the prevalence of right ventricular failure observed in this study was not remarkable. The mean values of preoperative pulmonary vascular resistances in all transplant recipients were 2.5 ± 1.5 W.U. The evolution of haemodynamic parameters after cardiac transplant confirmed a significant reduction and normalization in pulmonary arterial pressure and pulmonary wedge pressure, a behaviour which can define a good readaptation after surgery. This finding was not evident in right atrial pressure, as an expression of the right ventricular adaptation may be the presence of chronic volume overload.

The findings related to the presence of right bundle branch block and to the degree of right ventricular end diastolic diameter were not significantly different in patients with higher right atrial pressure and in the subjects with first month right atrial pressure within 10 mm Hg.

In a complex statistical evaluation of long-term survival, nevertheless, the haemodynamic data represented a useful parameter because the values of right atrial pressure and cardiac index for the first postoperative month showed a significant relationship with the probability of death.

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