Perfusion Lung Scanning Before and After Percutaneous Transvenous Mitral Commissurotomy
— Early Estimation of Lung Congestion Relief —

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Percutaneous transvenous mitral commissurotomy (PTMC) has recently been used to treat mitral stenosis. The aim of this study was to evaluate the usefulness of radionuclide perfusion lung scanning in assessing the effect of PTMC on the relief of lung congestion.

We studied 30 patients (7 males and 23 females, mean age 55 years). Perfusion lung scannings were performed within 1 week before and after PTMC. We calculated the ratio of activity in the upper quarter to that in the lower quarter of the right lung (U/L) as an index of lung congestion. After PTMC, the mean mitral valve area increased from 1.1 ± 0.3 to 1.9 ± 0.4 cm²; the mean left atrial pressure decreased from 14.8 ± 6.3 to 9.1 ± 3.5 mmHg, the mean pulmonary artery pressure decreased from 22.7 ± 8.6 to 17.4 ± 6.3 mmHg, and the U/L ratio decreased significantly from 0.89 ± 0.40 to 0.68 ± 0.24 (p < 0.0001). The U/L ratio showed greater improvement (4.5%) in patients whose NYHA class improved (n = 19) than in those whose NYHA class did not improve after PTMC. The U/L ratio was closely related to mitral valve area, and left atrial and pulmonary artery pressures. The change in the U/L ratio before and after PTMC also reflected symptomatic improvement. In conclusion, U/L ratios obtained from perfusion lung scannings before and after PTMC reflect mitral valve area and pressures, and can be used to assess lung congestion relief after PTMC. (Jpn Circ J 1995, 59: 309–314)

MITRAL stenosis reflects resistance to flow through the mitral apparatus during diastolic filling of the left ventricle. Radiographic changes in mitral stenosis are produced by left atrial hypertension which results in left atrial enlargement, changes in the pulmonary venous pattern, prominence of the pulmonary arteries, and right ventricular enlargement. In chronic pulmonary venous hypertension, not only do the vessels become prominent, but the flow redistributes from the bases to the apices of the lung. Normal lung perfusion distribution changes when pulmonary venous pressure rises, and, using a radionuclide method, this increase may be quantified to reflect changes in left atrial pressure!–³ Percutaneous transvenous

Key words:
Mitral stenosis
Pulmonary hypertension
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mitral comissurotomy (PTMC) is a new technique that was developed to treat mitral stenosis by extending the mitral orifice with a rapid decrease in left atrial pressure.

Perfusion lung scanning visualizes the distribution of blood flow, and quantifies it to reflect changes in left atrial pressure. In addition, it is simple, noninvasive, and available in most hospitals. The purpose of this study was to evaluate the usefulness of perfusion lung scanning in assessing the relief of lung congestion soon after PTMC.

PATIENTS AND METHODS

Patients
The study population consisted of 30 patients with mitral stenosis who underwent PTMC. The 7 males and 23 females ranged in age from 40 to 74 years (mean age 55 years). Twenty four patients were New York Heart Association (NYHA) functional class II, and 6 were class III. None of the patients were class I or IV.

PTMC Procedure
All patients underwent PTMC by the transseptal approach using a 25-mm Inoue balloon catheter as previously described. The transmitral gradient was recorded before and after PTMC, using simultaneous left atrial and ventricular pressure measurements. Cardiac output was determined by the thermodilution technique.

Mitrval valve areas before and after PTMC were obtained by two-dimensional echocardiography.

Perfusion Lung Scanning
Perfusion lung scanning was performed within 1 week before and after PTMC by slow intravenous injection of 185 MBq of technetium-99m-labelled macroaggregated human serum albumin (99mTc MAA), with the patient seated to maximize the perfusion gradient. Scanning was performed within 30 min of the 99mTc MAA injection using a scintillation camera (Ohio-Nuclear Σ410S) with a low-energy, all-purpose collimator linked to a computer system (DEC, PDP 11/60). Acquisition was obtained for a minimum of 300,000 counts in a 64 × 64 matrix. Planar images were obtained.

A longitudinal (apical to basal) activity profile in the posterior view of the right lung was obtained. The slit-width used to obtain the profile was 3 pixels. The apical and basal pulmonary edges were determined by extrapolating the large exponential slopes to the baseline. The ratio of activity in the upper quarter (U) to that in the lower quarter (L) was then calculated (Fig. 1). This U/L ratio was used as a numerical index of the regional distribution of pulmonary blood flow.

\[ \% \text{U/L change} = \frac{(\text{PRE} - \text{POST})}{\text{PRE}} \times 100\% \]

where PRE and POST are the U/L ratios before and after PTMC, respectively.

Statistics
Data were expressed as the mean ± 1 standard deviation (SD). The means of continuous variables before and after PTMC were compared using a two-tailed paired Student's t test. The means of continuous variables between two discrete groups were compared using a two-tailed unpaired Student's t test. Linear regression analysis was performed between U/L ratios before and after PTMC, between U/L ratios versus left atrial and pulmonary artery pressures, and between the U/L ratio and the pressure.
TABLE I COMPARISON OF PARAMETERS IN PATIENTS WITH MILD OR MODERATE (valve area $\geq 1.3$ cm$^2$) VERSUS MORE SEVERE (<1.3) MITRAL STENOSIS

<table>
<thead>
<tr>
<th></th>
<th>$\geq 1.3$ cm$^2$</th>
<th>$&lt;1.3$ cm$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Patients</td>
<td>9</td>
<td>21</td>
</tr>
<tr>
<td>NYHA Class</td>
<td>$1.8 \pm 0.4$</td>
<td>$2.2 \pm 0.6$</td>
</tr>
<tr>
<td>At 1 week</td>
<td>$1.2 \pm 0.4$</td>
<td>$1.5 \pm 0.6$</td>
</tr>
<tr>
<td>Hemodynamics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before PTMC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitral valve area (cm$^2$)</td>
<td>$1.4 \pm 0.1$</td>
<td>$0.9 \pm 0.2$*</td>
</tr>
<tr>
<td>Cardiac output (L/min)</td>
<td>$4.1 \pm 0.6$</td>
<td>$4.0 \pm 1.0$</td>
</tr>
<tr>
<td>Left atrial pressure (mmHg)</td>
<td>$13.4 \pm 3.3$</td>
<td>$15.4 \pm 7.1$</td>
</tr>
<tr>
<td>Pulmonary artery pressure (mmHg)</td>
<td>$20.6 \pm 5.6$</td>
<td>$23.5 \pm 9.5$</td>
</tr>
<tr>
<td>Gradient (mmHg)</td>
<td>$5.8 \pm 2.4$</td>
<td>$9.6 \pm 4.4$*</td>
</tr>
<tr>
<td>U/L ratio</td>
<td>$0.66 \pm 0.18$</td>
<td>$0.99 \pm 0.43$*</td>
</tr>
<tr>
<td>After PTMC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitral valve area (cm$^2$)</td>
<td>$2.1 \pm 0.3$</td>
<td>$1.8 \pm 0.4$*</td>
</tr>
<tr>
<td>Cardiac output (L/min)</td>
<td>$4.4 \pm 0.5$</td>
<td>$4.4 \pm 1.2$</td>
</tr>
<tr>
<td>Left atrial pressure (mmHg)</td>
<td>$9.8 \pm 4.2$</td>
<td>$8.9 \pm 3.3$</td>
</tr>
<tr>
<td>Pulmonary artery pressure (mmHg)</td>
<td>$17.8 \pm 5.3$</td>
<td>$17.3 \pm 6.89$</td>
</tr>
<tr>
<td>Gradient (mmHg)</td>
<td>$3.0 \pm 1.7$</td>
<td>$3.5 \pm 1.3$</td>
</tr>
<tr>
<td>U/L ratio</td>
<td>$0.62 \pm 0.14$</td>
<td>$0.71 \pm 0.27$</td>
</tr>
</tbody>
</table>

*p $< 0.05$, **p $< 0.001$

RESULTS

Mitral Valve Area, Hemodynamics and the U/L Ratio

Fig. 2 shows typical lung perfusion profiles in a patient before and after PTMC. Lung congestion was reduced after PTMC, and the peak of the profile shifted to the pulmonary base.

PTMC was completed successfully in all patients. It resulted in substantial increases in the mitral valve area (from $1.1 \pm 0.3$ to $1.9 \pm 0.4$ cm$^2$) and cardiac output (from $4.1 \pm 0.9$ to $4.4 \pm 1.1$ L/min) ($p < 0.0001$), and declines in the mean transmural pressure gradient (from $8.3 \pm 4.2$ to $3.3 \pm 1.5$ mmHg) ($p < 0.0001$), the mean left atrial pressure (from $14.8 \pm 6.3$ to $9.1 \pm 3.5$ mmHg) ($p < 0.0001$), and the mean pulmonary artery pressure (from $22.7 \pm 8.6$ to $17.4 \pm 6.3$ mmHg) ($p < 0.0001$). The U/L ratio decreased significantly from $0.89 \pm 0.40$ to $0.69 \pm 0.24$ ($p < 0.0001$).

Mitral regurgitation (MR) was observed in 17 and 22 patients before and after PTMC, respectively. Regurgitation was increased in 11 patients (MR: grade 0 to 0; 8 patients, grade 0 to 1; 5 patients, grade 1 to 1; 8 patients, grade 1 to 2; 3 patients, grade 1 to 3; 2 patients, grade 2 to 2; 3 patients, grade 2 to 3; 1 patient).

Before PTMC, 9 patients had mild or moderate valvular stenosis (mitral valve area $\geq 1.3$ cm$^2$) with a mean valve area of $1.4 \pm 0.1$ cm$^2$ and 21 patients had severe stenosis ($<1.3$ cm$^2$) with a mean valve area of $0.9 \pm 0.2$ cm$^2$. The results of PTMC in patients with mild or moderate stenosis were compared with those in patients with severe stenosis (Table 1). Patients with more severe mitral stenosis had a significantly higher mean pressure gradient ($p < 0.05$) and U/L ratio ($p < 0.001$) before PTMC.

Correlations with the U/L Ratio

The relation between the U/L ratios before and after PTMC is shown in Fig. 3. Using simple regression analysis, a significant positive correlation was found ($y=$...
Fig. 3. Scatterplots showing the linear relation between the U/L ratios before and after PTMC. The dotted line shows when these ratios are identical.

![Graph](image1)

\[ y = 0.23 + 0.52x, \quad r = 0.87 \quad (p < 0.001) \]

Fig. 4. Scatterplots showing the linear relation between the U/L ratio and left atrial pressure, and that between the U/L ratio and the pressure gradient.

PRE: before PTMC, POST: after PTMC.

![Graph](image2)

\[ y = 0.46 + 0.03x, \quad r = 0.47 \quad (P < 0.05) \]

\[ y = 0.55 + 0.02x, \quad r = 0.22 \]

Fig. 5. Change in New York Heart Association (NYHA) functional class before and after PTMC and the percent change in the U/L ratio.

PRE: before PTMC, POST: after PTMC

![Graph](image3)

NYHA CLASS

- IMPROVED: 20.4
- UNCHANGED: 15.9

0.23 + 0.52x, \( r = 0.87 \); \( p < 0.001 \).

Correlation coefficients between left atrial pressure and the U/L ratio before and after PTMC were 0.47 (\( p < 0.01 \)) and 0.22, respectively. Those between pulmonary arterial pressure and the U/L ratio before and after PTMC were 0.58 (\( p < 0.001 \)) and 0.48 (\( p < 0.05 \)), respectively. Similarly, the correlation between the U/L ratio and transmitral pressure gradient was better before PTMC (\( r = 0.76; \ p < 0.001 \)) than after PTMC (\( r = 0.07 \) (Fig. 4).

**NYHA Class and Change in the U/L Ratio**

At 1 month after PTMC, 17 of 24 patients changed from NYHA class II to I, while the remaining 7 remained in class II, and 2 of 6 patients changed from class III to I, 3 changed from class III to II, and 1 patient
remained in class III. The percent change in the U/L ratio in patients whose NYHA class improved was $20.4 \pm 15.5\%$, and that in patients whose NYHA class did not improve was $15.9 \pm 13.0\%$. However, this difference was not significant (Fig. 5).

**DISCUSSION**

**Perfusion Lung Scanning and Hemodynamics of the Lung**

PTMC using dilating balloon catheters has become a therapeutic alternative to surgical mitral commissurotomy for some patients with mitral stenosis. This procedure can be performed in a cardiac catheterization laboratory, percutaneously, without general anesthesia, and with relatively low risk. Although several reports have documented the beneficial effects of PTMC for the relief of mitral stenosis, few studies have measured pulmonary congestion relief after PTMC.

Perfusion lung scanning is safer than pulmonary angiography for visualizing blood flow distribution in the lung. To provide a reproducible and quantitative method for comparing regional blood flows, the ratio of radioactivity in the upper quarter to that in the lower quarter in the right lung (U/L ratio) was calculated and taken to represent the ratio of blood flow in the right lung. Observations made for the left lung were not analyzed since the enlarged left atrium in patients with mitral valve disease often lay within the counting field, which can result in an apparent decrease in radioactivity. Several reports demonstrated the usefulness of lung perfusion scanning for estimating pulmonary vascular pressures in mitral valve disease. Harris et al. used the ratio of the radioactivity in the upper half of the lungs to the total counts as an index of pulmonary venous hypertension. However, it is often difficult to accurately divide the top and bottom of the lung. Our index, the U/L ratio derived from the lung activity profile, is simple and reproducible. After PTMC, upper lobe blood diversion improved, and as a result, the U/L ratio decreased, along with the mean left atrial and pulmonary artery pressures.

**U/L Ratio and Hemodynamics**

Herrmann et al. demonstrated that percutaneous balloon dilation in patients with mild or moderate mitral stenosis (mitral valve area $\geq 1.3 \text{ cm}^2$) resulted in larger mitral valve areas than those in patients with more severe stenosis, and that symptomatic improvement was associated with the increase in valve area. The criterion for mild or moderate stenosis is based on the fact that Heger et al. and Herrmann determined that patients with preoperative or pre-PTMC valve area $\geq 1.3 \text{ cm}^2$ had good hemodynamic and functional improvement after surgery or PTMC. These findings are consistent with our present results. A large final valve area was achieved in patients with mild or moderate stenosis ($2.1 \pm 0.3$ vs $1.8 \pm 0.4 \text{ cm}^2$), which resulted in a small final U/L ratio ($0.62 \pm 0.14$ vs $0.71 \pm 0.27$). These results indicate that PTMC can effectively dilate a moderately stenosed mitral valve as well those with more severe stenosis, and can effectively improve lung congestion in such patients.

The U/L ratios before and after PTMC showed a strong correlation ($r=0.87$, $p<0.001$). Therefore, we can predict lung congestion relief after PTMC using the linear regression equation ($y=0.23 + 0.52x$).

The correlation between the U/L ratios versus left atrial and pulmonary artery pressures, and that between the U/L ratio and the pressure gradient were higher before PTMC. On the other hand, these correlations declined after PTMC. We believe that the decreased parameters (U/L ratio, left atrial and pulmonary artery pressures, pressure gradient) after PTMC induced scatterplots to converge at lower values.

**U/L Ratio and Symptoms**

In patients whose NYHA class improved, the percent change in the U/L ratio was higher than that in patients whose NYHA class did not improve. This result indicates that the improvement of pulmonary hypertension is directly related to symptoms. The U/L ratio might be a reliable parameter of NYHA class in patients with mitral stenosis.

However, a limitation of this study must be considered. Long-term follow-up of the patients was lacking. Cohen et al. reported that balloon mitral valvuloplasty for selected patients with mitral stenosis produced good...
long-term results. This study was not designed to predict survival. However, an increase in valve area has been shown to result in symptomatic improvement that is sustained for more than 1 year. Since the reduction in high left atrial and pulmonary artery pressures appeared immediately after commissurotomy, it may be possible to assess congestion relief within 1 week after PTMC.

Conclusion
This study provided new information about the usefulness of perfusion lung scanning for estimating lung congestion relief after PTMC. The U/L ratio derived from perfusion lung scanning was closely related to mitral valve area, cardiac output, trans-mitral pressure gradient, and left atrial and pulmonary artery pressures. The percent change in the U/L ratio before and after PTMC also reflected symptomatic improvement. Perfusion lung scanning is a simple and useful modality for assessing lung congestion relief after PTMC.

REFERENCES