

Our Experience of Surgical Treatment for Chronic Pulmonary Thromboembolism

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Chronic pulmonary thromboembolism is one of the causes of pulmonary hypertension and carries a poor prognosis. Medical therapy is generally unsatisfactory, and surgery provides the only possibility of a cure. Though over 1400 cases have undergone pulmonary thromboendarterectomy (PTE) worldwide, the surgical procedure is performed with success only at a few institutions.¹⁻³ It is important to select suitable patients, to perform PTE (not an embolectomy) and to manage successfully postoperatively. We report our experiences of surgical treatment for chronic pulmonary thromboembolism. Between June 1986 and March 2001, 50 patients (15 men, 35 women) underwent PTE at our hospital. The mean age was 51.3 years (range 22-73). We have adopted two surgical approaches to PTE. The number of operation deaths was 9 (18.0%). Forty-one patients survived, and the declines in their mean pulmonary arterial pressures (m-PAP) and pulmonary vascular resistance (PVR), and the increases in cardiac indices (C.I.), were significant postoperatively. Their PaO₂ improved significantly after 6 months. The symptoms were markedly reduced, and survival after PTE was 86-88% at 10 years. The only therapeutic alternative to PTE is lung transplantation. The great advantage of PTE includes an excellent long-term results without the risks associated with chronic immunosuppression and potential for chronic allograft rejection. We conclude that PTE can improve the prognosis of selected patients with chronic pulmonary thromboembolism, and morphological classification by CT scan could be useful for predictions about the surgical accessibility. (*Ann Thorac Cardiovasc Surg* 2001; 7: 261-5)

Key words: chronic pulmonary thromboembolism, thromboendarterectomy, surgical results, long-term follow-up, CT scan

Introduction

The natural history and poor prognosis of chronic pulmonary thromboembolism with pulmonary hypertension were reported by Riedel and colleagues in 1982.⁴ Medical treatment is not effective, and surgical treatment provides the only potential cure at this time. The largest series of surgical procedures has been performed at the University of California, San Diego (UCSD).⁵⁻⁷ In Japan, several reports has been demonstrated since the first

case was reported by Nakajima et al. in 1986.⁸⁻¹¹ In this paper, we report our surgical experience and the follow-up results.

Patients and Methods

Between June 1986 and March 2001, 50 patients (15 men, 35 women) underwent PTE at our hospital. The mean age was 51.3 years (range 22-73). Our surgical indications are based on the San Diego group criteria as follows: (1) m-PAP>30 mmHg; (2) PVR>300 dyne·sec·cm⁻⁵; (3) thrombi defined to be surgically accessible; (4) no-threatening concomitant disease.¹

We have adopted two surgical approaches to pulmonary thromboendarterectomy. The first method is the lateral thoracotomy approach (16 patients), and the other is

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Table 1. Operative experience (1986.11-2001.3)

| | |
|---------------------|----------------|
| Lateral thoracotomy | 16 |
| Median with CPB | 34 |
| Total | 50 |
| Male : female | 15 : 35 |
| Mean age | 51.3 (22 - 73) |

the median sternotomy approach with cardiopulmonary bypass (34 patients) (Table 1).

Results

Preoperative hemodynamics

The preoperative pulmonary hemodynamics data and gas change data are shown in Table 2. The data demonstrated pulmonary hypertension and hypoxemia (Table 2).

Surgical results

As shown in Table 3, the number of hospital deaths was 9 cases, the mortality was 18.0%. In particular six deaths of the median sternotomy approach patients were due to cardiac failure with residual pulmonary hypertension because of inadequate thromboendarterectomy (Table 3).

Postoperative hemodynamics

41 patients survived and were discharged from the hospital. The pulmonary hemodynamics data and gas change data of the 41 patients were shown in Table 2. The declines in m-PAP and PVR and the rise in cardiac indices were significant. The hemodynamic change between the median sternotomy approach group and the lateral thoracotomy approach group was not significant. The blood gas analysis after 1 month did not show a significant improvement; however, there was a significant improvement of hypoxemia after 6 months (Fig. 1).

Long-term survival

Survival after thromboendarterectomy was 86-88% at 10 years (Fig. 2). The marked improvement is sustained in long-term follow-up.

Discussion

Chronic pulmonary thromboembolism is known as a frequent cause of progressive pulmonary hypertension and carries a poor prognosis. The natural history and poor prognosis of this disease were reported by Riedel and

Table 2. Hemodynamics and respiratory function

| | Preoperation | Postoperation |
|--|--------------|---------------|
| m-PAP (mmHg) | 46.9 ± 8.6 | 26.7 ± 8.8 |
| C.I. (l/min/m ²) | 2.53 ± 0.57 | 3.25 ± 0.51 |
| PVR (dynes·sec·cm ⁻⁵) | 869.1 ± 299 | 344.4 ± 174.4 |
| PaO ₂ (mmHg) (under FiO ₂ = 0.21) | 57.7 ± 9.2 | 65.6 ± 13.2 |

The preoperative data demonstrated pulmonary hypertension and hypoxemia. The hemodynamic improvement was characterized by an immediate decrease of m-PAP and PVR.

m-PAP: mean pulmonary arterial pressure, C.I.: cardiac index, PVR: pulmonary vascular resistance.

Table 3. Surgical results

| | |
|-------------------------|-----------|
| Hospital death | 9 (18.0%) |
| Lateral thoracotomy | 2 |
| Pulmonary edema | 1 |
| Pneumonia | 1 |
| Median with CPB | 7 |
| Cardiac failure with PH | 6 |
| Late tamponade | 1 |

CPB: cardiopulmonary bypass, PH: pulmonary hypertension. The number of operative deaths was nine (18.0%). Of the median sternotomy approach patients, six deaths were due to cardiac failure with pulmonary hypertension because of inadequate thromboendarterectomy.

colleagues.⁴⁾

The etiology of chronic pulmonary thromboembolism remains unknown. Whether the failure to resolve emboli results from the deep vein thrombosis or from the pulmonary vascular endothelial change itself is uncertain. Why some patients have unresolved emboli is not certain, but unknown factors may play a role. The lytic mechanisms may be abnormal. A hypercoagulability may be present in a few patients. Abnormalities of protein C deficiency or anticardiolipin antibody deficiency were found in fourteen patients. We have experienced another two cases of pulmonary arterial stenosis caused by aortitis syndrome or solitary pulmonary arteritis.

In pulmonary thromboembolism, pulmonary hypertension progresses with time. The cause of the elevated pressure is unknown. This may be the result of recurrent embolic episodes or of a vasculopathy in the previously normal vascular bed.

Medical treatment is not effective, and thromboendarterectomy has improved the prognosis of selected patients. The largest series of thromboendarterectomies has been performed at UCSD, which has done pioneering

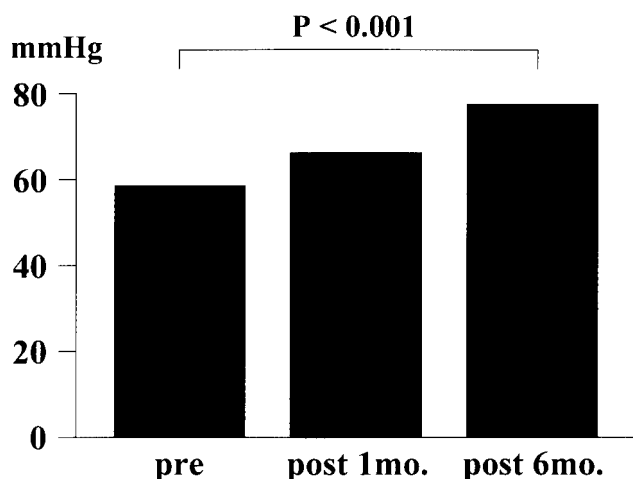


Fig. 1. Postoperative improvement of PaO₂.

The PaO₂ did not immediately improve after operation, but significantly improved after 6 months.

work in this procedure.⁵⁾ The mortality rate for pulmonary endarterectomy at UCSD is reported in the range of 5 to 7%. Patients treated by pulmonary endarterectomy reveal a marked symptomatic improvement immediately after surgery and sustain an improved condition in long-term follow-up.^{6,7)}

Most cases of PTE involve bilateral obstruction and pulmonary hypertension. Therefore, the median sternotomy approach is optimal. Occasionally the lateral thoracotomy approach is performed. However, the lateral thoracotomy approach may put the patient in hemodynamic jeopardy during the clamping of the pulmonary artery. Cardiopulmonary bypass with deep hypothermia and intermittent circulatory arrest is essential when the median sternotomy approach is performed.

Surgical indications were mentioned earlier. Recently, Jamieson et al. proposed to offer surgery to symptomatic patients whenever the angiography demonstrated thromboembolic disease with the increasing experience and safety of the operation.⁶⁾

The results obtained in our series demonstrated a marked improvement of hemodynamics and gas change. The hemodynamic improvement was characterized by an immediate decrease of PAP and PVR subsequent to an increase of cardiac output. The PaO₂ did not immediately improve after operation, but did improve during the follow-up period. Postoperatively reperfusion of the nonperfused area and an increase in cardiac output can be obtained. But especially when there is some residual hypertension, it may take a certain amount of time for stabilization of the redistributed blood flow to occur. It

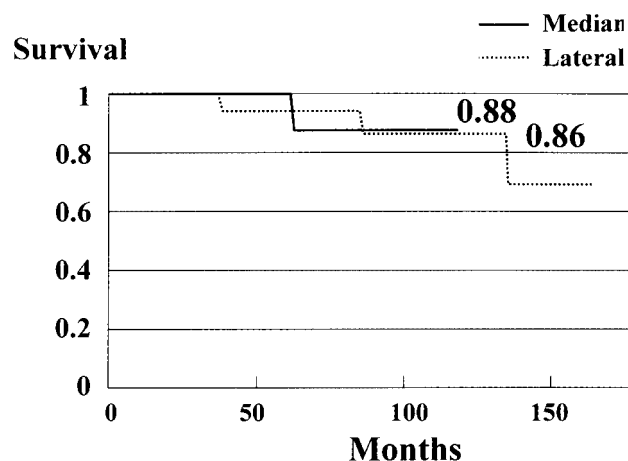


Fig. 2. Long-term results.

The marked improvement was sustained in long-term follow-up. Follow-up results between the median sternotomy approach and the lateral thoracotomy approach were not significant.

Median: median sternotomy approach, lateral: lateral thoracotomy.

is believed that pulmonary vascular steal delays improvement in the PaO₂ level.^{12,13)} The majority of patients did not require continuous oxygen therapy during the follow-up period.

In our experiences, surgical mortality was markedly high in the ineffectively thromboendarterectomized patients.¹⁴⁾ So it is very important to determine whether the lesion is accessible surgically for further improvement of results. A retrospective analysis of surgical accessibility in the median sternotomy (34 patients) was made according to the type of steno-occlusive lesion of pulmonary arteries. We tried to discriminate the central type disease from the peripheral localization of the lesion with a computed tomography (CT) scan. Assessment of tissue density by CT can differentiate chronic thrombus from vessel wall, and can be useful for delineating the proximal extent of thrombus.^{15,16)} In central type disease on CT, the thrombus is detected in main or lobar arteries (Fig. 3). In peripheral type disease on CT, the thrombus is not detected in main or lobar arteries and the occlusion of the arteries is confined mainly to segmental arteries (Fig. 4). The 34 patients were then classified according to the typing on CT scan. Thirty patients were classified as central type; 4 patients were classified as peripheral type. In 96% of effectively thromboendarterectomized patients, central thrombi could be found on CT scan, whereas in only 50% of non-effectively thromboendarterectomized patients, central thrombi could be found (Table 4). The absence of central thrombi

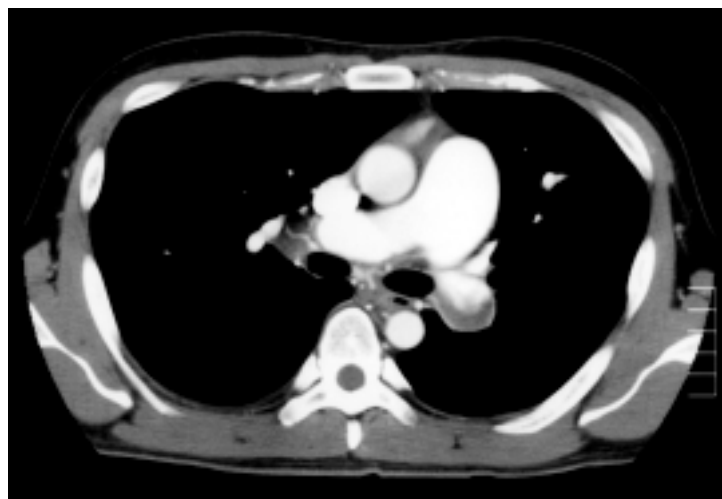


Fig. 3. Central type disease on CT scan.
The thrombi are detected in main pulmonary arteries.

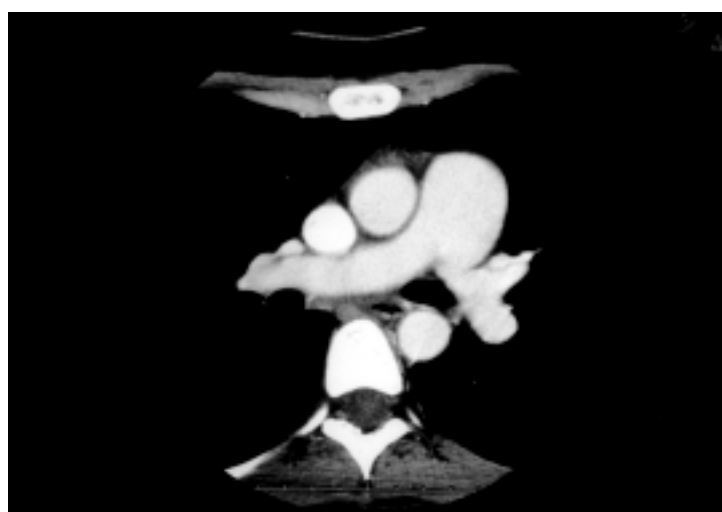


Fig. 4. Peripheral type disease on CT scan.
The thrombus is not detected in main or lobar pulmonary arteries.

**Table 4. Localization of the lesion on CT scan and operability
Pulmonary thromboendarterectomy (median with CPB)**

| Central type of CT scan | |
|-------------------------|------------------------|
| Effective (n=26) | Non-effective (n=8) |
| 25 / 26 (96%) | 4 / 8 (50%) |

CPB: cardiopulmonary bypass.

In 96% of effectively thromboendarterectomized patients, central thrombi could be found on CT scan, whereas in only 57% of non-effectively thromboendarterectomized patients, central thrombi could be found.

on the CT scan could predict the surgical accessibility for thromboendarterectomy.

Conclusions

Chronic pulmonary thromboembolism with pulmonary

hypertension carries a poor prognosis. Medical treatment is ineffective in prolonging life, pulmonary thromboendarterectomy can be expected to cure patients. The beneficial effects on hemodynamics and gas exchange are confirmed. The therapeutic alternative to pulmonary thromboendarterectomy is lung transplantation. The advantage of thromboendarterectomy includes excellent long-term results without the risks associated with immunosuppression. For further improvement of surgical outcomes, preoperative evaluation is vitally important. pulmonary angiography remains the gold standard to establish the diagnosis and CT can be useful for confirming occlusion in the main and lobar arteries. Detection of thromboembolic obstruction of central vessels may not ensure surgical success, pulmonary thromboendarterectomy is technically demanding. However, pulmonary thromboen-

arterectomy is the best procedure in selected patients with chronic pulmonary thromboembolism to improve clinical symptoms.

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