DEEP HYPOTHERMIC CIRCULATORY ARREST DURING PULMONARY THROMBENDARTERECTOMY IN PATIENTS WITH CHRONIC THROMBEMBOLIC PULMONARY HYPERTENSION

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Chronic thrombembolic pulmonary hypertension is a rare complication of acute pulmonary embolism. Narrowing or closure of pulmonary arteries is the cause of pulmonary hypertension and results in right ventricular overload and failure. The treatment of choice is pulmonary thrombendarterectomy. Deep hypothermic circulatory arrest is a very important factor required for complete removal of the thrombembolic material from the pulmonary arteries during the operation.

The aim of the study was the evaluation of the effectiveness of the use of deep hypothermic circulatory arrest during pulmonary thrombendarterectomy in patients with chronic thrombembolic pulmonary hypertension.

Material and methods. Between October 1995 and October 2006 seventy patients were operated on. All of them were operated on with the use of deep hypothermic circulatory arrest. Deep hypothermia (18-19°C), pharmacotherapy, and neuromonitoring were used as a protection of the central nervous system during circulatory arrest.

Results. In fifty-seven patients out of seventy, complete thrombendarterectomy was performed (more than 75% of branches opened). The average pulmonary artery pressure and pulmonary vascular resistance were decreased, and cardiac output and index were increased. Six patients died (8.6%).

Conclusions. Complete thrombendarterectomy gives significant hemodynamical improvement in patients undergoing the operation. Deep hypothermic circulatory arrest during the operation does not cause significant neurological complications. Incomplete thrombendarterectomy may be the cause of right ventricular failure and death after the operation.

Key words: chronic thrombembolic pulmonary hypertension, pulmonary thrombendarterectomy, deep hypothermic circulatory arrest
Deep hypothermic circulatory arrest during pulmonary thrombendarterectomy

In most cases it is dyspnea, exercise intolerance, leg oedema, atypical chest pain, headache, and syncope (6).

Pulmonary arteriography and multislice computed tomography are the most important examinations for differential diagnosis and distinguishing the possibility of surgical treatment (2).

Pulmonary thrombendarterectomy (PTE) is the treatment of choice, giving satisfactory results in patients with chronic thromboembolic pulmonary hypertension. The use of circulatory arrest makes the operation considerably easier with good exposure and bloodless field (3). Good cooperation of the surgeon and anaesthesiologist in these operations is especially important during circulatory arrest requiring brain protection (5).

Indications for pulmonary thrombendarterectomy:
1. Pulmonary vascular resistance above 300 dyn/sec/cm⁻⁵.
2. Mean pulmonary artery pressure above 40 mm Hg.
3. Exercise capacity (NYHA III and IV).
4. Proximal changes in pulmonary arteries (7).

The contraindications for PTE are other diseases leading to death in a very short time, independent of pulmonary insufficiency and peripheral vein thrombosis (3, 4).

The aim of this work was the evaluation of early results of pulmonary thrombendarterectomy with deep hypothermia and total circulatory arrest in patients with chronic thromboembolic pulmonary hypertension.

MATERIAL AND METHODS

70 patients (48 male) were operated on between October 1995 and October 2006. The age varied from 21 to 77 years of age (average age 51). The average time from first symptoms was about 2 years.

The most common risk factor was peripheral vein thrombosis – 49 patients (tab. 1).

In all patients the initial diagnosis was made on the basis of echocardiography (transthoracal or transoesophageal). Final diagnosis was made with the use of CT and pulmonary arteriography.

Surgical technique

All patients were operated on through a median sternotomy and with the use of extracorporeal circulation and deep hypothermic circulatory arrest (18-20°C). For complete thrombendarterectomy, the extracorporeal circulation was arrested completely at the temperature of 18-19°C. In most cases, a circulation arrest of 20 minutes was sufficient to complete the operation on one side. Once the operation on one side was completed, the extracorporeal circulation was restored for 5-10 minutes. After performing thrombendarterectomy of both branches of the pulmonary artery, the warming of the patients started. During rewarming, the necessary additional procedures were performed: aorto-coronary bypass grafts, valvular reconstructive operations or valve replacement, and closure of persistent foramen ovale. Three methods for protection of the central nervous system were used: deep hypothermia, pharmacotherapy, and in the last nine patients, neuromonitoring.

Anaesthesia

Anaesthesia was performed with fentanyl, etomidate, and pancuronium. For protection of the central nervous system, the patients were given dexaven at the beginning of extracorporeal circulation and thiopental infusion continued for a few hours after the operation.

Neuromonitoring

In nine patients, the brain oxymetria was monitored (rSO₂) with the use of NIRS (IN-
Extracorporeal circulation was performed with the flow adjusted to the body surface area of the patient, temperature, and \( \text{SvO}_2 \) value at the level of 70%. The average systemic pressure was kept at the level of 50-80 mm Hg. Before the circulatory arrest the patient was cooled to 18-20°C.

The hemodynamical parameter measurements were performed by the thermodilution method: after the introduction to anaesthesia, before and after extracorporeal circulation, and at the ICU every 12 hours. On the basis of cardiac output, cardiac index, and pulmonary and systemic vascular resistance inotropic, vasodilatative, and vasoconstrictive treatment was managed.

**RESULTS**

In 66 patients we performed bilateral and in 4 only right-sided pulmonary thrombendarterectomy. Simultaneously during rewarming of the patient the additional necessary cardio-surgical procedures were performed (tab. 2).

<table>
<thead>
<tr>
<th>Table 2. Description of operations</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral pulmonary thrombendarterectomy</td>
<td>66</td>
</tr>
<tr>
<td>Right-sided pulmonary thrombendarterectomy</td>
<td>4</td>
</tr>
<tr>
<td>Right atrial thrombus removal</td>
<td>4</td>
</tr>
<tr>
<td>Aorto-coronary by-pass grafts</td>
<td>3</td>
</tr>
<tr>
<td>Persistent foramen ovale closure</td>
<td>2</td>
</tr>
<tr>
<td>Tricuspid valve plasty</td>
<td>1</td>
</tr>
<tr>
<td>Mitral valve plasty</td>
<td>1</td>
</tr>
<tr>
<td>Mitral valve replacement</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Table 3. Hemodynamical data before and after the operation</th>
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<tbody>
<tr>
<td>Before the operation</td>
</tr>
<tr>
<td>CO* L/min</td>
</tr>
<tr>
<td>CI* L/min/m²</td>
</tr>
<tr>
<td>PVR* dyn/s/cm²</td>
</tr>
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<td>MPAP* mm Hg</td>
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\( * p<0.001 \)
Deep hypothermic circulatory arrest during pulmonary thrombendarterectomy

Fig. 1. Thrombotic material removed from the pulmonary arteries

of those patients, complete thrombendarterectomy was not possible.

DISCUSSION

Chronic thromboembolic pulmonary hypertension is a rarely recognized disease with very poor prognosis. Pharmacological treatment does not give satisfactory results. The treatment of choice is pulmonary thrombendarterectomy, with the alternative being lung transplant. The advantage of PTE is a lower death rate, better late results, and the lack of necessity of immunosuppression (1, 2, 6).

Pulmonary thrombendarterectomy is a difficult procedure requiring the involvement of not only the surgeon but the whole operating staff (anaesthesiologist, perfusionist). The result of PTE depends on the experience of the surgical team, on the location of pulmonary artery changes, and also on the progression of disease. The operation performed at the initial stage of disease is connected with a low risk of death (2).

Complete PTE gives a significant and permanent decrease of pulmonary artery pressure and pulmonary vascular resistance and right ventricular afterload. However, performing the operation in a layer that is too deep may lead to the perforation of the pulmonary artery (9).

Deep hypothermic circulatory arrest during the operation is necessary to stop the permanent blood inflow from the bronchial arteries (10). That way the obtained exposition allows the round dissection and the removal of thrombotic material incorporated in the main, lobar, and segmental branches of the pulmonary artery (9). The periods of circulatory arrest are usually limited to 20 minutes alternatively with reperfusion. In experienced hands, bilateral PTE may be performed in two 20 minute periods of circulatory arrest. The important factor increasing the perioperative death risk is persistent pulmonary artery pressure. This is usually associated with incomplete PTE due to technical difficulties or distal location of the thrombotic material (11).

Hypothermia is the basic method of protection of the central nervous system (CNS) during circulation arrest (CA). It reduces the metabolism of the CNS (CMRO₂) by about 7% for 1°C. During the circulatory arrest at a temperature of 18°C, the CMRO₂ is about 34%, and at a temperature of 15°C it is about 17% of the value for normothermia. The decrease of CMRO₂ induced by hypothermia increases the reserve of ATP in the neurons, and that way it secures the functioning of the sodium-potassium pump during anoxia (Editor note: Do you mean “anoxia” instead of “anoxemia”? Please revise if needed) and prevents brain oedema. Therefore it is assumed that the safe circulatory arrest at a temperature of 18°C is up to 30 minutes. Deeper hypothermia insignificantly prolongs the safe period of brain anoxemia but it may cause the blockade of platelet activity and dangerous coagulation disturbances (12).

The infusion of thiopental, mannitol, and steroids before and after circulatory arrest in hypothermia also has a protective function for the central nervous system.

The simple and non-invasive method allowing the permanent observation of the oxygenation of the cerebral cortex is the regional brain oximetry (rSO₂) evaluated with the use of spectroscopy in close infrared. With the aid of electrodes connected in the forehead area, the device sends the waves in close infrared of two wavelengths (730 nm and 805 nm). The
waves penetrate the skull to the cerebral cortex and are received by the sensor; therefore, the value of \( rSO_2 \) is dependent on hemoglobin oxygenation in vein blood (about 75%) and arterial blood (about 25%) in the cerebral cortex. The clinical research confirmed that the maintenance of proper values of \( rSO_2 \) should cause both the decrease of the amount and seriousness of brain and other organs complications after cardiac operations. They should shorten the time the patient has to spend in the ICU. This method seems to be exceptionally useful in patients with elective deep hypothermic circulatory arrest and in those with increased risk of neurological complications (13, 14). Monitoring of \( rSO_2 \) allows:

- Control of oxygenation of the cerebral cortex during the operation.
- Adjustment of parameters of extracorporeal circulation during the cooling and rewarming of the patient to changing metabolic needs and flows in central nervous system.
- Regulation of time of deep hypothermic circulatory arrest.

In our group of patients we did not observe significant neurological complications even though the average time of circulatory arrest was 27 minutes and the longest 93 minutes.

Pulmonary thrombendarterectomy with deep hypothermic circulatory arrest may safely be carried out with considerably low risk of death and with significant improvement of hemodynamical function of the right ventricle and with satisfactory effectiveness, providing the performed operation is complete.

CONCLUSIONS

1. Complete thrombendarterectomy gives significant hemodynamical improvement in patients undergoing the operation.
2. Intermittent deep hypothermic circulatory arrest during the operation does not cause significant neurological complications.
3. Incomplete removal of thrombembolic material may be the cause of heart failure and death in the post operation period.

REFERENCES