Study of Hemodynamic Changes with Oxygen Inhalation in VSD Associated with Pulmonary Hypertension

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VENTRICULAR septal defect (VSD) is one of the most common congenital heart disease. It also is well known as the most typical cardiac disease which has left to right shunt and causes pulmonary hypertension. Operative results of VSD is very excellent now. When pulmonary hypertension is advanced, however, operative results are not satisfactory yet. Correlation between severity of pulmonary hypertension and operative results have been studied by many investigators. Increase of pulmonary blood flow as the results of left to right shunt and elevation of pulmonary vascular resistance secondary caused by diminution of pulmonary vascular bed are the important factors to decide the mechanisms of pulmonary hypertension and the operative results are usually controlled by severity of pulmonary vascular resistance.

It has reported the pulmonary hemodynamic studies1,2 and this has done also to study postoperative changes of the pulmonary hemodynamics by 100% oxygen inhalation in the VSD associated with severe pulmonary hypertension.

CLINICAL

376 cases of isolated VSD were operated upon since 1961 to January of 1974 in Okayama University Hospital. The systolic pulmonary-systemic blood pressure ratio (Pp/Ps) of 307 cases was lower than 0.69 and their operative mortality is 4.9%. Another 69 cases were associated with severe pulmonary hypertension and their Pp/Ps was higher than 0.7, operative morality was 29%. Among them, 20 cases have 0.70–0.79 of Pp/Ps, 20 cases have 0.80–0.89 of Pp/Ps, and 29 have over 0.90 of Pp/Ps. The mortality of 62 cases which causes of death didn’t correlate directly with pulmonary hypertension such as bleeding, sepsis and so on was 21% (13 cases). They were divided into 5 groups according to pulmonary-systemic vascular resistance ratio (Rp/Rs) and pulmonary-systemic blood flow ratio (Qp/Qs) (Fig. 1). 10 cases of high resistance and low flow group which Rp/Rs is over 0.80 and Qp/Qs is less than 2.0 show very high mortality of 60%. It is thought that this group has very difficult problems to make operative indication.

28 cases which Pp/Ps is over 0.70 were selected. They were done radical operation and postoperative pulmonary hemodynamic studies were done in 20 cases. All 28 cases were done preoperative pulmonary hemodynamic studies with 100% oxygen inhalation. Their age distribution is between 7 months to 21 years, among them 9 cases were younger than 2 years, 8 cases were 2 to 4 years, 7 cases were 4 to 16 years, 4 cases were older than 16 years. Pp/Ps is between

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<td>Pp/Ps</td>
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<td>0.90--</td>
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<td>0.80–0.89</td>
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<td>0.70–0.79</td>
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Key Words:
- Ventricular septal defect
- Pulmonary hypertension
- Oxygen inhalation test
- Pulmonary vascular resistance

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0.70 to 0.79 in 9 cases. 4 cases were between 0.80 to 0.89 and 15 cases were over 0.90 (Table I). Postoperative death were seen in 4 cases.

**METHODS**

After the ordinary right heart catheterization is done, 100% oxygen is inhaled about 10 minutes, then right heart catheterization is repeated again. Pp/Ps, Qp/Qs and Rp/Rs are calculated by following formulae determined by Fick's principle.

For the infant and younger children, intratracheal anesthesia is done and 50% oxygen and 50% nitrous oxygen gas were inhaled and right heart catheterization is done as ordinary method. Then, 100% oxygen inhalation is done under spontaneous breathing, catheter study is repeated and Pp/Ps, Qp/Qs and Rp/Rs are calculated as above. At operation, in same manner, pulmonary hemodynamics is studied by direct puncture method.

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Pp/Ps = \frac{\text{pulmonary systolic pressure}}{\text{systemic systolic pressure}}
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Qp/Qs = \frac{\text{peripheral arterial O}_2 \text{ saturation} - \text{mixed venous O}_2 \text{ saturation}}{\text{peripheral arterial O}_2 \text{ saturation} - \text{pulm. arterial O}_2 \text{ saturation}}
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Rp/Rs = \frac{\text{mean pulmonary arterial pressure}}{\text{mean systemic arterial pressure}} \times \frac{1}{Qp/Qs}
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**RESULTS**

24 cases survived and well after operation (Group A) and 19 cases of them were done postoperative hemodynamic studies (Group B). There were 4 cases of postoperative death (Group C) and one of them was done postoperative study (Group D).

Systolic pulmonary blood pressure were in between 58 to 112 mmHg in all cases. Average pulmonary arterial systolic pressure fell down from 79.7 mmHg to 67.3 mmHg in most cases but 4 unchanged and 2 elevated in Group A. In Group C, it changed from 97.3 mmHg to 82.4 mmHg.

Pp/Ps were in between 0.70 to 1.10 in all cases. Average Pp/Ps fell down from 0.92 to 0.78 in Group A but 3 unchanged and 3 increased. It changed from 1.03 to 0.93 in Group C. In Group B, it changed from 0.85 to 0.78 and to 0.47 after operation, it changed from 1.0 to 0.77 and to 0.67 in Group D. In generally, Pp/Ps were higher.
in survivors than in nonsurvivors. There was no significant difference between survivors and nonsurvivors. No correlation to age distribution is seen, too. (Fig. 2)

Qp/Qs were in between 1.10 to 6.30 in survivors and between 0.90 to 1.40 in nonsurvivors. Average Qp/Qs increased from 2.41 to 6.10 in Group A except slight diminution in 2 cases and from 1.01 to 1.55 in Group C after oxygen inhalation. That is, increase of pulmonary blood flow is very prominent and Qp/Qs is over 2.0, but in nonsurvivors only a little increase of pulmonary blood flow is seen and Qp/Qs stay in less than 2.0 (Fig. 3).

RP/Rs were in between 0.12 to 0.84 and in average 0.42 in survivors, but was in between 0.8 to 1.0 and in average 0.99 in nonsurvivors.

Average Rp/Rs fell down from 0.42 to 0.12 in Group A after oxygen inhalation. In group B, it changed from 0.99 to 0.60 but still remained in higher value and it is the difference between these two groups. In Group B, it changed from 0.46 to 0.15 after oxygen inhalation and it changed to 0.42 after operation was done. In Group D, it changed from 1.0 to 0.54 then to 0.7. In all cases which are all living, Rp/Rs was below 0.5 after oxygen inhalation or after operation but in deceased cases it still remained at over 0.5 (Fig. 4).

In cases of high resistance and low flow group with over 0.8 of Rp/Rs and with below 0.2 of Qp/Qs, Rp/Rs decreased from 0.83 to 0.16 and Qp/Qs decreased from 0.99 to 0.66 and Qp/Qs increased from 1.01 to 1.56. The decreased cases remained over 0.5 of Rp/Rs and below 2.0 of Qp/Qs after oxygen inhalation (Fig. 5).

**DISCUSSION**

It has been discussed mainly about the pulmonary blood pressure to determine the severity and the operative indication of VSD. Elevation of the pulmonary vascular resistance results pulmonary hypertension and is also resulted by the diminution of pulmonary vascular bed. When the pulmonary vascular changes are functional and reversible, pulmonary vascular resistance could be recover after correction of VSD even if it is so high. To determine the vascular bed is
reversible or irreversible, many investigators have studied. Recently, operative results of VSD are getting better and it becomes one of the safest heart disease for operation. Operative results of the cases of severe pulmonary hypertension with high pulmonary vascular resistance are still not satisfactory yet. They agree with the high pulmonary vascular resistance which Rp/Rs is between 0.75 to 0.80 is the safe limit to make operative indication of VSD. In this study, 6 of 10 cases which Rp/Rs is over 0.70 and Rp/Rs is over 0.80 succumbed after the operation.

*Heath and Edwards* reported the pathological study of pulmonary arterioles. When the organic changes especially that of intima is slight, it will be expected pulmonary vascular resistance becomes lower and is able to recover by the operation. It has been done many investigations to know reversibility of diminution of pulmonary vascular bed.

Histological examination of pulmonary arterioles by preoperative lung biopsy is one of these studies. Some drugs such as Regitin, Phenoxycbenzamine, Acetylcholine, Priscolin, Hexamethonium were given to know pulmonary hemodynamic changes.

*Euler et al.* reported that pulmonary arterial pressure dropped by pure oxygen inhalation. There are some other reports of pulmonary vascular responsibility with oxygen inhalation. The oxygen inhalation test is very easy and stable and useful to know pulmonary vascular responsibility with operation of ventricular septal defect with severe pulmonary hypertension.

**Summary**

Pre- and postoperative pulmonary hemodynamic changes were studied in 28 cases with
ventricular septal defect, in whom pulmonary-systemic blood pressure ratio was more than 70 per cent. Pp/Ps decreased and Qp/Qs increased in majority of cases and Rp/Rs decreased in all cases after 100% oxygen inhalation. In survivors, Rp/Rs decreased to under 0.5 and Qp/Qs increased to more than 2.0 after oxygen inhalation or radical operation. In nonsurvivors, Rp/Rs decreased but stayed over 0.5, and Qp/Qs increased but stayed under 2.0.

It is emphasized that when Rp/Rs falls down to under 0.5 after oxygen inhalation, it will be an enough indication for operation even pulmonary hypertension is so advanced in the ventricular septal defect.

REFERENCES