

Hypoplastic Left Heart Syndrome with Ventricular Septal Defect and Patent Arterial Duct (SNUCH CPC 95-3)

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CASE HISTORY

Nine days old male was admitted to the intensive care unit because of the jaundice and suspicious cardiac disease. He was delivered at 39⁺⁵ weeks of gestation without peripartum events. His birth weight was 3.4kg. He was the second baby with healthy brother. The family history was not contributory.

He was initially transferred to the other hospital because of the jaundice at 2 days of age. Cardiac murmur was detected at that hospital. He was asymptomatic besides mild dyspnea. He was able to suck the milk of 70ml per feeding. He was referred to another hospital because the echocardiographic examination showed a small left ventricular size.

Physical examination at the emergency room revealed a mildly lethargic baby with dyspnea. Body weight was 3.28kg and height 52cm. His body temperature was 36.2°C, heart rate 150/min, respiration rate 76/min. The blood pressure on the right arm was 58/33mmHg, left arm 64/37mmHg, right leg 64/36mmHg and left leg 58/36mmHg. He was slightly anemic and icteric.

There was no definite cyanosis. Venous engorgement was not present. Pulse volume on the extremities seemed slightly decreased. Chest examination showed symmetric expansion of the chest with moderate retraction. The breathing sound was clear without rales. Cardiac examination revealed right ventricular impulse, single S₂ at left upper sternal border, and grade 2/6 systolic murmur along the left sternal border. Diastolic murmur was not clearly heard. His abdomen was slightly protruded. The liver was palpated four fingerbreaths below subcostal margin. The spleen was impalpable. There was no deformity on the extremities.

The blood gas analysis at the emergency room was pH 7.39, PaCO₂ 35mmHg, PaO₂ 62mmHg and bicarbonate 21mmol/L. CBC was Hb 10.8gm/dl, Hct 31.4%, WBC 5.7×10³/mm³ and RBC count 3.19×10⁶/mm³. Electrolytes were Na 130mmol/L, K5.3mmol/L and Cl 101mmol/L, and total CO₂ 18mmol/L. The other chemistry results were, BUN, 4mg/dl creatinine, 0.2mg/dl; bilirubin 9.5gm/dl, glucose, 132mg/dl and ionized calcium, 1.04mmol/L. The urinalysis was normal. The infantogram revealed increased pulmonary vascularity. The echocardiographic examination showed normal connections, small left ventricle, large right atrium, large right ventricle and enlarged pulmonary artery.

After admission to the neonatal intensive care unit, intravenous PGE₁(0.01 μgm/Kg/min), dobutamine(5 μgm/Kg/min), digoxin(16.4 μgm every 12

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hours) and lasix(2mg every 12 hours) were started. Ampicillin and gentamicin were also administered for the possibility of sepsis. About three hours after intravenous treatment, his respiration became irregular and intermittently apneic. Oxygen saturation was around 85%. There was no self voiding since admission. Because of the respiratory difficulty, oxygen administration at the flow rate of 5 L/min by means of hood was started. Additional intravenous diuretics were tried without effect. Oxygen saturation was monitored above 90% at that time. Blood gas analysis showed increased acidosis(7.30-40-79-19).

Because of persistent oliguria and acidosis, ventilator therapy was started as be; FiO_2 0.3, ventilator rate 20/min, PIP 20cmH₂, PEEP 3cmH₂, mean airway pressure 3cmH₂; I:E rate 1:7.4, inspiratory time 0.35 sec, and flow rate 10L/min. Urine output was not responsive to normal saline volume challenge. In the mean time, there was moderate amount of bronchial secretion and SaO₂ fluctuated markedly on stimulation. Controlled ventilator settings and respiratory paralysis were applied because of tachypnea(50-60/min), metabolic acidosis(ABGA 7.33-26-71-13→6.95-15-49-3) and hyperkalemia (7.2mmol/L). New setting were FiO_2 0.21, rate 16/min(→13/min), PIP 20 cmH₂, I:E ratio 1:9.5, inspiratory time 0.44 sec. Blood gas data after new ventilator setting was 7.02-59-36-14. Thereafter, pulse volume became increased and urine output became responsive to diuretics. SaO₂ was maintained around 70%. The follow-up blood gas was 7.26-57-31-25.

His parents rejected medical advice for operation and took the baby home on the 3rd hospital day (11 days after birth). he died soon after his discharge.

DISCUSSION

Dr. Sohn. Some clinical history is to be added to the protocol before we discuss this case. Was there any urine output when he was in the emergency room? How about his temperature at that time? Was the proportion of direct and indirect bilirubin available? Was this patient treated for anemia?

Dr. Chung Il Noh(Pediatrics, Seoul National

University Children's Hospital). I was the pediatrician in charge of this baby. We were informed that he voided before his arrival at the emergency room, but not in our hospital. He was normothermic but rather cold. Direct and total bilirubin were 0.6/9.5gm/dl. We transfused packed cells, and hemoglobin level after transfusion was 13.3gm/dl and hematocrit was 42.6%.

Dr. Sohn. This baby had a jaundice from the second day, and small left ventricle was detected by echocardiography which was performed because of cardiac murmur. This tachypneic baby was not severely cyanotic. Arterial pulse was slightly decreased at the extremities without blood pressure difference between upper and lower extremities. Positive cardiac and hemodynamic findings on physical examination were increased right ventricular impulse, single S2 sound, systolic murmur and hepatomegaly. Laboratory study revealed anemia, leukopenia, and hyperbilirubinemia. Arterial gas analysis data showed a significant change by the treatment at the neonatal intensive care unit. Initial data at the emergency room was still good, but after treatment including oxygen supply, metabolic acidosis became apparent while arterial oxygen saturation was still good. Persistent acidosis and oliguria were major problems. The ventilator setting was changed to maintain respiratory acidosis. Low oxygen fraction of the inspired gas(FiO_2 0.21) and hypoventilation(respiratory rate decreased from 16 to 13) could alleviate the metabolic acidosis, and arterial pulse of the extremities became stronger. Urination was noted at that time.

Dr. In-One Kim(Radiology). This baby had a chest radiogram, which revealed cardiomegaly and increased pulmonary vascularity. However, pulmonary venous congestion was not conspicuous.

Dr. Sohn. In summary. This nine days old male had a heart failure, increased pulmonary vascularity and a small left ventricle on echocardiography. Metabolic circuit in this patient could be summarized as in figure 1(Lirenman 1993). Metabolic acidosis with moderate arterial oxygenation suggests cardiac lesions with low cardiac output and increased pulmonary blood flow. There remains, however, a possibility of sepsis. Differential diagnosis of heart failure in a neonate could be listed

Table 1. Causes of cardiac failure by the age of onset in a newborn baby.

1. At birth :
1) hydrops fetalis associated with intrauterine hemolysis, arrhythmia or myocarditis
2. The first day
1) volume overload :
tricuspid regurgitation (Ebstein's anomaly), pulmonary valve regurgitation
2) arteriovenous fistula
3) hypoplasia of the left heart
4) total anomalous pulmonary venous return with obstruction
5) myocardial ischemia due to birth asphyxia
6) metabolic causes, e.g. hypoglycemia, anemia, hypocalcemia.
7) paroxysmal tachycardia
3. The second day to one week
1) severe left ventricular outflow tract obstruction :
hypoplastic left heart syndrome, interruption of the aortic arch, severe coarctation of aorta, critical aortic stenosis.
2) complete transposition of the great arteries
3) Patent arterial duct in premature baby
4) critical pulmonary valve stenosis

as in table 1.

Absence of edema excludes a possibility of fetal hydrops and tricuspid valvular lesions. Small left ventricle excludes a possibility of primary myocardial disease, arteriovenous fistula and other metabolic causes of heart failure. Most possible conditions in this patient, therefore, are a syndrome with a left ventricular hypoplasia and anomalous pulmonary venous return with pulmonary venous obstruction or varieties of univentricular heart without pulmonary stenosis including atrial isomerism complex. It is rather difficult to point out the cardiac condition without echocardiography. Univentricular heart without pulmonary stenosis, however, usually accompany congestive failure around 2 weeks of age due to decrease of the vascular resistance of the pulmonary bed. Total anomalous pulmonary venous return with venous obstruction may have a similar clinical features to hypoplastic left heart syndrome. Absence of significant hypoxemia and cyanosis, and radiologic findings denying pulmonary venous congestion suggest that total anomalous pulmonary venous return is less likely. Hypoplastic left heart syndrome is the most likely condition.

Aortic and mitral valves are stenotic or atretic in a heart with a hypoplastic left ventricle. Most common form is atresia of both mitral and aortic valves (Castaneda *et al.*, 1994, Backer *et al.*, 1994). Hearts with ventricular septal defect are rare (5%) but they have a left ventricle with a rather good size, and biventricular repair could be an option for surgery (Austin *et al.*, 1989). Hearts without ventricular septal defect have a diminutive left ventricle and biventricular repair is not possible (Backer *et al.*, 1994). After birth of a baby with a hypoplastic left heart syndrome, there are two significant hemodynamic alterations. Narrowing or closure of arterial duct markedly decrease systemic arterial perfusion including coronary arterial blood flow. Ratio of pulmonary and systemic vascular resistance (R_p/R_s) can determine the clinical features. Decrease of the pulmonary vascular resistance and increase of the systemic arterial resistance make the lung plethoric and systemic bed oligemic (Norwood 1991). The clinical features of hypoplastic left heart syndrome, therefore, depends significantly on the condition of the interatrial communication, whether it is restrictive or not (Table 2) (Castaneda *et al.*, 1994, Sohn *et al.*, 1986).

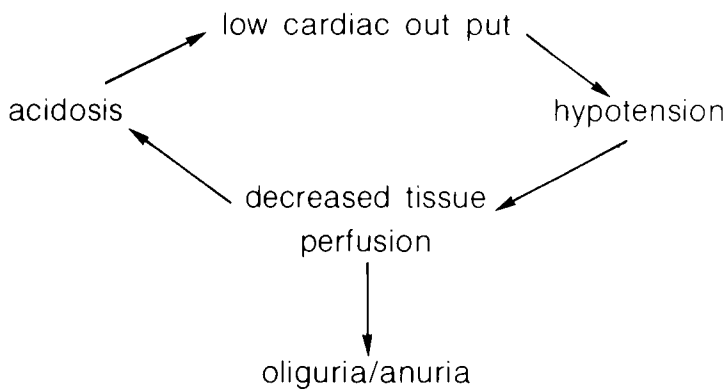


Fig. 1. Metabolic circuit responsible for the heart failure in this patient.

Dr. Jung Yun Choi (Pediatrics, Seoul National University). Which do you think is more important for this patient as a cause of death, ductal closure or decrease in pulmonary venous resistance?

Dr. Sohn. Sudden closure of the arterial duct could be a direct cause of death. Decrease of pulmonary venous resistance, however, would be more important because I don't think ductus is significantly narrowed in this patient.

Dr. Noh. In the management of this patient it is important to recognized that baby with hypoplastic left heart syndrome should not be maintained in a state of a high oxygen tension. This disease is often claimed by the parents that the baby became worse after the medical care at

the hospital. The principle of medical care in this patient is to balance the pulmonary and systemic resistance in order to keep adequate blood flow and adequate oxygen content. Low oxygen tension and high carbon dioxide tension in the inspired gas would control pulmonary blood flow by increasing pulmonary vascular resistance and prevent circulatory collapse. Non-restrictive atrial septal defect decreases pulmonary vascular resistance without pulmonary venous hypertension. Some degree of pulmonary venous hypertension is necessary in early neonatal period to maintain the systemic arterial pressure through the arterial duct and to decrease the pulmonary arterial blood flow. This nonrestrictive atrial septal defect is one of causes of the low cardiac output and moderate degree of arterial oxygen saturation.

Clinical Diagnosis (Dr. Sohn)

1. Hypoplastic left heart syndrome
2. Mildly restrictive interatrial communication

PATHOLOGICAL FINDINGS

(Dr. Jeong-Wook Seo; Patholgy)

Echocardiography has a crucial role in the clinical management in this patient. Echocardiogram performed by Drs. Chung Il Noh and Ho Sung Kim (Seoul National University Hospital)

Table 2. Spectrum of clinical profiles by the amount of interatrial communication in hypoplastic left heart syndrome.

Groups	I	II	III
Interatrial communication	restrictive	unrestrictive (low pulmonary resistance)	excessively restrictive (high pulmonary resistance)
Qp/Qs	~1.0	>>1.0	<<1.0
Major complications	apnea	systemic hypoperfusion	profound hypoxemia
Management plan	ventilation on apnea	correction of acidosis hypoventilation high CO ₂ in the inspired gas	hyperventilation high FiO ₂ increase systemic vascular resistance hypothermia immediate surgery

showed small left ventricle, large ventricular septal defect of muscular type, nonrestrictive atrial septal defect, mitral atresia and largely patent arterial duct. Coarctation of aortic isthmus was suspected. These findings reflect the autopsy findings very well.

Autopsy revealed congenital cardiac lesions of hypoplastic left heart syndrome. Mild cardiomegaly was present and small left ventricle was hidden on the left lateral aspect of a large right ventricle in the frontal aspect of the heart (Fig. 2). A redundant flap of oval fossa with an opening, a muscular ventricular septal defect were seen from the right ventricular aspect (Fig. 3) and the left ventricular aspect (Fig. 4). Figure 4 also shows that the left ventricle was not very much hypoplastic. Mitral valve was completely atretic. There was no valvar apparatus. Bicuspid stenotic aortic valve was present. Coarctation of the aorta and largely patent arterial duct were seen (Fig. 2, 5). Histologic study of lungs showed congestion of pulmonary veins but interstitium

was not edematous. Pulmonary arteries didn't show hypertensive change at all. There was no evidence of sepsis or disseminated intravascular coagulation. Liver was enlarged but histologic findings were within normal limit. Kidneys showed patchy hemorrhage, suggestive of ischemic change in this organ.

The degree of the left ventricular hypoplasia was not clearly mentioned in the protocol but it was not such small as in a case with atretic aortic and mitral valves. Presence of the ventricular septal defect and coarctation of aorta explains why the left ventricle was not so big as in a case with hypoplastic left heart syndrome. Even though there was coarctation of the aorta in a moderate degree, large arterial duct, large ventricular septal defect, relatively good ascending aorta explain the absence of discrepancy in the arterial pressure at extremities. Pulmonary artery was slightly small but decrease in the pulmonary vascular resistance resulted in the increased demand to the ventricular output, and

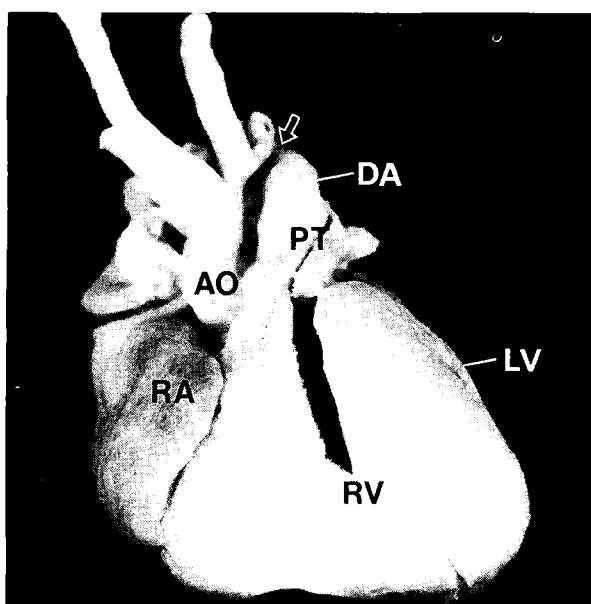


Fig. 2. Frontal aspect of the autopsied heart showing coarctation of aorta (open arrow) and patent arterial duct (DA). Ascending aorta (AO) is only mildly hypoplastic compared to the pulmonary trunk (PT). Right ventricle occupied the whole anterior wall of the heart, whereas only a thin rim of the left ventricle (LV) is seen from this frontal aspect. Right atrium (RA) is enlarged.

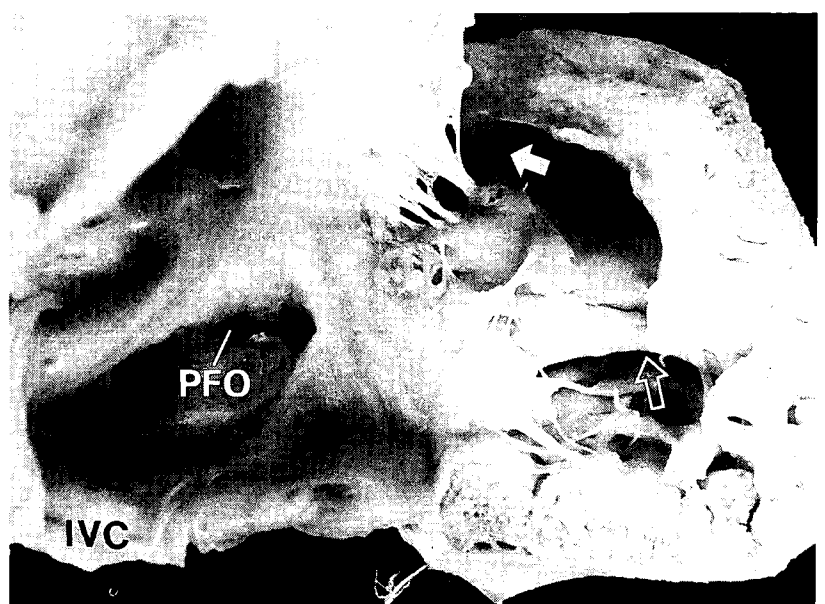


Fig. 3. Right atrial and ventricular aspect of the autopsied heart showing muscular slit-like defect (open arrow) at the right ventricular trabecular zone. Atrial septum is redundant and patent oval foramen (PFO) is open as an interatrial communication. Closed arrow indicates pulmonary arterial outlet. (IVC: inferior caval vein)

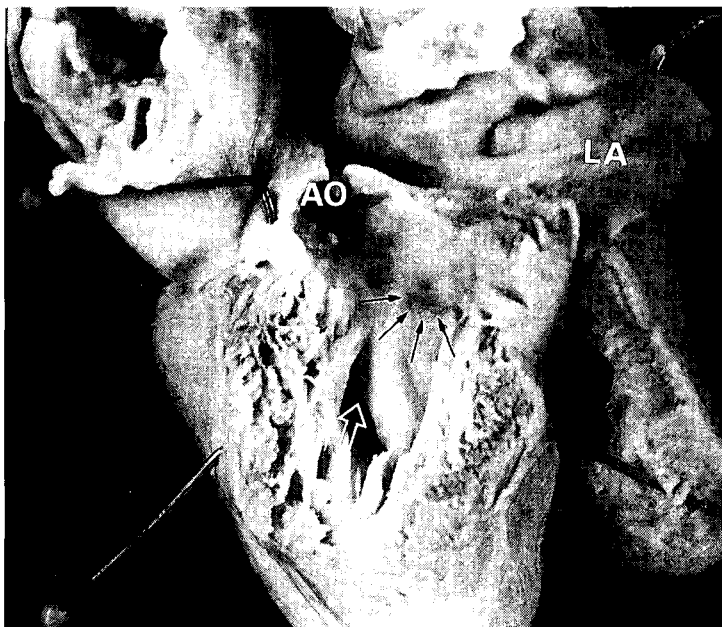


Fig. 4. Left ventricular aspect shows mild hypoplasia of the ventricular volume, mitral atresia (Black arrows) and bicuspid stenotic aortic valve (AO). Ventricular septal defect (white arrow) is also seen.

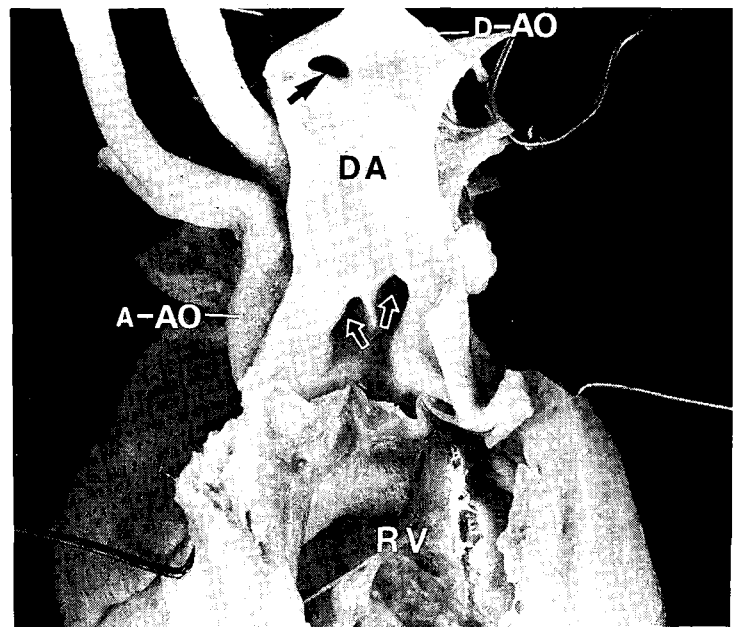


Fig. 5. Opening the pulmonary trunk and arteries show two openings for the right and left pulmonary arteries (open arrows). Blood flow to the descending aorta (D-AO) is from the right ventricle (RV) through the pulmonary valve and the arterial duct (DA), which has a wrinkled intimal surface. A small opening distal to the arterial duct (black arrow) is the aortic arch with coarctation, which is connected to the ascending aorta (A-AO).

finally resulted in the heart failure.

It is not certain why this baby had anemia, hyperbilirubinemia and leukopenia. I suppose general circulatory instability was superimposed to the physiologic jaundice and subclinical sepsis.

Pathologic diagnosis

1. Hypoplastic left heart syndrome :
 - 1) Mitral atresia
 - 2) Small left ventricle
 - 3) Aortic stenosis and bicuspid valve
 - 4) Ventricular septal defect, muscular
 - 5) Patent oval foramen
 - 6) Coarctation of aorta, isthmus
 - 7) Patent arterial duct
2. Congestive hepatomegaly
3. Pulmonary congestion
4. Ischemic hemorrhage, kidneys

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