Fetal Hydrops in a Newborn With Hypoplastic Left Heart Syndrome: Tricuspid Valve “Stopper”

PAUL M. WEINBERG, MD, FACC, KAREN PEYSER, MD, JAMES R. HACKNEY, MD
Philadelphia, Pennsylvania

Fetal hydrops in a newborn infant with hypoplastic left heart syndrome led to the discovery of tricuspid stenosis and insufficiency from an unusual malformation of the right venous valve of the embryonic sinus venosus. This

Fetal hydrops is most commonly associated with hemolytic disease of the newborn. However, it also occurs in the presence of other abnormalities, including fetal arrhythmias and structural heart disease. We report a case of hypoplastic left heart syndrome with aortic stenosis and virtual mitral atresia in which there was moderately severe hydrops. The hydrops was probably related not to the hypoplastic left heart alone but rather to an unusual associated malformation of the eustachian valve and tricuspid valve—tricuspid valve “stopper.” As a result of this complicating lesion, surgical palliation of the hypoplastic left heart was thought to have a very poor prognosis.

Case History

This male infant was the 3.75 kg product of a 37 week gestation, noted to be hydropic at birth. The Apgar scores were 2 and 4, and he was intubated and transported to The Children’s Hospital of Philadelphia. On physical examination, there was marked edema of the head and trunk and ascites. There was a single second heart sound, a grade 3/6 long systolic murmur at the left lower sternal border and no diastolic murmur. The liver was not enlarged. Arterial partial pressure of oxygen (Po$_2$) was 60 mm Hg in 100% oxygen.

Two-dimensional echocardiography revealed hypoplastic left heart syndrome. In addition, the right atrium contained multiple echo densities thought to indicate rete Chiari.

The foramen ovale was small. The tricuspid valve leaflets were thickened, and insufficiency was suggested by contrast injection as well as movement of the Chiari tissue with each systole (Fig. 1). The right ventricle was dilated and contracted poorly.

The infant was treated with prostaglandin E$_1$, dopamine and ventilatory support. Cardiac catheterization was performed to assess the tricuspid valve, with a view toward possible surgical palliation. Mean right atrial pressure was 16 mm Hg, and severe tricuspid insufficiency was noted on the angiogram. Because surgery was contraindicated, the decision was made to withdraw support and the baby died at 28 hours of age.

Postmortem Examination

The overall heart size was two times normal. On external inspection (Fig. 2A), the right atrial appendage was markedly enlarged. The left anterior and posterior descending coronary arteries delineated an absolutely small left ventricle and an enlarged right ventricle (Fig. 2B). The ascending aorta was very small, 5 mm in diameter. On opening the right atrium, an extensive rete Chiari is recognized (Fig. 3B). This web of venous valve tissue partially separated the superior and inferior venae cavae from the atrial appendage and tricuspid valve. The lower portion formed a windsock-like structure that fit into the tricuspid valve orifice and measured 4 mm in diameter (Fig. 3A and D). The tricuspid valve itself was dysplastic with a small primary orifice (4 × 5 mm, normal 13 mm in diameter) and fusion and shortening of chordae tendineae. The anterior and posterior leaflets as well as the anterior and septal leaflets were partially fused (Fig. 3C). Only the septal-posterior commissure was well developed. The leaflets were thickened, especially at their free margins.
Figure 1. Echocardiogram, apical four chamber view. A, The “stopper” (*) is just above the abnormally thickened tricuspid valve with its narrow orifice. B, The hollow structure of the stopper is clearer and its relation to the rete Chiari (RC) is evident. It is clearly separate from septum primum (SEPT I) of the atrial septum. C, The tricuspid valve is closed with the stopper flipping around in the atrium. D, The intermittent plugging of the tricuspid valve by the stopper (compare with Fig. 3A and 3D). A = anterior; L = left; LA = left atrium; P = posterior; R = right; RA = right atrium; TV = tricuspid valve.

Figure 2. A, Anteroposterior view of the heart exterior showing the markedly hypoplastic ascending aorta (Asc Ao). The black arrows point to the left anterior descending coronary artery which indicates the position of the leftward displaced ventricular septum seen with hypoplastic left ventricle (LV). B, Left lateral view of the heart exterior showing the boundaries of the hypoplastic left ventricle. Note the relatively posterior position of the left anterior descending coronary artery (LAD) typical of left ventricular hypoplasia. Asc Ao = descending aorta; IVC = inferior vena cava; LAA = left atrial appendage; PA = pulmonary artery; PDA = patent ductus arteriosus; PV's = pulmonary veins; RAA = right atrial appendage; RV = right ventricle; SVC = superior vena cava.
The atrial septum was abnormal in that the foramen ovale was quite small (3 mm in diameter). The right ventricle and pulmonary arteries were enlarged but architecturally normal. The ventricular septum was intact. The pulmonary veins entered the left atrium normally. The left atrium was small but structurally normal. It led to a peculiar sac-like mitral valve through a small orifice (3 mm in diameter, normal 11) that ultimately exited through two tiny openings (<1 mm in diameter) between rudimentary chordae into the left ventricular cavity proper (Fig. 4). The left ventricle was one-fourth the normal size, but had two papillary muscles and characteristic fine trabeculations. The aortic valve was bicuspid with a rudimentary intercoronary commissure and a 3 mm anulus (7 mm is the lower limit of normal). There was a normal left aortic arch and a patent ductus arteriosus.

Liver histologic examination revealed centrilobular hepatic congestion with hemorrhage and necrosis and hepatic sinusoidal thrombi, which are commonly seen with hypoplastic left heart syndrome (1). However, there was also a peculiar form of portal and sinusoidal fibrosis without bile duct proliferation. There were many ill-defined lobular foci of increased sinusoidal collagen. In general, these focal areas of sinusoidal fibrosis did not obliterate the underlying lobular architecture of the liver.

Figure 3. Right atrium. A, Right posterolateral view of opened right atrium (RA) showing “stopper”-like tissue excrescence (STPR) situated in the tricuspid valve orifice (TVO). B, In a more nearly right lateral view, the stopper is noted to arise from right venous valve tissue of the inferior vena cava (IVC) forming a so-called rete Chiari (RC). A small foramen ovale (FO) is seen. The stopper is distinctly separate from atrial septal tissue. C, Similar to A but with the stopper retracted from the tricuspid valve orifice to demonstrate fusion of septal (SL), anterior (AL) and posterior (PL) leaflets of the tricuspid valve (TV). Note the small tricuspid valve orifice (4 x 5 mm). D, Close-up of stopper attached to rete Chiari with the tip of the stopper in the tricuspid orifice (similar view to that in A). LA = left atrium; Sept II = septum secundum; other abbreviations as in Figures 1 and 2.

Discussion

Structural heart disease alone is rarely associated with hydrops fetalis. Most lesions that result in congestive heart failure postnatally do not do so in utero, because of flow through the ductus arteriosus and the high pulmonary vascular resistance. The onset of decompensation in hypoplastic left heart syndrome is generally delayed until several hours after birth, with the closure of the ductus.

Causes of fetal hydrops. Lesions that produce heart failure independent of these factors include valvular insuffi-
Hydrops with Tricuspid Valve "Stopper"

Figure 4. A, Posterior view of the left atrial (LA) interior. The apparent mitral valve orifice (MV "O") is shown. B and C are the orientation view and a close-up, respectively, of the sac-like mitral valve (MV) viewed from the opened left ventricle (LV). D, A conceptual drawing of a hypothetical oblique section through the sac-like mitral valve (MV) demonstrating the apparent mitral valve orifice and the true outlet from the sac (MV Out). AL PM = anterolateral papillary muscle; MVA = mitral valve anulus; PM PM = posteromedial papillary muscle; other abbreviations as before.

Pathophysiology. These cases all involved abnormalities that could potentially cause obstruction to the right atrial outflow. The foramen ovale in each case was restrictive, a frequent finding in hypoplastic left heart syndrome. One infant had probable tricuspid insufficiency and one had a prominent eustachian valve (right venous valve of the inferior vena cava) that may have at least intermittently interfered with systemic venous return. In our patient, there was evidence of significant tricuspid stenosis and insufficiency. The stenosis was caused by a peculiar malformation involving the eustachian valve. This valve forms in embryonic development during incorporation of the sinus venosus into the primitive right atrium (37 days after ovulation), temporarily separating these two components of the definitive right atrium. Normally the valve withers away and by 55 days after ovulation it has regressed to a small rim of tissue at the junction of the inferior vena cava and the right atrium. Sometimes the tissue fenestrates but does not resorb, and a veil-like network or rete Chiari persists, usually with no hemodynamic consequence. If the entire venous valve persists without even fenestration, a malformation known as cor triatriatum dexter occurs. In our patient, the upper three-fourths of the venous valve became fenestrated but the lower portion formed a small windsock-like structure.
that could fill with blood and float like a stopper into the tricuspid valve orifice. In addition to and possibly as a result of this clearly obstructive malformation, the tricuspid valve itself was stenotic with fusion of the leaflets. This valve was shown to be regurgitant by angiography but was clearly stenotic as well. The stenosis was even more profound because with near mitral atresia, the entire pulmonary and systemic circulations had to pass through the tricuspid valve, which is typically much larger than normal. In this case, it was half the normal size.

**Developmental hypothesis.** A restrictive foramen ovale resulted in the left heart hypoplasia, causing nearly all of the systemic venous return to pass through the tricuspid valve. If the restrictive foramen ovale occurred while the right venous valve of the sinus venosus was still quite large, this extra flow toward the tricuspid valve could carry the thin valve in its stream and eventually mold it into a windsock-like pocket. A similar malformation of the atrial septum, aneurysm of the septum primum (which is part of the left venous valve system of the sinus venosus) (10), has been noted with AV valve atresia (11), presumably as a result of torrential flow toward the nonatretic AV valve with an interposed pliable membrane. Thus, the venous valve pocket, or 'stopper,' remains thick as it is pounded in the stream of blood, while the remainder of the venous valve begins fenestration and resorption resulting in the rete Chiari. As the stopper is carried into the tricuspid orifice it tends to obstruct the orifice. It is conceivable that if the obstruction were severe enough, this would limit flow across the tricuspid valve and contribute to secondary tricuspid valve stenosis. The presence of a restrictive foramen ovale as well as supravalvular and valvular tricuspid stenosis would lead to marked elevation in systemic venous pressure, eventually resulting in edema.

The peculiar histologic pattern of hepatic sinusoidal fibrosis seen in this patient may also be related to at least intermittent obstruction of the only functional AV valve by the stopper, with consequent reduction in forward systemic blood flow as well as retardation of right atrial emptying. To our knowledge, these findings have not been previously reported in fetuses or newborns since most fetuses with obstructive cardiac lesions have only unilateral obstruction. Systemic output is therefore maintained through either the foramen ovale (right heart obstruction) or the ductus arteriosus (left heart obstruction). Severe bilateral fixed obstruction which might produce these hepatic findings could be expected to cause fetal death in most cases. However, in this case, there was an intermittent component to the right heart obstruction by the stopper. This may explain how this fetus could survive until birth and yet show evidence of diminished cardiac output in the hepatic sinusoidal fibrosis.

The staged repair of hypoplastic left heart syndrome developed by Norwood et al. (12,13) recruits the right ventricle as the systemic ventricle. Adequate function of the right ventricle and tricuspid valve is essential to the success of this operation. The abnormality that led to the clinical appearance of hydrops in our case also created a hemodynamic contraindication to attempted repair.

**Conclusions.** An unusual malformation of the right venous valve of the embryonic sinus venosus formed a windsock-like structure that fell, like a stopper, into the tricuspid valve orifice. This was associated with a dysplastic tricuspid valve, and was responsible for producing fetal hydrops in a patient with a hypoplastic left heart. A previously unreported pattern of fetal hepatic sinusoidal fibrosis makes this case even more unusual. A possible explanation for how these conditions could be related was discussed. This uncommon association precluded attempts at surgical palliation of the hypoplastic left heart since the tricuspid valve, the only functioning AV valve, was stenotic and regurgitant. The tricuspid valve lesion itself probably could not be repaired. The presence of fetal hydrops in a patient with hypoplastic left heart syndrome should raise the question of an additional right heart obstructive or regurgitant lesion. This particular lesion can be identified noninvasively, and it is a virtual contraindication to surgery.

We appreciate the secretarial assistance of Marie Rice in the preparation of this manuscript.

**References**