Coanda Effect on Ductal Flow in the Pulmonary Artery

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The Coanda effect (the tendency of a jet stream to adhere to a boundary wall), and the relevant anatomy, may explain the location of ductal jets within the main pulmonary artery. With the usual insertion of the duct close to the left pulmonary artery, during right ventricular ejection, the ductal jet adheres to the left wall of the main pulmonary artery. When right ventricular ejection is absent in pulmonary atresia, the ductal jet streams down the right wall of the pulmonary artery to the pulmonary valve, reverses, and maintains a parallel column back toward the bifurcation. If the reversed flow is mistaken for ejection from the right ventricle, the diagnosis of pulmonary atresia may be missed. KEY WORDS: Coanda effect; Ductus arteriosus; Pulmonary atresia; Doppler echocardiography.

Abbreviations

MPA, Main pulmonary artery; RV, Right ventricular engineer. If the angle formed at the interception of the jet with the boundary wall is small, the jet maintains its integrity and velocity downstream in contrast to the gradual dispersal of a more central jet as it progresses away from a restricted orifice into a column of fluid. With any jet, an area of low pressure surrounds the jet attributable to the Bernoulli effect (the inverse relationship between velocity and pressure in moving fluid). When the low pressure entirely surrounds the jet in the middle of a column of fluid, it contributes to the dispersal of the jet downstream. However, when the jet attaches to the boundary wall, the counterflow toward the wall is unopposed, maintaining the attachment of the jet to the boundary wall.

Coanda observed the effect that bears his name in the early days of flight with his “flying saucer.” The Coanda effect has become a standard means of directional control in rocket flight and has wide applications in fluid control theory, but it has been described only rarely in the clinical literature.
In 1970, we presented evidence\(^3\) that asymmetry of blood pressure in the arms of patients with supravalvular aortic stenosis could be explained by a jet stream adhering to the right wall of the ascending aorta, causing the kinetic energy of the jet to be expressed in a higher pressure in the right subclavian artery (Fig. 1B). The hourglass narrowing at the sino-tubular junction creates a gradual “step” between the left ventricular outflow tract and the aorta, favoring adherence of the jet to one wall of the ascending aorta, usually the right wall. The jet is maintained downstream, causing a higher velocity and pressure in the right brachial artery relative to the left. In valvular aortic stenosis, the jet is more centrally located in the ascending aorta, producing an abrupt step at the valve that leads to rapid dispersal of the jet (Fig. 1A).

**MATERIALS AND METHODS**

Doppler echocardiographic studies from our neonatal intensive care unit are routinely recorded for the presence and size of a persistent ductus arteriosus. These studies formed the basis for determining the characteristics of the ductal jet in otherwise normal premature infants.

In addition, occasional cases of congenital heart disease in neonates are detected by echocardiography, and two of these cases, with pulmonary atresia, were studied in detail for the effects of that anomaly on the ductal flow by spectral Doppler sonography, and one by color Doppler sonography.

**RESULTS**

Coanda Effect with Normal Ductal Flow into the MPA

Doppler ultrasonographic studies in neonatal intensive care units reveal a high percentage of premature infants with a persistent ductus arteriosus, and the usual pattern of flow from the arterial duct into the MPA suggests a Coanda effect. Because of the usual insertion of the duct, closer to the left pulmonary artery, and the RV ejection slightly preceding the ductal flow, the high velocity ductal jet adheres to the left wall of the MPA (Fig. 2) and remains attached until near the pulmonic valve.

We observed one exception to the rule of attachment to the left wall in an infant with agenesis of the left lung, in whom the jet attached to the right wall of the MPA. The heart was markedly displaced leftward and posteriorly, causing torsion and elongation of the duct.

Coanda Effect on Ductal Flow in Pulmonary Atresia, Mimicking Normal RV Ejection

In the first of two neonates with pulmonary atresia, the diagnosis was delayed after pulsed Doppler recordings of the MPA demonstrated forward flow in the pulmonary artery with a normal velocity, which appeared to rule out pulmonary atresia or severe pulmonic stenosis. Color Doppler studies were not routine at the time of this earlier study. The pulmonary valve was well developed, and the diameter of the MPA was normal. However, the infant also had severe tricuspid regurgitation, and the velocity was 5 m/s, indicating a suprasystemic pressure in the right ventricle, which implied obstruction to RV outflow, which was assumed to be below the valve. On that basis, the infant was sent for cardiac catheterization, which demonstrated complete atresia of the pulmonary valve. The valve was
opened under hypothermic cardiopulmonary bypass surgery, and she improved gradually. At 9 years of age she is totally asymptomatic, with insignificant pulmonic stenosis but severe pulmonic regurgitation and mild tricuspid regurgitation.

The correct diagnosis of pulmonary atresia in the second case was made easier by the availability of color Doppler sonography, which demonstrated two discrete streams in the MPA. The ductal jet was toward the pulmonic valve (Fig. 3, red), along the patient’s right wall of the pulmonary artery (viewer’s left). The unusual position of the ductal stream may have reflected the absence of competition from RV ejection. The peripheral streaming (Fig. 3, blue), after the ductal flow reversed at the atretic valve, occurred along the patient’s left wall of the pulmonary artery (viewer’s right) (Fig. 3). With careful positioning of the pulsed Doppler sampling volume, the two streams were demonstrated to have different velocities as well as opposite directions (Fig. 4A and B). The initial ductal stream demonstrated a higher velocity, over 2 m/s, and the antegrade velocity was only slightly higher than normal.

As in the first case, tricuspid regurgitation was severe, and the velocity indicated RV pressures at least at the systemic level, but pulmonic stenosis was ruled out by the low “ejection” velocity and the absence of infundibular stenosis. The pulmonic valve structure had a relatively normal diameter and was not particularly thick. The diagnosis of pulmonary atresia was made, and the infant underwent interventional catheterization. The catheter could not be passed beyond the plane of the pulmonary valve tissue, confirming atresia. A radiofrequency burn in the center of the atretic valve was created with an ablation catheter, followed by balloon valvuloplasty. The infant improved markedly and is doing well.

**DISCUSSION**

Prior to the introduction of color Doppler sonography, only inferences of the Coanda effect were possible from, for example, observations of ischemia in the absence of thrombosis, due to effects of an atherosclerotic plaque that caused an increase in velocity (Bernoulli effect) and diverted the jet to one wall of an artery. If this happened proximal to a branch point, all the flow might be directed to only one branch, creating stasis in the other branch and resulting in ischemia in the tissue supplied by that branch, without actual occlusion.
With the clinical application of Doppler echocardiography, particularly the color Doppler technique, actual observations of the Coanda effect have been reported. Aortic regurgitant jets may appear smaller when the jet is adjacent to a ventricular wall, with attachment of the jet to the ventricular wall. (In some instances, the volume of regurgitation may appear larger if sufficient entrainment of blood occurs.) In a model, the adherence of the jet to a surface was uniformly found to retard dispersal of a jet, causing a smaller color Doppler jet area, which could lead to an underestimate of the severity of a regurgitant jet.

Neither of the two infants we evaluated was studied prenatally. Had they been, pulmonary atresia probably would have been diagnosed with fetal echocardiography by detecting a reversal of ductal flow (left to right).

**REFERENCES**


**Figure 4 A**, From the same patient as in Figure 3. Pulsed Doppler flow with the sample volume positioned in the MPA in the ductal flow (red in Fig. 3). The velocity is over 2 m/s. **B**, Pulsed Doppler flow with the sample volume in the pulmonary artery in the flow away from the pulmonic valve (blue in Fig. 3). The peak velocity approximates 1.3 m/s and mimics the normal RV ejection, which could cause the pulmonary atresia to be missed.