Congenitally Corrected Transposition of the Great Arteries
Situs Solitus or Inversus

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Congenitally corrected transposition of the great arteries (ccTGA) is characterized by atrioventricular and ventriculoarterial discordance, with an incidence of 0.5% of all congenital heart disease. In ccTGA, the morphological left ventricle connects to the right atrium and the pulmonary artery and the right ventricle to the left atrium and the aorta.1 ccTGA may present as situs solitus or situs inversus. Of these, situs inversus, characterized by mirror-image atria and a right-sided systemic right ventricle, is uncommon, representing just 34% of ccTGA. The pathogenesis of ccTGA is currently unknown and is considered multifactorial. We present a unique case of fraternal twins with ccTGA and primary ciliary dyskinesia (PCD). One twin has ccTGA with situs solitus, whereas his twin brother has ccTGA with situs inversus and dextrocardia. Our aim is to outline the similarities and differences between the twins through their echocardiographic and electrocardiographic findings.

Case

Fraternal twin males, without prenatal diagnosis, were born at 36 weeks’ gestation and were well at birth. On day 1 of life, they developed respiratory distress and tachypnea. A chest radiograph was suspicious for dextrocardia in twin B, yet twin A had levocardia (Figure 1). Subsequent echocardiographic findings confirmed ccTGA in both twins; but twin A had situs solitus, whereas twin B had situs inversus (Figures 2 and 3). The electrocardiographic findings were consistent with their differing situs: twin A had sinus rhythm and twin B had left atrial rhythm (Figure 4; Movies I, II, and III, in the Data Supplement).

During the next 2 years, both twins struggled with multiple respiratory infections, resulting in the diagnosis of PCD, which improved and stabilized over early childhood. Both twins have been physically active with adequate growth and development and no cardiac symptoms. Annual assessments show no signs of right ventricular dysfunction, pulmonary obstruction, tricuspid valve dysfunction, bradycardia, or heart block. Consequently, they have been managed expectantly, without intervention.

Discussion

ccTGA arises from an embryonic malrotation of the atria, ventricles, and great arteries resulting in atrioventricular and ventriculoarterial discordance.1 The pathogenesis of ccTGA is considered to be multifactorial with rare familial incidence. The occurrence of fraternal twins with similar environmental intrauterine exposures resulting in the same diagnosis of PCD and ccTGA but contrasting situs highlights the role that genetics and environmental factors may play in the development of ccTGA and its variants. PCD is a predominantly autosomal recessive disease that affects cilia structure and motility, leading to respiratory symptoms. Although the association of PCD with situs inversus is well described, recent cases outline a relationship between PCD and ccTGA.2 Interestingly, the first link between cilia and cardiogenesis was made in a baby chick.3 Willaredt et al further found a link between Sonic hedgehog signaling at the primary cilium and the role of bone morphogenetic protein in the cardiogenesis of the endocardial cushions. This literature, in relation to our case, raises the question of whether the genetic changes leading to ciliary dysfunction in PCD may play a role in the abnormal ventricular looping and connections seen in ccTGA.

The natural history of ccTGA with differing situs is also uniquely emphasized in this case. Oliver et al compared outcomes of adults with both variants of ccTGA and found that individuals with situs solitus had significantly more complications. The intracardiac composition of ccTGA with situs solitus predisposes to complete atrioventricular block and tricuspid regurgitation, leading to right ventricular dysfunction.4 In situs solitus, the atrial and ventricular septa are malaligned so the atrioventricular node cannot penetrate the ventricular mass. Instead, a secondary node penetrates the anterior septum, predisposing to high-grade atrioventricular block.4 This is in contrast to situs inversus where the posteriorly positioned atrioventricular node connects with the conduction bundle at the posterior septal rim, similar to atrioventricular concordant hearts.4 The septal malalignment in situs solitus also leads to a higher prevalence of Ebstein-like anomalies. This explains...
why in the study by Oliver et al,\textsuperscript{4} 50% of ccTGA with situs solitus had an abnormal tricuspid valve, whereas there were none in the situs inversus group.\textsuperscript{4} Thus, septal malalignment in situs solitus alters cardiac hemodynamics and conduction pathways leading to an increased risk of complications.

In summary, this case raises questions about the origins of ccTGA, especially in light of its relationship with PCD, and the key role that atrial situs plays in long-term prognosis. At this time, both twins are asymptomatic, but as in all patients with ccTGA, they will continue to be followed regularly.

**Disclosures**

None.

**References**


**KEY WORDS:** echocardiography ■ transposition of great vessels

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**Figure 1.** Left. Levocardiia with cardiac apex pointing to the left in twin A. Right. Dextrocardia in twin B with the cardiac apex pointing to the right in twin B. LA indicates left atrium; LV, left ventricle; RA, right atrium; and RV, right ventricle.

**Figure 2.** Upper. Subcostal view. Left. Abdominal situs solitus in twin A, with the aorta (Ao) on the left and inferior vena cava (IVC) on the right of the spine (S). Right. Abdominal situs inversus in twin B, with the Ao on the right and the IVC on the left of the spine. Lower, Four-chamber view. Left. Situs solitus in twin A where the morphological right atrium (RA) is on the right side and the morphological left atrium (LA) is on the left side. Right. Situs inversus in twin B where the morphological RA is on the left side and the morphological LA is on the right side. Note the pulmonary venous drainage (∗) entering into the morphological LA. In ccTGA, there is atrioventricular discordance, as such the morphological RA is attached to the morphological left ventricle (LV) and the morphological LA is attached to the morphological right ventricle (RV), regardless of situs. The atrioventricular valves are associated with the morphological ventricle, with the more apically displaced tricuspid valve (short arrow) corresponding to the morphological RV and the mitral valve (long arrow) corresponding with the morphological LV.
Figure 3. Parallel outflow tracts. As in transposition of the great arteries (TGA), the outflow tracts are parallel and differentiated by the branching pulmonary arteries (star) from the main pulmonary artery. The most common outflow tract arrangements in congenitally corrected TGA has the aorta anterior and leftward of the pulmonary artery, however in both twins the aorta is anterior and rightward of the pulmonary artery. Ao indicates aorta; PA, pulmonary artery; and RV, right ventricle.

Figure 4. ECG: Sinus rhythm with superior axis in twin A (left) and left atrial rhythm with northwest axis in twin B (right).
Supplemental Material

Video Legends

**Video 1 - Twin A:** Subcostal sweep. Levocardia with cardiac apex pointing to the left.

**Video 1 – Twin B:** Subcostal sweep. Dextrocardia with cardiac apex pointing to the right.

**Video 2 (upper) – Twin A:** Abdominal situs solitus, with the aorta on the left and IVC on the right of the spine.

**Video 2 (upper) – Twin B:** Abdominal situs inversus, with the aorta on the right and the IVC on the left of the spine.

**Video 2 (lower) – Twin A:** 4-Chamber view. Situs solitus with the morphological right atrium on the right side and the morphological left atrium is on the left side. In ccTGA there is atrio-ventricular discordance, as such the morphological right atrium connects to the morphological left ventricle and the morphological left atrium connects to the morphological right ventricle, regardless of situs. The AV valves are associated with the morphological ventricle, with the more apically displaced tricuspid valve corresponding to the morphological right ventricle and the mitral valve corresponding with the morphological left ventricle.

**Video 2 (lower) – Twin B:** 4-Chamber view. Situs inversus with the morphological right atrium positioned on the left side and the morphological left atrium positioned on the right side. As in twin A, the morphological right atrium connects to the morphological left ventricle; however this is now on the left side due to situs inversus. The morphological left atrium connects to the morphologic right ventricle, on the right side. This can be visualized by noting the more apically displaced tricuspid valve of the right ventricle on the right-hand side.

**Video 3 – Twin A:** Subcostal view. Parallel great arteries with the aorta anterior and rightward of the main pulmonary artery

**Video 3 – Twin B:** Subcostal view. Subcostal view. Parallel great arteries with the aorta anterior and rightward of the main pulmonary artery. The most common outflow tract arrangements in ccTGA has the aorta anterior and leftward of the pulmonary artery, however in both twins the aorta is anterior and rightward of the pulmonary artery.