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**CASE REPORT**
*Cardiovascular imaging*

# Challenges in diagnosing pulmonary embolism in an adult with Fontan physiology: a case report

**Catherine Teng [1]*, Ribesh Shrestha[1,2], and Jason Phillips[1]**

[1]Division of Cardiology, Department of Medicine, University of Texas Health Science Center San Antonio, TX, USA; and [2]Department of Internal Medicine, University of Texas Health Science Center, San Antonio, TX, USA

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**Background** With the increasing longevity of congenital heart disease patients and limited number of adult congenital heart disease specialists, it is becoming increasingly imperative for general cardiologists to understand not only the unique physiology of Fontan patients but also imaging protocol considerations when treating this group of patients.

**Case summary** Here, we present a patient with a history of congenital tricuspid atresia status after the Fontan procedure who presented for gut translocation–related bacteraemia. Importantly, the patient was falsely diagnosed with pulmonary embolism resulting from inaccurate acquisition of computed tomography imaging.

**Discussion** This case illustrates the complex intricacies that clinicians should consider when facing the challenge of treating Fontan patients.

**Keywords** Case report • Fontan procedure • Delayed-phase contrast enhancement • Pulmonary embolism

**ESC Curriculum** 2.1 Imaging modalities • 2.4 Cardiac computed tomography • 9.7 Adult congenital heart disease

## Learning points

- To be familiar with the proper imaging protocol in Fontan to accurately diagnose pulmonary embolism
- To understand the reasoning of such protocol in the setting of Fontan physiology

## Introduction

With the increasing longevity of congenital heart disease patients[1,2] and limited number of adult congenital heart disease (ACHD) specialists,[2,3] it is becoming increasingly imperative for general cardiologists to understand not only the unique physiology of Fontan patients but also imaging protocol considerations when treating this group of patients. Here, we present a patient with a history of congenital tricuspid atresia status post-bidirectional Glenn and Fontan circulation, who presented for gut translocation–related bacteraemia. Importantly, the patient was falsely diagnosed with pulmonary embolism (PE) and unnecessary radiation exposure resulting from inaccurate acquisition of computed tomography (CT) imaging. This case illustrates the complex intricacies that clinicians should consider when facing the challenge of treating Fontan patients.

* Corresponding author. Tel: 210-567-4602, Fax: 210-450-2446, Email: tengc1@uthscsa.edu
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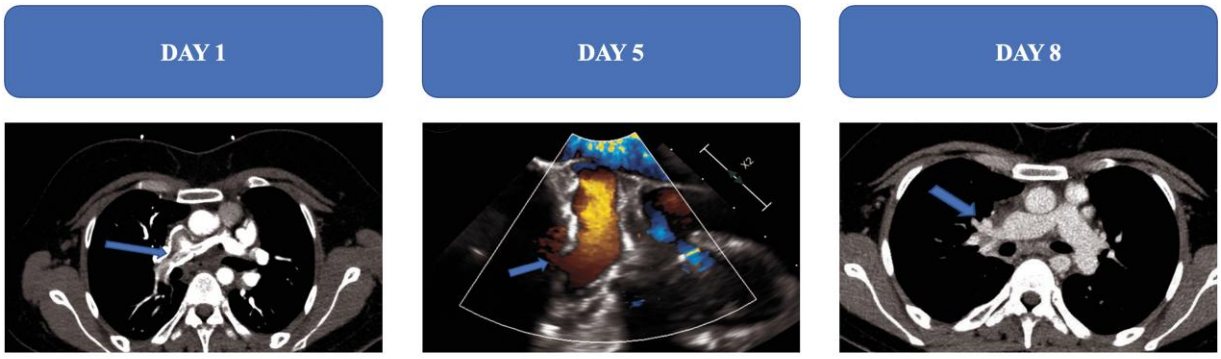
## Summary figure




CT PE: Computed Tomography Pulmonary Embolism; TEE: Transesophageal Echocardiogram; IVC: Inferior Vena Cava; RA: Right Atrium

## Case presentation

A 23-year-old Pakistani female presented with fever, headache, nausea, vomiting, diarrhoea, and dyspnoea for 5 days after her recent travel to Pakistan. The patient's past medical history included tricuspid atresia with a normal great arterial position, possible patent ductus arteriosus, a restrictive ventricular septal defect (VSD), and a large bidirectional atrial septal defect (ASD). She reportedly underwent serial staged surgeries at ages 3 months and 3 years old. Past surgical records were unavailable. She was lost to follow-up for the past 6 years due to lack of insurance.

Upon presentation, she was febrile (102.9°F) and tachycardic (96 b.p.m.) with borderline oxygen saturation, requiring 2 L of nasal cannula therapy to maintain an oxygenation level of 94%. Physical examination revealed a 2/6 harsh systolic ejection murmur at the left second intercostal space with normal distal extremity pulses, and the patient was euvolaemic on examination. Lab tests were obtained and revealed a normal complete blood count and basic metabolic panel with the exception of mildly low sodium levels of 133 mEq/L (normal range, 135–145 mEq/L). Aspartate transaminase (AST) was 53 U/L (normal range, 8–33 U/L), and alanine transaminase (ALT) was 59 U/L (normal range, 4–36 U/L). The international normalized ratio was 1.3 (normal range, 1.1 or below), and albumin was 2.3 g/dL (normal range, 3.4–5.4 g/dL). Her blood culture grew salmonella species. The chest X-ray was unremarkable.

The transthoracic echocardiogram (TTE) revealed preserved left ventricular and valvular function with no apparent vegetation. A subsequent transoesophageal echocardiography (TEE) was done due to bacteraemia and revealed a hypoplastic right ventricle, atretic tricuspid valve, fenestration between the right atrium (RA) and the extracardiac Fontan baffle with no clear flow or gradient (*Figure 1*), large ASD with a bidirectional shunt, and restrictive peri-membranous VSD with inlet extension. A CT chest with contrast was done for PE rule-out and showed filling defects involving the right pulmonary artery (RPA), right lateral segmental pulmonary artery, and lower lobe pulmonary arteries suggestive of thrombus (*Figure 2B*), in addition to congestive hepatopathy. The anatomy of the superior vena cava (SVC) and inferior vena cava (IVC) (which was connected with a Gore-Tex conduit) anastomosis to the RPA was confirmed (*Figure 2A*). The patient was subsequently started on rivaroxaban and ceftriaxone. Deep vein thrombosis (DVT) tests including D-dimer and ultrasound in addition to coagulopathy labs were negative.

While post-Fontan patients are at increased risk for thrombosis and PE,[1] the transthoracic echo showed phasic, laminar flow in the SVC and Fontan baffle. Thorough review of her CT scan images with the cardiac congenital heart disease specialist suggested that filling defects were related to the contrast-blood mixing artefact that is related to the flow of contrasted and non-contrasted blood. A repeat CT angiogram with a delayed-phase contrast sequence with simultaneous upper and lower extremity contrast injections was performed and showed no evidence of PE (*Figure 3*). Anticoagulation was discontinued. Her bacteraemia was thought to be secondary to gut translocation and thus was discharged on oral levofloxacin in addition to aspirin 81 mg daily for thromboprophylaxis.

The patient followed up in the clinic and finished 4 weeks of oral antibiotics. She reported doing well and is asymptomatic.

## Discussion

Long-term survival after the Fontan procedure has been steadily improving due to technical advancements and surgical techniques, as the current post-operative 30-year survival rate is ~85%.[4,5] This paediatric population often grows into adulthood and requires lifelong adult congenital heart specialist follow-ups. Although the survival rate has been improving, the gap in care remains in adulthood due to the limited access to ACHD specialists. Therefore, general cardiologists should improve their familiarity with Fontan physiology and its relative management.

First reported in 1971 by Fontan and Baudet, the Fontan procedure is the most common palliation of single ventricle physiology seen in adults by diverting systemic venous blood directly into the pulmonary artery, bypassing the ventricles.[4,6] The original Fontan procedure involved a direct atriopulmonary connection between the RA and the pulmonary artery using a homograft. The progressive RA dilation, however, can result in turbulent flow and therefore can be a high risk for thrombosis.[7] Several modifications of the Fontan procedure have been reported since, leading to the current approach. The procedure is now routinely performed in a staged manner to reduce mortality,

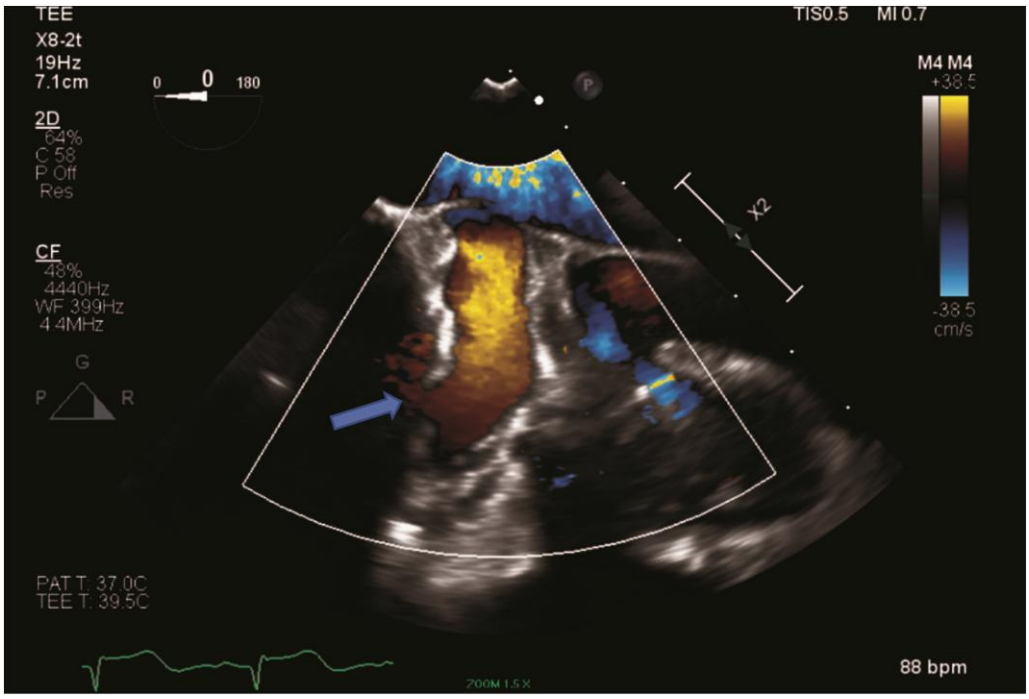



**Figure 1** Transoesophageal echocardiography demonstrated fenestration between the inferior vena cava conduit and the right atrium with no clear flow.

as a single total correction may cause pulmonary congestion. First, a modified Blalock–Taussig shunt (BT shunt) is typically placed between the subclavian artery and the pulmonary artery to allow the pulmonary artery to adapt to increased blood flow.[7] Second, a bidirectional cavo-pulmonary shunt (bidirectional Glenn) is performed. The cavoatrial junction is ligated, and the SVC is connected to the pulmonary artery. This procedure is usually performed at age 4–10 months.[7] The third step is the Fontan completion procedure. In our case, the patient had an extracardiac Fontan with fenestration, in which the IVC is connected to the pulmonary artery via a conduit by passing the RA.[7] In certain high-risk cases, fenestrations are made between the lateral IVC tunnel and the RA, providing a pressure release valve to prevent pulmonary volume overload. This procedural addition was noted to have fewer post-operative complications without known differences in long-term outcomes.[8]

The Fontan circulation described above results in slow, non-pulsatile flow in the pulmonary circulation, elevated pressure in the caval system, and reduction of the systemic output.[9] Due to the passive flow of venous blood into the pulmonary circulation and incomplete mixing of caval blood return, evaluation for PE is especially challenging and often results in false positives like in our case patient. In a standard imaging protocol, contrast is injected into the upper limb veins that feed into the SVC, and images are optimally acquired and automatically triggered once the contrast is detected in the main pulmonary artery, which usually takes 10–15 s post-injection. In the Fontan circulation, there is incomplete mixing of the SVC and IVC blood due to the lack of the subpulmonary ventricle. As a result, the pulmonary artery is often mixed with both contrasted and non-contrasted blood with the standard protocol. To overcome this, dual injection of contrast via the upper and lower limb central veins with delayed-phase filling is recommended by experts in order to achieve optimal imaging quality and avoid false-positive diagnoses.[10,11] Currently, two techniques for CT angiography are suggested to achieve optimal results. The dual-injection technique requires two 20-gauge peripheral catheters, one placed in the antecubital vein and one in the dorsal foot vein.[12] Typically, a total of 2 mL/kg of 370 mg/mL or 3 mL/kg of 300 mg/mL iodinated contrast is injected, with 40% of the amount distributed in the upper extremity and 60% distributed in the lower extremity. The injection rate of the upper extremity is recommended to be faster with 3–4 mL/s as compared with 2.0–2.5 mL/s in the lower extremity to allow for optimal mixing of contrast in the pulmonary artery. The first scan can be obtained in the earlier arterial phase, and the second scan is often delayed to 60–90 s in order to allow adequate contrast mixing. Alternatively, the single-injection, single-phase technique can be adopted.[12] With this technique, a single upper extremity venous catheter can be used to inject a total of 3 mL/kg contrast at a constant rate of 2.0 mL/s. The imaging acquisition begins with a 70 s delay after contrast administration.[12] In our case, the first technique was adopted to ensure adequate imaging quality.

The 'Fontan physiology' as described above is the major cause of many late complications, including thrombo-embolic events, which can occur in up to 20% of patients.[13] When it occurs, the outcome can be catastrophic, often resulting in significant Fontan circuit obstruction and haemodynamic instability.[9] The current anticoagulation of choice is a vitamin K antagonist as a Class I recommendation,[14] though the benefit of lifelong anticoagulation is uncertain and practice varies by centres.[15] Prior studies have examined the benefit of thromboprophylaxis in Fontan, and there is a general consensus on the use of antiplatelet therapy or antithrombotic therapy for primary prevention.[15] Recent meta-analysis of 22 studies by Van den Eynde *et al.*[15] suggested that aspirin tended to have a favourable profile with a reduced thrombo-embolic event incidence and a lower risk of major bleeding when used in thromboprophylaxis compared with warfarin and non-vitamin K oral anticoagulation (DOACs). In our case, our patient was discharged with aspirin 81 mg daily for thrombosis primary prevention.

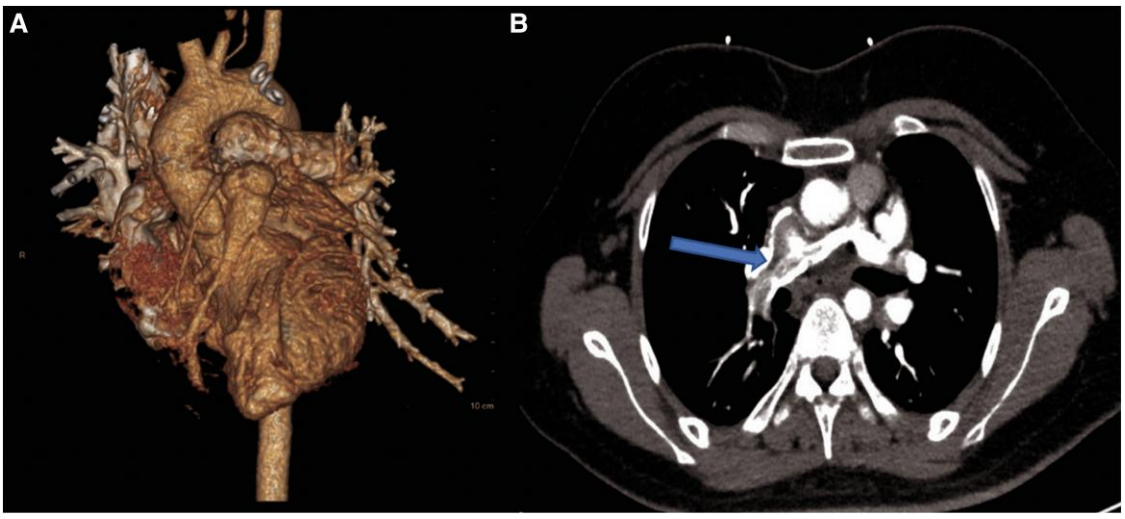



**Figure 2** (*A*) Computed tomography angiography thoracic reconstruction demonstrating the hypoplastic right ventricle, normal positioned great arteries, inferior vena cava Gore-Tex conduit, and superior vena cava anastomosis to the right pulmonary artery. (*B*) Computed tomography angiography of the chest, showing filling defects involving the right pulmonary artery, right lateral segmental pulmonary artery, and lower lobe pulmonary arteries suggestive of thrombus.

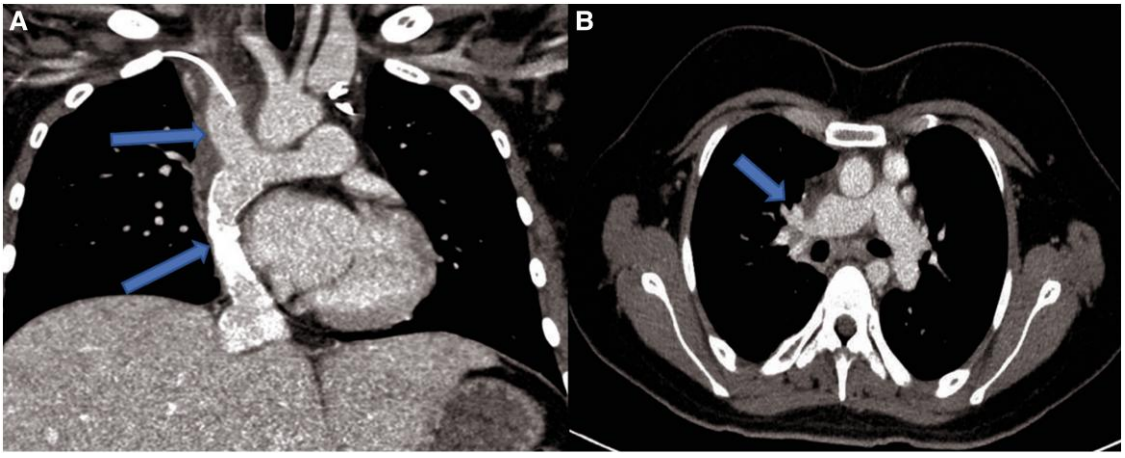


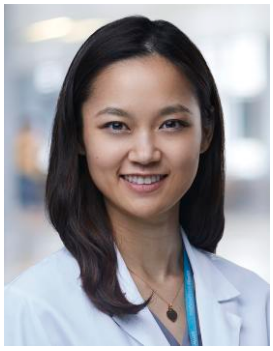

**Figure 3** (*A*) Computed tomography angiography of the chest with dual injection of contrast via the upper and lower limb central veins with delayed-phase filling showing the patent superior vena cava and inferior vena cava draining into the right pulmonary artery. (*B*) Computed tomography angiography of the chest with dual injection of contrast via the upper and lower limb central veins with delayed-phase filling showing the patent left pulmonary artery and right pulmonary artery.

Data on Fontan palliation and management are limited due to the sample size; the current 2018 AHA/ACC guideline[14] recommends that outpatient ACHD cardiologists follow up annually with yearly electrocardiogram (ECG), TTE, and Holter monitoring for physiological Stage A and B patients. In addition, cardiac magnetic resonance imaging (CMR) and exercise tests are also recommended every 2 years for Stage A and B patients. Stage C patients should be followed by outpatient ACHD cardiologists every 6 months with at least yearly ECG, TTE, Holter monitoring, and exercise tests in addition to CMR every 2 years. Stage D patients should also be followed by specialists every 3–6 months with the same testing frequency as Stage C patients if no issues arise.[14] Of note, CMR is the imaging modality of choice recommended by the European Society of Cardiology in this population,[13] owing to its ability to illustrate detailed anatomical information, its accuracy in chamber quantification, and its quantification of blood flow distribution in the left and right lungs. Cardiac CT is an alternative if CMR is not feasible. Right heart catheterization is also required when intervention is considered or when information on haemodynamics is needed, as pulmonary vascular resistance is often difficult to assess in this setting.[14,16]

## Conclusion

In conclusion, this case highlights the importance of understanding the Fontan physiology for proper diagnosis of PE. In addition, while the Fontan procedure has significantly improved survival in patients with a single ventricle congenital disease, there still remains a gap in care due to the lack of ACHD specialists. Increased awareness of Fontan physiology complications and guidelines among general cardiologists will result in improved care for our Fontan patients.

## Lead author biography



Catherine Teng, MD, is currently a chief cardiology fellow at the University of Texas Health Science Center, San Antonio. She completed her internal medicine i residency at Yale New Haven Health, Greenwich Hospital. She graduated from Chongqing Medical University. Her interests include Takotsubo cardiomyopathy outcome research and studying non-ischemic cardiomyopathy using various imaging modalities.

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**Consent:** The authors confirm that written consent for submission and publication of this case report including images and associated text has been obtained from the patient in line with COPE guidance.

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## Data availability

The authors confirm that the data supporting the findings of the study is available within the article.

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