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The Initial Exploration of Time-Resolved CT Angiography (4D-CTA) in the Diagnosis of Patent Ductus Arteriosus in a Pediatric Patient - A Case Report

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Abstract

Patent Ductus Arteriosus (PDA) is a kind of congenital heart disease, which means that ductus arteriosus connecting the junction of the main or left pulmonary artery to the descending aorta remains patent beyond 3 months of life in full-term infants and beyond 1 year in premature infants. The classic murmur of PDA may be the first clue to its presence, and it may be detected by transthoracic echocardiography, computed tomography, or magnetic resonance angiography. Dynamic CT Angiography (4D-CTA), by multiple subsequent CT acquisitions or a continuous volume CT acquisition for a period of time, has been developed in recent years as a technique that combines the noninvasive nature of CT angiography with the dynamic acquisition of DSA. This case reported a 11-year-old female child with PDA detected by 4D-CTA for the first time and demonstrated that 4D-CTA enables the noninvasive evaluation of morphology of PDA as well as flow dynamics of the ductus arteriosus.

Keywords: Congenital Heart Disease; Patent Ductus Arteriosus; 4D-CTA; The Time Density Curve; Pediatric

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Introduction

Congenital heart disease, a congenital malformation caused by abnormal development of the heart and great vessels in embryo, with an incidence of up to 1‰ [1], is the most common heart disease leading cause of death in newborn [2,3] and has the highest mortality rate in the first year of life [4]. Patent Ductus Arteriosus (PDA) is a common type of congenital heart disease in children. Most of it exist alone or with any other form of congenital heart disease. If not treated in time, it will not only affect the growth and development of children, but also cause death due to complications such as pulmonary hypertension, endocarditis and heart failure. Therefore, early and accurate diagnosis is crucial to initiate appropriate treatment. Echocardiography is the most commonly method for the diagnosis of PDA, but not all PDA can be accurately diagnosed by ultrasound. In these cases, further examination such as cardiac catheterization or angiography are needed.

This case reported a child with patent ductus arteriosus that cannot be diagnosed by ultrasound, while diagnosed by the time-resolved CT Angiography (4D-CTA).

Case Presentation

Clinical data

The study protocol was approved by our institutional ethics committee. We told the parents about the risks of CTA radiation exposure and the need for contrast medium, and written informed consent was taken from parents.

An 11-year-old female child was admitted to our hospital because of a heart systolic murmur between the 2nd and 3rd intercostal spaces of the left margin of the sternum found during auscultation by cardiac surgeon voluntary clinical activity. Echocardiography showed abnormal blood flow in the main pulmonary artery, which seemed to originate from the initial part of the left pulmonary artery. Patent ductus arteriosus was suspected and further examination was suggested. There were no other abnormal clinical manifestations (such as dyspnea, cyanosis, flushing pulse, microvascular pulsation, or shooting sound of the femoral artery), laboratory tests and special past or family medical history. And she was examined by chest 4D-CTA.

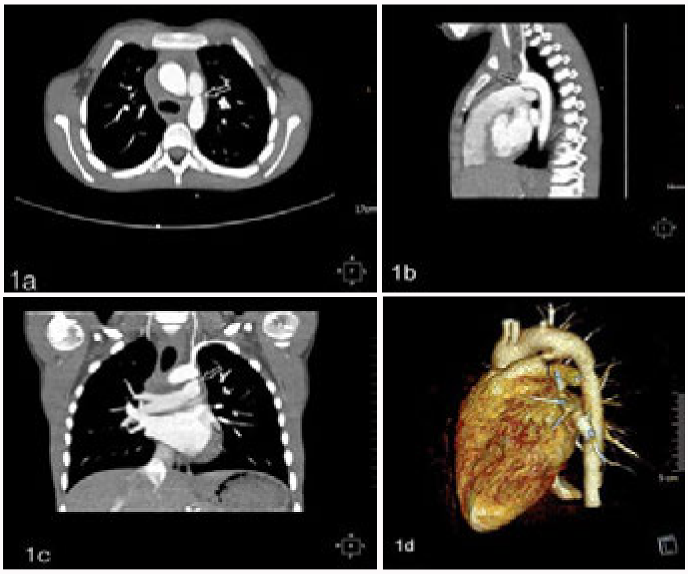

Figure 1a-1d: The arrow refers to the patent ductus arteriosus in CTA multiplanar reconstruction and VR reconstruction.

Scanning protocol and image processing

CT examinations was performed on SOMATOM Definition Flash scanner (Siemens, Germany). The scan parameters were as follows: Tube voltage 70 kvp, tube current time 90 mAs, collimation 128 mm × 0.6 mm, FOV 278 mm, rotation time, 0.28s. In this patient, a total of 13 spiral acquisitions were performed with a variable interscan delay in order to obtain the non-contrast phase, pulmonary circulation phase, and systemic circulation phase over time. The first acquisition was started at 10s after the contrast injection, 2nd to 8th acquisition at intervals of 2 sec, and 9th to 13th acquisition at intervals of 4 sec. The total examination time was 35.02s. The total of 2808 reconstruction images with a slice thickness of 1.0 mm and increment of 1.0 mm were transmitted to the reprocessing station (syngo.via VB20A, Siemens, Germany). The patient was scanned in a cranio-caudal direction from the lung apex to the liver dome. 5 mm lead equivalent apron was used to wrap the non-examined parts of the patient. 20 ml nonionic contrast medium Iopamidol (370 mg/ml) was injected *via* foot dorsal vein to avoid high-contrast artefacts caused by the influx of contrast in the upper limb vein, with a flow rate of 1.5~2.0 ml/s using a 22-gauge indwelling needle followed by 10 ml of saline flush. Image analysis was performed by two radiologists with 10 years of cardiovascular experience independently.

4D-CTA results

Morphological features: Multi-planner reconstruction CTA images showed a patent funnel-like ductus arteriosus about 16 mm in length between the descending aorta and the main pulmonary artery, with a larger diameter at the aortic end (about 10 mm) and a smaller diameter at the pulmonary end (about 2.9 mm), which was diagnosed as a funnel type of patent ductus arteriosus (Figure 1). We measured the diameter of the main pulmonary trunk (about 18 mm) and lower right pulmonary trunk (about 7 mm) and found on sign of pulmonary hypertension. There was a slight dilatation of the left atrium and left ventricle.

Hemodynamic characteristics: Blood flow from aorta to main pulmonary through ductus arteriosus started to be visible at pulmonary artery showed two peaks, the first peak at 12.58s after contrast agent injection, and the second peak at 20.62s after contrast agent injection, which was consistent with the peak time of aorta, indicating left-to-right shunting. The time-density curve of ductus arteriosus showed additional information about the blood flow shunting (Figure 2).

Figure 2: The time density curve.

ROI [4] is the time density curve of the pulmonary artery; ROI [5] is the time density curve of the aorta, ROI [6] is the time density curve of ductus arteriosus. Pulmonary artery showed two peaks, the first peak at 12.58s after contrast agent injection, and the second peak at 20.62s after contrast agent injection, which was consistent with the peak time of aorta, indicating left-to-right shunting.

Brief summary

CT angiography is a widely used technique for the noninvasive evaluation of neurovascular pathology. Because CTA is a snapshot of arterial contrast enhancement, information on flow dynamics is limited. 4D-CTA enables the noninvasive evaluation of morphology of PDA as well as flow dynamics of the ductus arteriosus in pediatric patients with acceptable radiation dose.

Discussion

This case displayed a new CTA technique (4D-CTA) that was first used to detect patent ductus arteriosus in a pediatric patient.

PDA is a type of congenital heart disease, which means that ductus arteriosus connecting the junction of the main or left pulmonary artery to the descending aorta remains persistently patent. Because the pressure of the aorta is higher than that of the pulmonary artery, it will result in left-to-right shunting, which increasing pulmonary circulation and blood return of the left heart. Increased pulmonary circulation and blood return of the left heart lead to dyspnea, pulmonary hypertension, pneumonia, left side heart volume overload, and left atrial and ventricular dilatation. Not only that, the left to right shunting may manifest as "ductal theft", resulting in low systematization diastolic and wide pulse pressures. This may lead to compromised perfusion in vital organs including the intestine, kidneys and brain [5,6]. So, the earlier a correct diagnosis is established, the sooner the patients can receive treatment that includes a variety of conservative and minimally invasive treatments.

At present, echocardiography is the most commonly method for the diagnosis of patent ductus arteriosus, but if it is combination of pulmonary hypertension, small amount of shunting in the arterial duct, low flow rate, and small or short catheter, ultrasonic diagnosis has certain difficulties. And it is impossible to accurately measure PDA length (especially tortuous PDAs) by echocardiogram [7]. Furthermore, echocardiogram is often limited regarding image post-processing and also depends on the experience of the clinician [8].

MRI allows three-dimensional reconstruction of cardiac and vascular structures and detection of functional parameters without radiation exposure, and have dramatically changed the diagnostic approach to CHD [9]. However, the disadvantages of MRI examination are low availability, high cost, low spatial resolution and long examination times [10,11]. Furthermore, due to the reason of most children can't cooperate, sedation or anesthesia and intravenous contrast agents are often required, which is an ongoing matter of debate regarding harmful effects of pediatric brain development [12].

CT is subjected to radiation exposure and iodine contrast agent using. However, new CT techniques can achieve high quality of imaging and detailed presentation of cardiac anatomy, thoracic vessels and extracardiac structures in an extremely short time and reduced radiation dose even in children [13,14]. In this case, a new technique of time-resolved CT angiography was first used in the diagnosis of pediatric PDA. The 4D-CTA images showed a funnel-like ductus arteriosus between the descending aorta and the main pulmonary artery, which was in accordance with surgical findings. Through multiplanar reconstruction, we can measure the length and diameter of the ductus arteriosus, which can help for the selection of treatment options.

As we know, if the diameter of the lower right pulmonary artery is greater than 15 mm, it indirectly indicates pulmonary hypertension. In this patient, the diameter of the lower right pulmonary artery was 7 mm and no sign of pulmonary hypertension was found. We also found a slight dilatation of the left atrium and left ventricle.

The 4D-CTA can provide information about the blood flow shunting in the ductus arteriosus by the time-density curve. Pulmonary artery showed two peaks, the first peak at 12.58s after contrast agent injection, and the second peak at 20.62s after contrast agent injection, which was consistent with the peak time of aorta, indicating left-to-right shunting. If the aorta appears two peaks, the first peak of the aorta appearing simultaneously with the pulmonary artery peak, which indicated right-to-left shunting. If the aorta and pulmonary artery have two peaks at the same time, that is to say there is a bidirectional shunting. What's more, the mean flow velocity of blood in the ductus arteriosus can be obtained by the time-density curve. However, information about blood flow shunting and blood flow velocity can't be found using other CT techniques such as retrospectively ECG-gated CTA and prospective ECG-gated CTA [15,16].

Most of the children cannot cooperate with a breath-hold or lie still without sedation, fast acquisition is crucial to obtaining motion-free images without sedation [16]. We used only 35.02s to complete the 4D-CTA scan by simply asking the child to breathe quietly, without anesthesia or sedation. For conventional CT angiography, it is essential to have a precise timing of the contrast medium. This means that the scan must be performed when the vessel of interest has the optimal contrast enhancement. However, when hemodynamic abnormalities occur in children with congenital heart disease, such as left-to-right shunting, right-to-left shunting or bidirectional shunting, conventional examination techniques such as test bolus or bolus tracking may lead to misdiagnosis. As a result, patients may be difficult to diagnose, treatment, and more likely to increase the risk of re-scanning CTA. While 4D-CTA technology can avoid these.

In conclusion, the accuracy of 4D-CTA in diagnosing PDA is high, and information of the morphology, diameter, length of the ductus arteriosus, cardiac anatomy, thoracic vessels, extracardiac structures, blood flow shunting and blood flow velocity can be obtained at the same time in a short time. Thus, 4D-CTA can provide more valuable information for clinical diagnosis and treatment.

References

1. Van der Linde D, Konings EE, Slager MA, Witsenburg M, Helbing WA, Takkenberg JJ, et al. Birth prevalence of congenital heart disease worldwide: A systematic review and meta-analysis. J Am Coll Cardiol. 2011;58(21):2241-7.
2. Hoffman JI. The global burden of congenital heart disease. Cardiovasc J Afr. 2013;24(4):141-5.
3. Dolk H, Loane M, Garne E; European Surveillance of Congenital Anomalies (EUROCAT) Working Group. Congenital heart defects in Europe: Prevalence and perinatal mortality, 2000 to 2005. Circulation. 2011;23(8):841-9.
4. Tennant PW, Pearce MS, Bythell M, Rankin J. 20-year survival of children born with congenital anomalies: A population-based study. Lancet. 2010;375(9715):649-56.
5. Petrova A, Bhatt M, Mehta R. Regional tissue oxygenation in preterm born infants in association with echocardiographically significant patent ductus arteriosus. J Perinatol. 2011;31(7):460-4.
6. Martini S, Aceti A, Galletti S, Beghetti I, Faldella G, Corvaglia L. To feed or not to feed: A critical overview of enteral feeding management and gastrointestinal complications in preterm neonates with a patent ductus arteriosus. Nutrients. 2019;12(1):83.
7. Jadhav SP, Aggarwal V, Masand PM, Diaz E, Zhang W, Qureshi AM. Correlation of ductus arteriosus length and morphology between computed tomographic angiography and catheter angiography and their relation to ductal stent length. Pediatr Radiol. 2020;50(6):800-9.
8. Henzler T, Vogler N, Lange B, Dally F, Meyer M, Schoenberg SO, et al. Low dose time-resolved CT-angiography in pediatric patients with venous

malformations using 3rd generation dual-source CT: Initial experience. Eur J Radiol Open. 2016;3:216-22.

9. Hussain T, Parish V, Habib G, Edvardsen T, Geva T, Baumgartner H, et al. Imaging the adult with congenital heart disease: a multimodality imaging approach-position paper from the EACVI. Eur Heart J Cardiovasc Imaging. 2018;19(10):1077-98.
10. Babu-Narayan SV, Giannakoulas G, Valente AM, Li W, Gatzoulis MA. Imaging of congenital heart disease in adults. Eur Heart J. 2016;37(15):1182-95.
11. Stout KK, Daniels CJ, Aboulhosn JA, Bozkurt B, Broberg CS, Colman JM, et al. 2018 AHA/ACC guideline for the management of adults with congenital heart disease: Executive summary: A report of the American College of Cardiology/American Heart Association Task Force on clinical practice guidelines. J Am Coll Cardiol. 2019;73(12):1494-563.
12. Barnes RK. "Pediatric anesthetic neurotoxicity": Time to stop! Anesth Analg. 2020;131(3):734-7.
13. Chen B, Zhao S, Gao Y, Cheng Z, Duan Y, Das P, et al. Image quality and radiation dose of two prospective ECG-triggered protocols using 128-slice dual-source CT angiography in infants with congenital heart disease. Int J Cardiovasc Imaging. 2019;35(5):937-45.
14. Raimondi F, Warin-Fresse K. Computed tomography imaging in children with congenital heart disease: Indications and radiation dose optimization. Arch Cardiovasc Dis. 2016;109(2):150-7.
15. Leschka S, Wildermuth S, Boehm T, Desbiolles L, Husmann L, Plass A, et al. Noninvasive coronary angiography with 64-section CT: Effect of average heart rate and heart rate variability on image quality. Radiology. 2006;241(2):378-85.
16. Jadhav SP, Golriz F, Atweh LA, Zhang W, Krishnamurthy R. CT angiography of neonates and infants: comparison of radiation dose and image quality of target mode prospectively ECG-gated 320-MDCT and ungated helical 64-MDCT. AJR Am J Roentgenol. 2015;204(2):W184-91.