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TECHNICAL NOTE / *Cardiovascular*

Synchronization of contrast media administration with retrograde blood flow in patients with hypoplastic ascending aorta

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Detailed cardiovascular assessment, including careful evaluation of the great vessel origins, their relationship to the cardiac chambers, and associated anomalies, should be part of the routine cardiac/coronary CT angiography (CTA) assessment of hypoplastic left heart syndrome (HLHS) [1—3]. CTA provides detailed anatomical and functional information of the heart and coronaries, via two-dimensional (2D) reformatted and three-dimensional (3D) reconstructed images [4]. Obtaining optimal diagnostic images is critical in understanding patients' anatomy and cardiovascular hemodynamics. Matching compromised cardiovascular dynamics with patient-specific iodinated contrast material administration (CM) protocols is considerably improved with the use of ECG-gated thoracic CTA. The importance of predicting CM administration in patients with compromised blood flow requires an understanding of CM administration and scanner parameters affecting bolus geometry.

Case presentation

A 2-day-old male newborn, initially diagnosed in utero with a HLHS was born by a normal vaginal delivery at our institution. His Apgar score; assessing the appearance, pulse,

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grimace, activity, and respiration; was 8, 9, and 10 at 1, 5, and 10 minutes after birth, respectively. Arterial blood gases were drawn; where results yielded a pH of 7.24 and base excess of −2.8. His heart rate was 140 beat per minute. Systolic arterial blood pressure measurement was found to be 70 mmHg; equal in both the upper and lower limbs. The saturation of oxygen was 91%. The newborn underwent an initial chest radiograph, which revealed a normal heart size. This was followed by an echocardiogram that confirmed the antenatal diagnosis but did not clearly reveal the ascending aorta. In order to maintain the patency of the ductus arteriosus, prostaglandin was administered intravenously and a CTA was scheduled for the next day.

Technical method and discussion

With the patient positioned supine and arms placed above his head, ECG-gated cardiac/coronary CTA was performed using a 256-MDCT scanner (Philips iCT, Philips Healthcare, The Netherlands). Antero-posterior and lateral scout scans were performed, with a scan range from the apex of the chest to the costophrenic angle. ECG-gated cardiac CT scan parameters were as follows: detector width of 256×0.625 mm, pitch of 0.2:1 ratio, rotation time of 0.27 s, 80 kVp, 80 mA, with z-axis modulation, and scanning time of 2.1 s. A caudocranial scan direction was employed.

Iodinated contrast material administration

Via a 22 gauge venous catheter, placed in the right brachiocephalic vein, CM was injected with an automated dual barrel power injector (Optivantage, Mallinckrodt, Cincinnati, OH, USA). Right-sided venous access was used in this study because it provides a uniform opacification of contrast to the heart, with the least possible dilution. Hence, this approach promotes optimal image quality coupled with reduced contrast volumes [5—8]. Both the contrast media and saline injection rates were 1.8 mL/s. A total of 8 mL of contrast material were used (including 1 mL of contrast for the test-bolus).

Contrast bolus geometry

Bolus geometry is an opacification pattern measured in the region of interest (ROI) and plotted on a time(s)/attenuation Hounsfield units (HU) curve after an intravascular injection of contrast material. This technique was employed where the ROI was plotted inside the abdominal aorta at the level of the aortic hiatus. The procedure comprised of a small amount of contrast material (1 mL) injected at the same rate as that of the main bolus. ROI assessed the time to peak (TTP) and determined the arteriovenous circulation time for the thoracic vasculature at the level of the aortic hiatus (Fig. 1).

The ability to control contrast volume administration and predict the exact arteriovenous circulation time in the hypoplastic ascending aorta and coronary arteries is limited by bolus triggering. Bolus triggering only allows a pre-selected contrast volume (whether the entire contrast volume is required or not which) that is known to increase the possibility of contrast related artefacts in the superior vena cave (SVC) and BCV that lie adjacent to the hypoplastic ascending aorta. Injecting contrast without understanding the exact behavior of arteriovenous blood circulation in already compromised patients with HLHS could increase these artefacts significantly. Additionally, we can reduce our contrast media volume by knowing the TTP (start of the scan acquisition), and cease contrast media injection 3 seconds prior (substituting a saline chaser to flush the SVC and BCV) to the scan acquisition. The test-bolus technique resulted in elimination of perivenous artefacts by increasing visibility of the hypoplastic ascending aorta.

Synchronization between contrast media administration and scanner acquisition

To synchronize data acquisition with optimal arterial opacification, it has been recommended that scan direction during CTA should be in the opposite direction of CM flow during CTA [5,8]. During CTA, it is feasible to scan at a faster rate than that of CM traversing the vessel. A drawback to faster scan acquisitions is poor arterial opacification, particularly when antegrade blood flow from the brachiocephalic trunk to the coronary arteries exists. Such pathological processes cause turbulence of blood flow before, within, and after the origin of the ascending aorta, resulting in a slowing down of the passage of contrast associated with the antegrade blood flow from the origin of the ascending aorta to the distal segments of the coronary arteries. Even though there are clear limitations in the literature regarding the impact of fast scan times and associated contrast/blood flow dynamics, a practical solution to overcome such limitation is to measure the opacification peak of the descending thoracic aorta at the distal segment. Once these data are available, the exact contrast/blood flow dynamics can be predicted irrespective of blood flow dynamics. Therefore, optimal synchronization between blood/contrast media flow with a caudocranial CT scan direction, achieves peak opacification throughout the entire hypoplastic ascending aorta and coronary arteries (Fig. 2).

Image reconstruction

The following parameters were set: standard reconstruction of axial images at 0.625 mm slice width, reconstruction interval of 0.5 mm, field of view of 180×180 mm, and an iterative reconstruction technique software (iDose4; Philips Healthcare) with a window width and level of 420 and 65 respectively. The ECG-gated scan reconstruction interval, with the least motion artifacts, was determined by reconstructing a slice at the mid segment of the ascending aorta in 2% steps from 35% to 75% of the R-R interval. For diagnostic interpretation, reconstruction of the CTA images was used; where a time point with the least motion artifact was located at the mid segment of the ascending aorta (48%).

CTA revealed the following pattern of the aorta: a hypoplastic ascending aorta, measuring 1.5 mm, followed by a normal aortic arch from which the subclavian artery originate. The distribution of these vessels was normal (Fig. 3). There was no coarctation at the aortic isthmus. Hence, the diagnosis of a HLHS with an existing ascending aorta was confirmed.