Original paper

Multidetector computed tomographic angiography in evaluation of neonates with suspected extracardiac congenital heart disease: experience in Vilnius University Hospital Santariškių Klinikos

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Summary

The aim of this study was to determine the frequency of extracardiac pathology in neonatal patients with suspected congenital heart disease referred to undergo multidetector computed tomography (MDCT) angiography in Vilnius University Hospital Santariskiu Klinikos. The safety of MDCT angiography (intravenous contrast media volume injected, scanning time and exposure to ionising radiation) was also evaluated.

Patients and Methods: During the period of 2006–2012, in Vilnius University Hospital Santariskiu Klinikos 186 pediatric patients were referred to undergo MDCT angiography of whom 71 were neonates with suspected complex congenital heart disease (CHD) and extracardiac pathology.

Results: Sixty nine (97.2%) of referred neonates were found to have extracardiac pathology (36 had extracardiac vascular pathology only, 4 – extracardiac non-vascular pathology only and 29 – both extracardiac vascular and non-vascular pathology). In 47 patients diagnosis of extracardiac pathology was verified intraoperatively. Remainder ($n = 24$) of the group were not operated (12 patients died because of hemodynamic instability and inoperable complex CHD, 9 patients were scheduled for later surgery, in 3 patients surgery was not indicated). Mean contrast media volume used was 4.18 ± 1.03 ml, mean scanning time was 1.07 ± 0.77 s and mean effective radiation dose was 2.8 ± 0.69 mSv. No adverse reactions or complications were observed.

Conclusions: MDCT angiography is accurate and safe method in diagnosis of complex congenital heart disease with extracardiac pathology.

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Introduction

Precise evaluation of intracardiac and extracardiac vascular anatomy in suspected neonatal congenital heart disease (CHD) is important for effective management strategies. Bedside neonatal echocardiography allows comprehensive evaluation of intracardiac defects. Limitations of echocardiography are well known: dependence on operator experience, poor imaging window due to lung, rib cage interference, and poor visualisation of extracardiac structures [1]. Thus, cardiac catheterization often remains the gold standard for the complete diagnosis of CHD. However, longer procedure time, difficult vascular access and complications related to cardiac catheterization (including arrhythmia, bleeding, heart perforation, cardiac tamponade, thromboembolism, shock, hypoxemia and vessel occlusion) remain a major concern for performing the procedure [2]. Multidetector computed tomographic (MDCT) angiography could provide comprehensive non-invasive information on intracar-

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diac and extracardiac vascular and non-vascular anatomy in one imaging session.

Patients and methods

During the period of 2006–2012, in our institution MDCT angiography was performed in 186 pediatric patients of whom 71 were neonates (thereafter "patients") with suspected complex CHD and extracardiac pathology. Prior to the scan, possible adverse effects of contrast medium injection and radiation exposure were thoroughly explained to the patients' parents, who gave informed signed consent. Intravenous sedation was used and during the scan all patients were free-breathing. MDCT scanner General Electric LightSpeed VCT XT (GE Healthcare, Milwaukee, Wisconsin, USA) was used with the following scanning parameters: collimation 64×0.625 mm, pitch 1.375, tube voltage 80 kV, tube current up to 375 mAs. Non-ionic iodinated contrast medium (1 ml per 1 kg of body weight) was injected via peripheral vein with a rate of 1 ml per second. We used one scanning phase with optimal enhancement of the heart chambers and major thoracic vessels. Bolus tracking technique was used for the initiation of the scan. Statistical analysis was done using SPSS version 16 for Windows (SPSS, Inc.) Descriptive statistics was used; continuous variables were expressed as mean and standard deviation (SD), and categorical variables were expressed as percentages.

Results

MDCT angiographic images were of adequate quality in all 71 patients. Fifty one (71.8%) patients were first week neonates, 20 (28.2%) were 8 or more days old. Weight of study participants ranged from 2.6 kg to 6.7 kg and mean weight (±SD) was 3.9 kg (±0.61). Images of 69 (97.2%) patients revealed 137 extracardiac pathologic findings. Spectrum of extracardiac pathology is presented in Table 1.

Thirty six (50.7%) patients had extracardiac vascular pathology only (53 extracardiac vascular pathologic findings), 4 (5.6%) – extracardiac non-vascular pathology only (6 extracardiac non-vascular pathologic findings) and 29 (40.9%) – both extracardiac vascular and non-vascular pathology (43 extracardiac vascular and 35 extracardiac non-vascular pathologic findings). Figure 1 shows distribution of extracardiac vascular and non-vascular pathology.

Four patients had 4 extracardiac pathologies, 16 patients – 3 extracardiac pathologies, 24 patients – 2 extracardiac pathologies, 25 patients – 1 extracardiac pathology. In 2 patients MDCT angiography showed no extracardiac pathology.

Table 1.
Extracardiac pathology reported in MDCT angiography images

Extracardiac pathology	Number of patients, *n*	Percentage of patients, %
Patent arterial duct	50	70.4
Coarctation of aorta/arch hypoplasia	20	28.2
Pulmonary pathology	14	19.7
Bronchial pathology	13	18.3
Anomalous drainage of pulmonary veins	8	11.3
Anomalies of systemic veins	8	11.3
Tracheal compression	6	8.5
Pleural pathology	6	8.5
Major aortopulmonary collaterals	5	7.0
Interrupted aortic arch	4	5.6
Other tracheal pathology	2	2.8
Aortopulmonary window	1	1.4

In 47 patients diagnosis of extracardiac pathology was confirmed intraoperatively. Remainder ($n = 24$) of the group were not treated surgically (12 patients died because of hemodynamic instability and inoperable complex CHD, 9 patients were scheduled for later surgery, in 3 patients surgery was not indicated).

Mean contrast media volume used was 4.18 ± 1.03 ml. Mean scanning time was 1.07 ± 0.77 seconds. Exposure to ionising radiation was evaluated using conversion coefficient of 0.039 [3,4] and mean effective dose was 2.8 ± 0.69 mSv.

Discussion

Primary evaluation of congenital cardiac abnormalities traditionally relies on echocardiography and conventional angiography, both of them having potential limitations. Echocardiography is an operator-dependent study, limited by a small acustic window and patient movement. Conventional angiography is an invasive procedure with an inherent risk of catheter complication such as vessel damage, bleeding, stroke, and infection. During angiography, overlapping of the pulmonary and systemic circulation often provides a confusing picture given complex anatomy. Another limiting factor of particular significance in young children is radiation dose and contrast administration during catheterization procedures [5]. MDCT angiography allows rapid evaluation of the heart as well as the lungs, great vessels, and airways. Coupled with high spatial resolu-

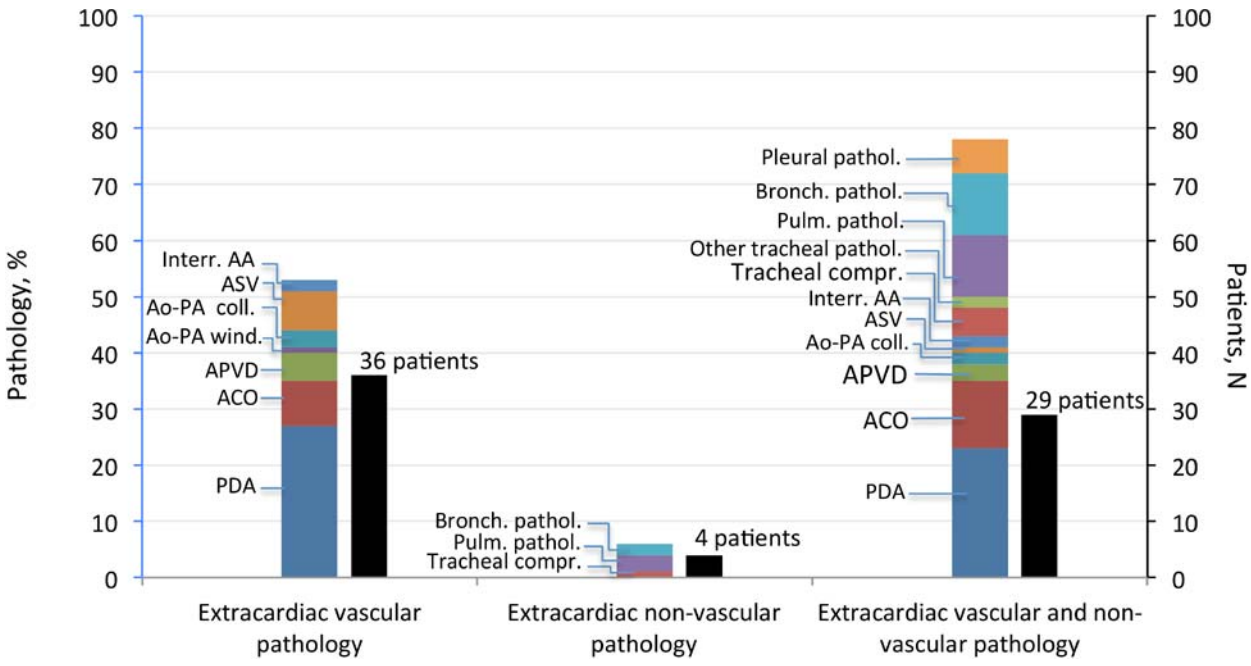

Figure 1. Distribution of extracardiac vascular and non-vascular pathology (left vertical light blue axis and colorful columns correspond percentage of particular congenital cardiac defect in three patient groups: first – with only extracardiac vascular pathology, second – with only extracardiac non-vascular pathology, third – with both extracardiac vascular and non-vascular pathology; right vertical black axis and black columns correspond number of patients in each patient group; AA – aortic arch, ACO – aortic coarctation, Ao-PA – aortopulmonary, APVD – anomalous pulmonary venous drainage, ASV – anomalies of systemic veins, PDA – patient ductus arteriosus.

tion and availability of three-dimensional reconstruction it provides an easily perceptible view of venoatrial and atrioventricular junctions, atrioventricular valves and ventriculoarterial junctions [5,6]. The most frequent extracardiac vascular pathology found on MDCT angiography was patent ductus arteriosus and coarctation of the aorta. Aortic coarctation is one of structural defects which can be difficult to detect using echocardiography and requires extensive training and continued practice [1]. Several reasons may make the echocardiographic diagnosis difficult. A large patent ductus arteriosus may mask aortic isthmus narrowing and decreased ventricular function will underestimate the Doppler gradient. A rapid diagnosis is crucial for critically ill newborns complex ductal-dependent congenital heart defects, as they may need therapy to maintain ductal patency and sustain cardiac function [7]. On the other hand MDCT depicts extracardiac non-vascular structures and helps to exclude pneumonia, atelectasis, pneumothorax, bronchogenic cysts and pulmonary edema [5,8]. In patients with both vascular and non-vascular extracardiac pathology, third most frequent non-vascular pathology was tracheal compression. Anomalous position and coursing of major thoracic vessels may impact on tracheobronchial tree and cause respiratory symptoms [9].

Magnetic resonance imaging (MRI) has been an alternative imaging method to cardiac catheterization and echocardiography for patients who need evaluation of cardiac disease [5]. However, MRI requires long scan time and effective sedation during noisy scanning. Mechanical ventilation, electrocardiographic monitoring equipment, or infusion pumps are often incompatible with the strong magnetic field. The application of MRI to the critically ill patient is therefore impractical. MDCT, on the other hand, is fast and efficient, with very short scan times, and is not associated with the presence of strong magnetic fields [8]. Mean scan time (±SD) in our study was 1.07 ± 0.77 seconds and this is comparable to results of other studies [10].

In infants and neonates, contrast volume is an important consideration because of the low blood volume of the patient and the hypertonicity (and potentially detrimental cardiac effects) of even nonionic monomeric contrast media [11]. Mean weight of our study population was 3.9 kg and mean contrast media volume was 4.18 ml resulting in a mean contrast volume of 1.07 ml per kg of body weight. Authors report 2–4 times higher volumes (2–3 ml/kg up to 4 ml/kg) of contrast media used during cardiac catheterisation [2,11].

Because of the higher radiosensitivity of infants and children compared with adults, there is a need to evaluate the doses delivered to pediatric patients who undergo interventional cardiac pro-

cedures. For diagnostic cardiac catheterizations, a median effective dose of 4.6 mSv was found. Therapeutic procedures resulted in a higher median effective dose of 6.0 mSv because of the prolonged use of fluoroscopy [12]. Radiation burden using MDCT ECG-gated cardiac imaging ranges from 2.17 to 3.41 mSv, limiting its use to complex CHD and as a problem solving technique [13]. Our average effective dose was in this range (2.8 ± 0.69 mSv). However, using newer techniques and applying prospective gating on a second generation DSCT it is possible to achieve marked dose reduction with an effective dose of only 0.26 ± 0.6 mSv (i.e. equivalent annual background dose) [14].

Limitations

We acknowledge the following limitations of the study. Despite high accuracy of MDCT angiography in operated patients, the findings were not compared to golden standard – cardiac catheterisation. However, recent reports indicate the potential of MDCT angiography to provide robust alternative to invasive cardiac catheterisation [8]. Autopsy for patients with lethal outcome was not performed.

In conclusion, MDCT angiography is an accurate, safe and fast method in diagnosis of complex congenital heart defetcs with extracardiac pathology in neonates.

References

[1] Mertens L, Seri I, Marek J, Arlettaz R, Barker P, McNamara P et al. Targeted neonatal echocardiography in the neonatal intensive care unit: practice guidelines and recommendations for training. *Eur J Echocardiogr* 2011; 12:715–736.

[2] Vitiello R, McCrindle BW, Nykanen D, Freedom RM, Benson LN. Complications associated with pediatric cardiac catheterization. *J Am Coll Cardiol* 1998; 32:1433–1440.

[3] Kim JE, Newman B. Evaluation of a radiation dose reduction strategy for pediatric chest CT. *AJR Am J Roentgenol* 2010; 194:1188–1193.

[4] Thomas KE, Wang B. Age-specific effective doses for pediatric MSCT examinations at a large children's hospital using DLP conversion coefficients: a simple estimation method. *Pediatr Radiol* 2008; 38:645–656.

[5] Bean MJ, Pannu H, Fishman EK. Three-dimensional computed tomographic imaging of complex congenital cardiovascular abnormalities. *J Comput Assist Tomogr* 2005; 29:721–724.

[6] Fratz S, Schuhbaeck A, Buchner C, Busch R, Meierhofer C, Martinoff S et al. Comparison of accuracy of axial slices versus short-axis slices for measuring ventricular volumes by cardiac magnetic resonance in patients with corrected tetralogy of fallot. *Am J Cardiol* 2009; 103:1764–1769.

[7] Mivelaz Y, Di Bernardo S, Meijboom EJ, Sekarski N. Validation of two echocardiographic indexes to improve the diagnosis of complex coarctations. *Eur J Cardiothorac Surg* 2008; 34:1051–1056.

[8] Long YG, Yang YY, Huang IL, Pan JY, Wu MT, Weng KP et al. Role of multi-slice and three-dimensional computed tomography in delineating extracardiac vascular abnormalities in neonates. *Pediatr Neonatol* 2010; 51:227–234.

[9] Lee EY, Mason KP, Zurakowski D, Waltz DA, Ralph A, Riaz F et al. MDCT assessment of tracheomalacia in symptomatic infants with mediastinal aortic vascular anomalies: preliminary technical experience. *Pediatr Radiol* 2008; 38:82–88.

[10] Kroft LJ, Roelofs JJ, Geleijns J. Scan time and patient dose for thoracic imaging in neonates and small children using axial volumetric 320-detector row CT compared to helical 64-, 32-, and 16- detector row CT acquisitions. *Pediatr Radiol* 2010; 40:294–300.

[11] Stanger P, Heymann MA, Tarnoff H, Hoffman JI, Rudolph AM. Complications of cardiac catheterization of neonates, infants, and children. A three-year study. *Circulation* 1974; 50:595–608.

[12] Bacher K, Bogaert E, Lapere R, De Wolf D, Thierens H. Patient-specific dose and radiation risk estimation in pediatric cardiac catheterization. *Circulation* 2005; 111:83–89.

[13] Tsai IC, Chen MC, Jan SL, Wang CC, Fu YC, Lin PC et al. Neonatal cardiac multidetector row CT: why and how we do it. *Pediatr Radiol* 2008; 38:438–451.

[14] Paul JF, Rohnean A, Elfassy E, Sigal-Cinqualbre A. Radiation dose for thoracic and coronary step-and-shoot CT using a 128-slice dual-source machine in infants and small children with congenital heart disease. *Pediatr Radiol* 2011; 41:244–249.