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ORIGINAL ARTICLE

Diagnostic Application of Multidetector-Row Computed Tomographic Coronary Angiography to Assess Coronary Abnormalities in Pediatric Patients: Comparison With Invasive Coronary Angiography

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Key Words
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Background: Multidetector-row computed tomographic (MDCT) coronary angiography has been validated for noninvasive assessment of coronary anatomy. However, we have less experience in diagnosing children with congenital or acquired coronary artery abnormalities by MDCT. We compared the results of MDCT with invasive coronary angiography (ICA) on identifying coronary abnormalities in infants, children, and adolescents with coronary artery abnormalities, including aneurysm, coronary fistula, or anomalous left coronary artery from pulmonary artery (ALCAPA).
Methods: From January 2002 to December 2009, patients with congenital or acquired coronary abnormalities underwent either ICA, MDCT, or both studies for assessment of coronary anatomy. We reviewed all patients' clinical diagnosis, coronary abnormalities identified by MDCT or ICA, and analyzed the advantages and disadvantages between those two methods.
Results: Thirty-three patients (20 males and 13 females) with a mean age of 10.3 years (range: 18 days to 25 years) had coronary abnormalities, including coronary artery aneurysm in Kawasaki disease ($n = 15$), coronary artery fistula ($n = 12$), myocardial bridge ($n = 2$), and ALCAPA ($n = 4$). In 17 patients only referred for ICA, 5 coronary aneurysms (3 on left main coronary artery, 1 on left anterior descending artery segment proximal, 1 on right coronary artery segment proximal), 11 coronary artery fistulas, and 2 ALCAPAs were detected. Sixteen patients

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received MDCT study, and 14 coronary artery aneurysms (4 on right coronary artery, 5 on left main coronary artery, 4 on left anterior descending artery, 1 on left circumflex artery), 3 myocardial bridges, 1 coronary artery fistulas, and 2 ALCAPAs were assessed. Ten patients with Kawasaki disease-related coronary lesions received MDCT study, and totally 102 (78.5%) segments permitted visualization with accurate diagnostic image quality. In this study, there were 11 patients with indication for conventional ICA spared invasive angiography after precise assessment by MDCT.

Conclusion: We conclude that MDCT is a good and useful modality for assessment of congenital or acquired coronary abnormalities in pediatric patients. However, MDCT cannot replace invasive cardiac catheterization and ICA because of lack of therapeutic role.

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1. Introduction

Recently, multidetector-row computed tomography (MDCT) with higher spatial and temporal resolution has offered the potential to improve visualization of the coronary arteries. This advance allows gated coronary MDCT angiography, especially at higher pediatric heart rate. Numerous studies have shown that MDCT has a high diagnostic accuracy for the evaluation of significant coronary artery disease ($\geq$50% luminal narrowing) compared with coronary angiography.[1] However, there are fewer studies demonstrating the accuracy of MDCT for pediatric coronary abnormalities.[2–4] The primary objective of this study was to assess the feasibility and application of MDCT angiography for children and compare of MDCT and conventional invasive coronary angiography (ICA) for identifying coronary artery abnormalities in children.

2. Materials and Methods

2.1. Patients

We reviewed all patients with congenital or acquired coronary abnormalities diagnosed in the Department of Pediatrics, Taipei Veterans General Hospital from January 2002 to December 2009. There were 33 patients (20 males and 13 females) who had coronary abnormalities, including coronary artery aneurysm in Kawasaki disease (KD), coronary artery fistula, myocardial bridge, and anomalous left coronary artery from pulmonary artery (ALCAPA). All the patients received either MDCT or ICA or both examinations for the diagnosis and treatment of coronary artery abnormalities from January 2008 to December 2009. We made the subgroups on the basis of patients with different coronary abnormalities and demonstrated the coronary lesions detected by MDCT and conventional ICA.

2.2. Imaging technique

Computed tomography coronary angiography was carried out with 64-slice MDCT (Toshiba Aquilion 64 Tochigi, Japan) after intravenous injection of nonionic contrast without breath holding. For the patients who could not cooperate, 10% chloral hydrate was applied at a dose of 0.5 mL/kg around 30 minutes before scanning. Oral β-blocker (propranolol HCl) was used to control the heart rate at a dose of 1–2 mg/kg around 1 hour or 30 minutes before examination by MDCT. The image analysis, including 13 arterial segments, including right coronary artery (RCA) segment proximal (RCAp), RCA segment middle (RCAm), RCA segment distal (RCAd), posterior descending artery (PDA), left main coronary artery (LM), left anterior descending artery (LAD) segment distal (LADd), LAD segment middle (LADm), LAD segment proximal (LADp), diagonal branch, left circumflex artery (LCX) segment proximal (LCXp), LCX segment middle (LCXm), LCX segment distal (LCXd), and first diagonal. The raw data were transferred to an off-line workstation for three-dimensional (3D) reconstruction.

3. Results

Thirty-three patients (20 males and 13 females) with a mean age of 10.3 years (range: 18 days to 25 years) had coronary abnormalities, including coronary artery aneurysm in KD ($n = 15$), coronary artery fistula ($n = 12$), myocardial bridge ($n = 2$), and ALCAPA ($n = 4$).

According to Table 1, 17 patients were only referred for ICA, including 4 KDs, 11 coronary artery fistulas, and 2 ALCAPAs. Eleven patients received only MDCT examination, including 7 KDs, 3 myocardial bridges, and 1 ALCAPA. For diagnostic accuracy or therapeutic purpose, there were five patients who underwent both MDCT and ICA, including three KDs with medium or giant coronary aneurysms (>5 mm), one patient who had single left coronary artery (LCA) and coronary fistula, and 1 ALCAPA. Among them, only the patient with single LCA and coronary fistula received coil embolization after conventional ICA.

The result of the numbers of coronary artery abnormalities was shown in Table 2. Seventeen patients underwent ICA, which detected five coronary aneurysms/stenosis (three on LM, one on LADp, and one on RCAp) in 4 patients with KD, 11 coronary artery fistulas (5 on RCAd, 4 on LADd, 1 on LCXd, and 1 on diagonal branch) in 11 patients, and 2 patients with ALCAPA. Eleven patients received MDCT and 13 coronary aneurysms/stenosis were well visualized, including 4 on RCAp, 4 on LM, 2 on LADp, 2 on LADm, and 1 on LCXp. Three patients with myocardial bridges and one ALCAPA were detected by MDCT. There were five patients who underwent both examinations of ICA and MDCT, and four coronary aneurysms/stenosis (one on RCAm, one on LM, one on LADp, and one on LADm), one coronary fistula on LADp, and one ALCAPA were detected.

Table 1 Number of patients undergoing coronary angiography

Coronary angiography and coronary abnormality	KD ($n = 14$)	CoF ($n = 12$)	MyB ($n = 3$)	ALCAPA ($n = 4$)	Total ($n = 33$)
ICA	4	11	—	2	17
MDCT	7	—	3	1	11
MDCT + ICA	3	1*	—	1	5

* Single left coronary artery with CoF.
ALCAPA = anomalous left coronary artery from pulmonary artery; CoF = coronary artery fistula; ICA = invasive coronary angiography; KD = Kawasaki disease; MDCT = multidetector-row computed tomography; MyB = myocardial bridge.

Table 2 Number of coronary artery abnormalities

Coronary angiography and coronary abnormality	Aneurysm/stenosis				CoF			MyB	ALCAPA
	RCA	LM	LAD	LCX	RCA	LAD	LCX	LCA	
ICA (17 patients)	1p	3	1p	—	5d	4d/1di	1	-	2
MDCT (11 patients)	4p	4	2p/2m	1p	—	—	—	3	1
ICA + MDCT (5 patients)	1m	1	1p/1m	—	—	1p*	—	—	1

* Single left coronary artery with CoF.
ALCAPA = anomalous left coronary artery from pulmonary artery; CoF = coronary artery fistula; d = distal segment; di = diagonal branch; ICA = invasive coronary angiography; LAD = left anterior descending artery; LCA = left coronary artery; LCX = left circumflex artery; LM = left main coronary artery; m = middle segment; MDCT = multidetector-row computed tomography; MyB = myocardial bridge; p = proximal segment; RCA = right coronary artery.

In this study, a total of 10 patients had KD-related coronary artery abnormalities detected by MDCT (shown in Table 3). A total of 102 of 130 (78.5%) segments permitted visualization with accurate diagnostic image quality. There were 14 aneurysms detected by MDCT, including 4 aneurysms on RCA with average size of 7 mm, 5 on LM with average size of 6.6 mm, 4 on LAD with average size of 6.4 mm, and 1 on LCX with average size of 3.4 mm. The most common location of coronary aneurysms was LM ($n = 5$, 36%) followed by RCAp ($n = 4$, 29%) (Figure 1). Similar results had been reported in other literature that coronary aneurysms are commonly located in the proximal of coronary artery.[2,5] There were nine segments of coronary arteries with stenosis less than 50%, and three stenosis located in RCA, two stenosis in LM, three stenosis in LAD, and one in LCX. There was no severe stenosis of coronary artery visualized by MDCT in this study.

Table 3 KD-related coronary artery abnormalities detected by MDCT

KD patients who underwent MDCT (10 patients)	Coronary arteries			
	RCA	LM	LAD	LCX
Aneurysm (n)	4	5	4	1
Average size of aneurysm (mm)	7	6.6	6.4	3.4
Stenosis <50% (n)	3 (2p/1m)	2	3 (2p/1m)	1p
Significant stenosis ≥50%	—	—	—	—

d = distal segment; KD = Kawasaki disease; LAD = left anterior descending artery; LCX = left circumflex artery; LM = left main coronary artery; m = middle segment; MDCT = multidetector-row computed tomography; p = proximal segment; RCA = right coronary artery.

4. Discussion

4.1. Patients with KD

The coronary artery complications are the major issues of KD because patients with KD-related coronary aneurysms may suffer from strictures or thrombus resulting in myocardial infarction or sudden death.[2] Therefore, it is crucial to detect the coronary artery lesions in the early stage by careful examinations. Transthoracic echocardiography was the basic and major technique assessing the coronary artery lesions; however, the insufficient resolution power of echocardiography makes it difficult to assess coronary lesion precisely, especially the far end of a coronary artery and obstructive lesion.[2,5] In this study, 10 patients with KD-related coronary lesions were referred for MDCT, and totally 102 of 130 (78.5%) segments were visualized with accurate diagnosis. The high detection rate has been reported in past lectures.[2,5–7] We found some limitations of MDCT for assessing light stenosis, small collateral vessels, and blood flow dynamics. Nevertheless, comparing with conventional ICA, MDCT not only showed the size, shape, numbers, and positions of the coronary aneurysms but also was capable of detecting calcification, thrombus, and stenosis. Three KD patients underwent both MDCT and ICA, and we found that there was strong consistency of the results between MDCT and ICA in this subgroup (Figure 2). Moreover, MDCT had advantages of minimal invasiveness and less cost compared with conventional ICA.

4.2. Patients with coronary fistula

Transthoracic echocardiography is the most common utility for evaluating coronary fistula, but it has its limits in evaluating anatomy, size, and distribution of coronary fistula.

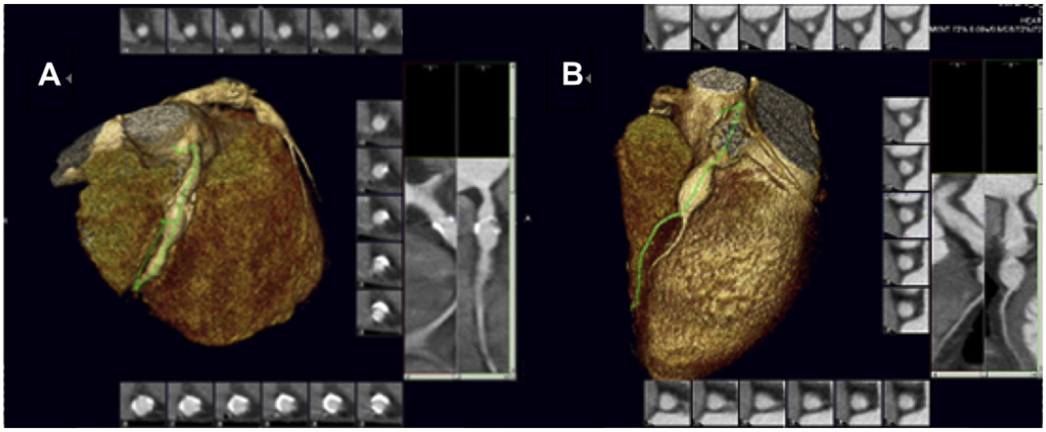

Figure 1 Three-dimensional volume rendering and maximum intensity projection image demonstrate large fusiform aneurysms on (A) right coronary artery segment middle and (B) left anterior descending artery segment proximal.

Conventional ICA provides definition of vascular anatomy, but it carries additional risk of invasive procedure. In this study, a 2-year-old boy with single LCA and LADp draining into the right ventricle was assessed by MDCT. Afterward, the boy received conventional ICA for coil (a 3×5 mm) embolization of coronary fistula successfully. This technology offers the capability to provide a comprehensive, diagnostic workup of coronary abnormalities, including arterial origins, and delineate the entire fistulous course. In addition, MDCT also assessed the size and function of the patient's right ventricle, which reflected potentially adverse effect of coronary steal. Few reports shared the experience of assessment of coronary fistula by MDCT,[4,8] and further study is necessary to specify the sensitivity and specificity.

4.3. Patients with myocardial bridge

The coronary artery anomalies are less prevalent in general population and are found in 2% of the group undergoing catheter coronary angiography.[8–10] Myocardial bridge or intramyocardial tunneling is anomalous coronary course, which may lead to myocardial ischemia, and conventional ICA has been a domain in the diagnosis of these anomalies. In our study, we reported three patients with anginal symptoms who received MDCT, and the three myocardial bridges were detected (Figure 3). MDCT takes far less time than conventional ICA and has less invasive risk, including bleeding at puncture site, hematoma formation, and arteriovenous fistula. Using conventional ICA, the precise course of the anomalous vessel may be difficult to delineate because of its complex 3D geography displayed in two dimensions fluoroscopically.

4.4. Patients with ALCAPA

Anomalous origin of the left coronary artery from pulmonary trunk is the most common major congenital malformation of coronary circulation (about 1:300,000 live births), but this manifests itself in infancy. In this study, we described two

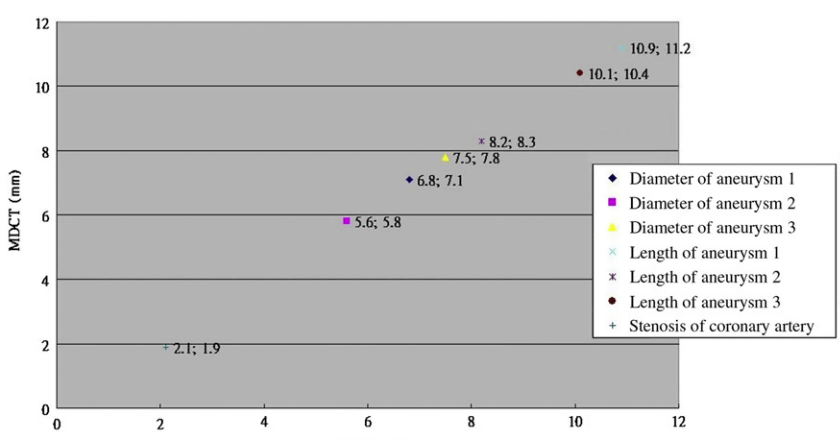

Figure 2 Sizes of coronary aneurysms and stenosis assessed by MDCT and ICA. There were strong consistency between MDCT and ICA for assessing coronary aneurisms size and stenosis. ICA = invasive coronary angiography; MDCT = multidetector-row computed tomography.

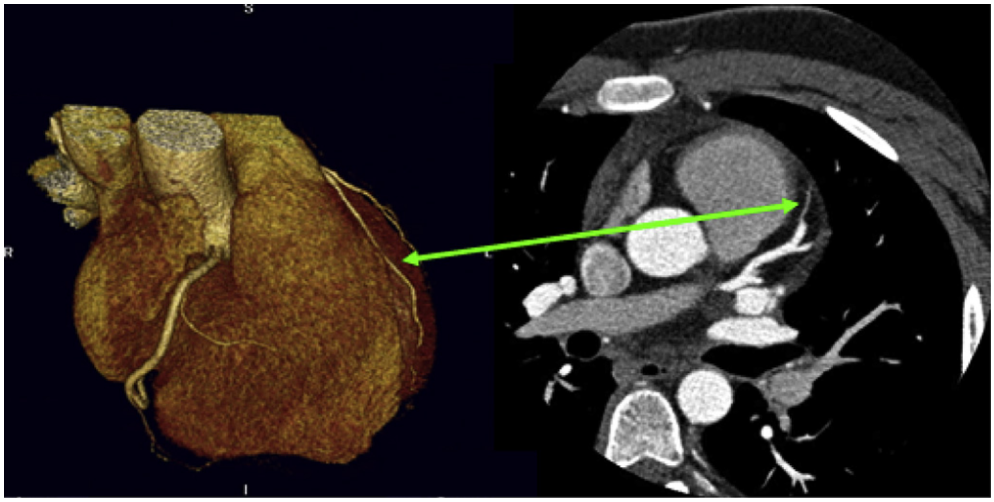

Figure 3 Multidetector-row computed tomography and three-dimensional volume-rendering image show the myocardial bridge on the left anterior descending artery of a 19-year-old boy.

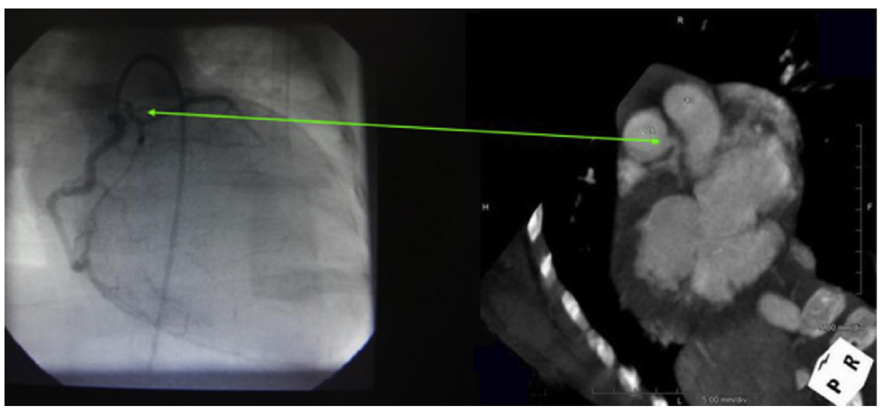

Figure 4 The invasive coronary angiography and multidetector-row computed tomography show abnormal origin of left coronary artery on the main pulmonary artery in a 5-month-old infant.

infants (18 days and 5 months) who received MDCT and were diagnosed with ALCAPA (Figure 4). Both infants had clinical symptoms of heart failure and cardiomegaly, and the transthoracic echocardiography could not rule out congenital coronary anomalies. Under adequate sedation and prescription of β-blocker, the average heart rate declined to 90–120/min. In this circumstance, the precise coronary anatomy was assessed by MDCT, which provided sufficient information about coronary course and major collateral arteries to the surgeon.

In this study, 11 patients with coronary abnormalities who had indication for conventional ICA were spared invasive catheterization after accurate assessment by MDCT.

5. Conclusion

We conclude that MDCT is a good and useful modality for assessment of coronary abnormalities in pediatric patients with coronary aneurysms, coronary fistula, myocardial bridge, and ALCAPA. Compared with conventional ICA, MDCT has less invasive risk and cost,[11] and it proves valuable for accurate diagnosis of pediatric coronary abnormalities. On the other hand, MDCT cannot replace invasive cardiac catheterization and ICA because of lack of therapeutic role.

References

1. Stein PD, Yaekoub AY, Matta F, Sostman HD. 64-slice CT for diagnosis of coronary artery disease: a systematic review. *Am J Med* 2008;**121**:715–25.
2. Peng Y, Zeng J, Du Z, Sun G, Guo H. Usefulness of 64-slice MDCT for follow-up of young children with coronary artery aneurysm due to Kawasaki disease: initial experience. *Eur J Radiol* 2009;**69**:500–9.
3. Huang B, Law MW, Mak HK, Kwok SP, Khong PL. Pediatric 64-MDCT coronary angiography with ECG-modulated tube current: radiation dose and cancer risk. *AJR Am J Roentgenol* 2009;**193**:539–44.
4. Lerner CB, Frush DP, Boll DT. Evaluation of a coronary-cameral fistula: benefits of coronary dual-source MDCT angiography in children. *Pediatr Radiol* 2008;**38**:874–8.
5. Chu WC, Mok GC, Lam WW, Yam MC, Sung RY. Assessment of coronary artery aneurysms in paediatric patients with Kawasaki disease by multidetector row CT angiography: feasibility

and comparison with 2D echocardiography. *Pediatr Radiol* 2006;**36**:1148—53.
6. van Werkhoven JM, Heijenbrok MW, Schuijf JD, et al. Diagnostic accuracy of 64-slice multislice computed tomographic coronary angiography in patients with an intermediate pretest likelihood for coronary artery disease. *Am J Cardiol* 2010;**105**: 302—5.
7. Aggarwala G, Iyengar N, Burke SJ, et al. Kawasaki disease: role of coronary CT angiography. *Int J Cardiovasc Imaging* 2006;**22**: 803—5.
8. Manghat NE, Morgan-Hughes GJ, Marshall AJ, Roobottom CA. Multidetector row computed tomography: imaging congenital coronary artery anomalies in adults. *Heart* 2005;**91**: 1515—22.
9. Srinivasan KG, Gaikwad A, Kannan BR, Ritesh K, Ushanandini KP. Congenital coronary artery anomalies: diagnosis with 64-slice multidetector row computed tomography coronary angiography: a single-centre study. *J Med Imaging Radiat Oncol* 2008; **52**:148—54.
10. Baltaxe HA, Wixson D. The incidence of congenital anomalies of the coronary arteries in the adult population. *Radiology* 1977;**122**:47—52.
11. Mowatt G, Cummins E, Waugh N, et al. Systematic review of the clinical effectiveness and cost-effectiveness of 64-slice or higher computed tomography angiography as an alternative to invasive coronary angiography in the investigation of coronary artery disease. *Health Technol Assess* 2008;**12**:iii—iiv. ix—143 [Review].