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Evaluation of anomalous pulmonary venous return using 320-row multidetector computed tomography

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Abstract

We determined the diagnostic accuracy of 320-row multidetector computed tomography (MDCT) for anomalous pulmonary venous return and pulmonary vein stenosis, the quality of pulmonary vein images, factors affecting image quality, and the amount of radiation exposure in 19 pediatric patients with congenital heart disease. The results of surgery or cardiac catheterization for 74 pulmonary veins in 10 and 9 patients with anomalous and normal pulmonary venous return, respectively, served as the gold standard. The diagnostic accuracy of anomalous pulmonary venous return was 100%. The observers missed pulmonary vein stenosis that was detected by cardiac catheterization at two sites, and misread an additional three normal pulmonary veins as stenotic. Image quality was evaluated using scores from 1 (poor) to 4 (excellent). The median score assigned to each pulmonary vein was 4. A small physique and spontaneous respiration were both significantly associated with high scores for image quality. The median effective radiation dose was 1.50 mSv. These results show that 320-row MDCT has good ability to diagnose anomalous pulmonary venous return, but rather low ability to diagnose pulmonary vein stenosis. Patients were exposed to less radiation with 320-row MDCT than with conventional 64-row MDCT.

Key words : 320-row multidetector computed tomography, pulmonary vein, anomalous pulmonary venous return, diagnostic accuracy, effective radiation dose

I. Introduction

Total and partial forms of anomalous pulmonary venous return (APVR) comprise a congenital heart disease (CHD) that affects the return of venous blood to the systemic veins and/or right atrium. The clinical picture of APVR ranges from being asymptomatic to causing heart failure in early infancy, depending on the number of pulmonary veins (PV) with abnormal return. The only treatment for total APVR is early surgery, for which the venous return path and the presence or absence of stenosis within it must be defined. Such accuracy is particularly important in mixed-type disease involving several paths of return to the systemic venous circulation.

Echocardiography is the most popular modality for diagnosing APVR. However, the accurate definition of the venous return path by echocardiography can be hampered by a limited acoustic window and operator skill. On the other hand, MRI provides better visualization of the PV without involving radiation exposure [1], but protracted image acquisition and a need for MRI-compatible medical devices cause difficulties with assessments of neonates and infants with serious illnesses.

Sixteen- and 64-row multidetector CT (MDCT) offer excellent visualization of the pulmonary venous return paths but at the cost of high radiation exposure [2-7]. Newer 320-row MDCT offers the advantages of less radiation exposure and more rapid image acquisition than previously possible. The application of 320-row MDCT to patients with CHD has not been described in detail [8, 9], and the diagnostic accuracy for APVR or image quality has not been validated.

Here, we used 320-row MDCT to assess pediatric patients with CHD with or without APVR and return path stenosis confirmed by surgery or cardiac catheterization to determine the diagnostic accuracy of the imaging modality, the quality of APVR images and stenosis, and the amount of radiation exposure.

II. Materials and methods

1. Patients

We used 320-row MDCT to assess 22 pediatric (age≤15 years) patients with CHD in whom the presence or absence of APVR and return path stenosis had been confirmed by surgery or cardiac catheterization at our institution between January 2008 and July 2012. The following three patients were excluded: a 2-month-old infant with blurred PV in cardiac catheterization images; a 1-day-old neonate with a levoatriocardinal vein; and a 6-year-old with pulmonary arteriovenous fistula who had been assessed using a dynamic volume imaging protocol.

We compared the effective dose and duration of radiation exposure between these 19 patients and 19 age-, height- and weight-matched controls that were selected from among those who had been assessed for CHD by 64-row MDCT at our institution between 2007 and 2008.

The present study was approved by the Ethics Committee of Iwate Medical University School of Medicine (Approval No. H22-181).

2. CT angiography

The patients were administered with a chloral hydrate enema or with oral triclofos sodium or diazepam, and both midazolam and pentazocine were then injected intravenously immediately before CT angiography. Thirteen of the patients breathed spontaneously without breath-holding throughout the procedure, and six on artificial ventilation were switched to bag ventilation, for which the bag was squeezed for about 5 seconds at the time of image acquisition.

Angiographic images were acquired in the cranial-caudal direction using an Aquilion ONE 320-row MDCT (Toshiba Medical Systems, Tokyo, Japan) under the following conditions: tube rotation period, 0.35 s; tube voltage, 80–100 kV; tube current, 50–180 mA; slice thickness, 0.5 or 1 mm; imaging range, 8–16 cm. The tube current was not modulated and

Table 1. Scoring scale for image quality of pulmonary vein.

1 (poor)	=non-diagnostic
2 (fair)	=structures of the pulmonary connection are visible but blurred
3 (good)	=only primary branches can be assessed
4 (excellent)	=the second branches of the pulmonary vein and connection are easily assessed

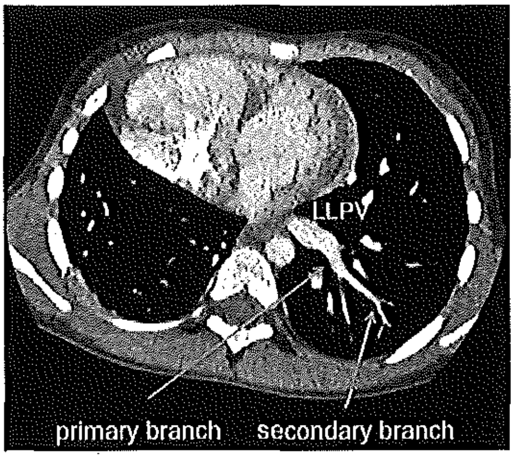

Fig. 1. Left lower pulmonary vein assessed by 320-row MDCT using MPR.
Secondary branch of left lower pulmonary vein and connection are easily assessed. This image was evaluated as 4 (excellent). MDCT, multi-detector row computed tomography; MPR, multiplanar reformation.

ECG synchronization was omitted.

Omnipaque 300, 360, and 370 contrast agents (1 mL/kg) were diluted 1.5- to 3-fold with physiological saline and infused into two, one and sixteen patients, respectively. Undiluted contrast agent was required to optimize visualization of the scimitar vein in one patient with scimitar syndrome (Patient No. 8). Contrast agent was infused into a peripheral vein using a DUAL SHOT® GX injector (Nemoto Kyorindo; Tokyo, Japan) and a 24 G needle at a rate of 0.5–2.0 mL/s to a maximum of 2.0 mL/kg, and then switched to physiological saline, which was infused at the same rate in a volume of 1.5–2.0 mL/kg to drive the contrast medium. The amount of time taken for the contrast medium to arrive at target sites was estimated using automatic bolus tracking. Image acquisition was started when the contrast medium reached a target site.

3. CT image reconstruction

The CT images were reconstructed using a work station (Ziosoft Inc., Tokyo, Japan). Volume rendering and maximum intensity projection images as well as multiplanar reformation images were created, and 3D images were created using volume rendering.

4. CT diagnosis

Two certified radiologists with at least 15 years of experience who were blinded to the clinical information and the surgical or test results separately diagnosed the conditions of the patients twice based on the same multiplanar reformation images. The CT findings were then retrospectively compared with those of surgery or cardiac catheterization, and the diagnostic accuracy for APVR and return path stenosis was evaluated. The two radiologists evaluated the presence or absence of APVR and return path stenosis on the same set of images of 9 randomly assigned patients from among the 19 at 1 year later to determine the reproducibility of the CT diagnosis.

5. CT image evaluation

The quality of CT images of the PV was evaluated as described by Kawakami et al.[1]. The following scores (Table 1 and Fig. 1) were assigned to each of the four PV: 1, poor (non-diagnostic); 2, fair (pulmonary connection structures visible but blurred); 3, good (only primary branches assessable); or 4, excellent (secondary branches of PV and connections easily assessable). The reproducibility of image quality was similarly assessed 1 year later as described above.

6. Amount and duration of radiation exposure

The estimated radiation exposure is expressed as the effective dose-length product (DLPe [mGy × cm] obtained by multiplying the CT dose index [CTDI (mGy)]) by the imaging range, and the effective dose (mSv) was obtained by multiplying that value by a conversion coefficient. The conversion coefficients of 0.039, 0.026, 0.018 and 0.013 mSv/mGy × cm differed according to the ages of <1, 1-4, 5-9 and 10-15 years, respectively [10]. We compared the effective dose and duration of exposure between the two groups of patients assessed by 320-row and 64-row MDCT.

7. Statistical analysis

The characteristics of the patients, imaging conditions, inter-observer evaluations of each PV site and estimated radiation exposure were compared between the two groups using the Mann-Whitney test. Intra-observer values for PV sites were compared among the four groups using the Kruskal-Wallis test. The resultant data are expressed as median (range) values. Inter-observer evaluations of the image quality and the reproducibility of intra-observer evaluations for each PV site were assessed using kappa coefficients [11]. Factors affecting image quality were determined by multiple regression analysis, for which the image quality scores for each observer and for each PV site were included as dependent variables, and patient characteristics (age, height, weight), presence/absence of tracheal intubation, imaging conditions (tube voltage, tube current, imaging range), duration of radiation exposure, CTDI, DLPe and effective dose were included as independent variables. All data were statistically analyzed using SPSS for Windows (SPSS Japan, Tokyo, Japan), and $p<0.05$ (two-tailed) was considered to indicate a statistically significant difference. Unless otherwise stated, all data presented in this manuscript are expressed as in the original publications, as means ± standard deviation (SD).

III. Results

1. Characteristics of the patients

Three patients had total APVR, 3 had partial APVR (2 had scimitar syndrome), six had asplenia (4 had complication of total APVR), 5 had polysplenia and 1 each had PV stenosis and Cantrell's syndrome. Eleven patients had heterotaxy syndrome (Table 2). The patients comprised 8 males and 11 females (median age, 20 days; range, 0 d-74 m; height 51.0 cm; range, 42.0-109.0 cm; weight, 3.7 kg; range, 1.8-18.9 kg). 6 patients who required a respirator weighed significantly less than the other 13 who breathed spontaneously (median and range: 3.0 and 1.8-3.9 vs. 5.1 and 2.5-18.9 kg, respectively, $p = 0.043$). Age (median and range: 5 and 0-30 vs. 90 and 0-2220 d, respectively, $p=0.065$) and height (median and range: 48.3 and 42.0-55.0 vs. 60.3 and 45.5-109.0 cm, respectively, $p=0.148$) did not significantly differ between the two groups. The gold standards comprised 13 and 6 patients who were assessed by catheterization and surgery, respectively. The accuracy of detecting the pulmonary venous return (PVR)

Table 2. Patients' characteristics.

Case	Gender	Age	Weight(kg)	Diagnosis
< Anomalous Pulmonary Venous Return >				
1	M	0 d	2.8	TAPVR(Ⅳ), PDA
2	F	1 d	3.0	TAPVR(Ⅲ), ASD
3	F	10 d	1.8	TAPVR(Ⅳ), ASD
4	M	0 d	2.5	TAPVR(Ⅲ), Asplenia, SA, SV, PS
5	M	1 d	2.9	TAPVR(Ⅳ), Asplenia, SV, PA, MAPCA, Bil SVC
6	F	9 d	3.7	TAPVR(Ⅱ b), Asplenia, SA, SV, PA, PDA, PLSVC
7	M	4 m	4.9	TAPVR(Ⅱ b), Asplenia, cAVSD, DORV, PS
8	F	1 y 1 m	7.5	Scimitar Syndrome, Sequestration
9	F	6 y 2 m	18.9	Scimitar Syndrome, Sequestration, Dextrocardia
10	M	2 m	5.3	PAPVR, TOF, ASD, PDA, PLSVC, LPA stenosis
<Normal Pulmonary Venous Return>				
11	F	12 d	3.4	Asplenia, cAVSD, PA, Bil PDA, LSVC
12	M	1 y 4 m	10.0	Asplenia, SV, PA, LSVC, Dextrocardia
13	M	3 d	2.4	Polysplenia, SV, PA, MAPCA
14	F	5 d	2.9	Polysplenia, HLHS, SV, MA, PDA, CoA,Dextrocardia
15	F	20 d	3.9	Polysplenia, SV, TGA, MA, VSD, ASD, PDA
16	F	1 m	3.9	Polysplenia, SV, DORV, PS
17	F	3 y 8 m	11.9	Polysplenia, cAVSD, PA, PAVF
18	F	2 y 1 m	8.8	LPV stenosis, ASD, PLSVC
19	M	15 d	3.0	Cantrell Syndrome, SV, DORV, PA, MA, ASD, PDA

ASD=atrial septal defect, Bil SVC=bilateral superior vena cava, cAVSD=complete atrioventricular septal defect, CoA=coarctation of the aorta, DORV=double-outlet right ventricle, LPA=left pulmonay artery, LSVC = left superior vena cava, MA=mitral atresia, MAPCA= major aortopulmonary collateral artery, PA=pulmonary atresia, PAPVR=partial anomalous pulmonary venous return, PAVF=pulmonary arteriovenous fistula, PDA=patent ductus arteriosus, PLSVC=persistent left superior vena cava, PS=pulmonary stenosis, SA=single atrium, SV=single ventricle, TAPVR=total anomalous pulmonary venous return, (Ia)=supracardiac type to innominate vein, (Ib)=supracardiac type to superior vena cava, (IIb)=paracardiac type to right atrium, (III)= infracardiac type, (IV)=mixed type, TGA=transposition of the great arteries, TOF=tetralogy of Fallot, VSD=ventricular septal defect.

path did not significantly differ between the two groups.

All patients were assessable by CT without complications. The interval between CT assessment and surgery or cardiac catheterization was 25 (0-310) days.

The 19 patients who had been assessed by 64-row MDCT at our institution had a median age of 2 months (3 d-67 m), were 54.0 (43.0-110.0) cm tall, and weighed 3.7 (2.0-17.0) kg; additionally, two of these patients had heterotaxy syndrome.

2. CT diagnosis of PVR path and its reproducibility

Figure 2 shows CT images typical of total APVR. Cardiac catheterization was unable to visualize 2 of 76 PV in the 19 patients; therefore, a total of 74 PV were evaluated. The CT diagnoses of the PVR path reached agreement between the two radiologists in terms of both normal and anomalous return, and the sensitivity, specificity, positive and negative predictive values and accuracy were all 100% (Table 3). The diagnoses of PVR in 3 patients with mixed-type total APVR also agreed with the surgical findings. The

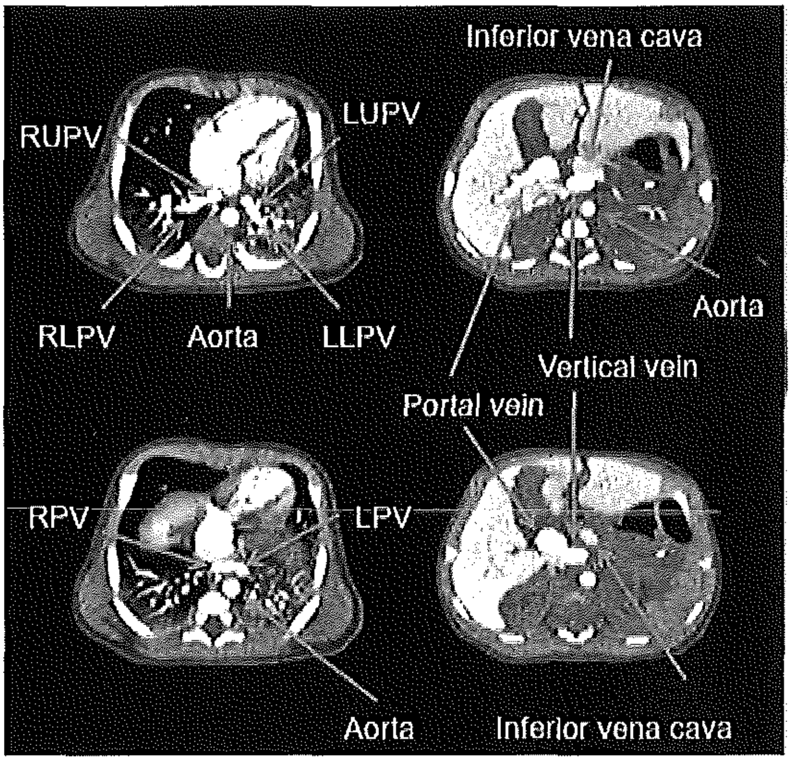

Fig. 2. Infra-cardiac type total anomalous pulmonary venous return assessed by 320-row MDCT using MPR. A common PV trunk is formed by the RUPV, RLPV, LUPV and LLPV. Vertical vein runs caudally and connects to portal vein. LLPV, left lower pulmonary vein; LPV, left pulmonary vein; LUPV, left upper pulmonary vein; MDCT, multi-detector row computed tomography; MPR, multiplanar reformation; RLPV, right lower pulmonary vein; RPV, right pulmonary vein; RUPV, right upper pulmonary vein.

Table 3. Diagnostic accuracy of 320-row MDCT for detection of pulmonary venous return.

		Operation or Catheter		
		Anomalous return	Normal return	Total
320-row MDCT	Anomalous return	26	0	26
	Normal return	0	48	48
	Total	26	48	74

Sensitivity 100%, Specificity 100%, Positive Predictive Value 100%,
Negative Predictive Value 100%, Accuracy 100%

reproducibility of the CT diagnostic results was investigated by reevaluating 34 veins in 9 patients 1 year later, and the accuracy was 100% for both observers.

3. Evaluation of PV stenosis and reproducibility

Cardiac catheterization confirmed PV stenosis in the left upper and left lower PV (Patient 18). Seventy-four and 34 veins in the 19 and 9 patients were assessed during the first and second CT evaluations. The two sites of stenosis were not recognized by the radiologists at both assessments of the images (Table 4). Observer A assigned an image quality rating of "excellent" for these sites at both visual assessments, whereas Observer B

Table 4. Diagnostic accuracy of 320-row MDCT for detection of pulmonary venous stenosis.

<First time of observer A>			Operation or Catheter	
19 patients		Stenosis	No stenosis	Total
320-row MDCT	Stenosis	0	0	0
	No stenosis	2	72	74
	Total	2	72	74

Sensitivity 0%, Specificity 100%, Positive Predictive Value 0%, Negative Predictive Value 97%, Accuracy 97%

<Second time of observer A>			Operation or Catheter	
nine of the 19 patients		Stenosis	No stenosis	Total
320-row MDCT	Stenosis	0	6	6
	No stenosis	2	26	28
	Total	2	32	34

Sensitivity 0%, Specificity 81%, Positive Predictive Value 0%, Negative Predictive Value 93%, Accuracy 76%

<First time of observer B>			Operation or Catheter	
19 patients		Stenosis	No stenosis	Total
320-row MDCT	Stenosis	0	2	2
	No stenosis	2	70	72
	Total	2	72	74

Sensitivity 0%, Specificity 97%, Positive Predictive Value 0%, Negative Predictive Value 97%, Accuracy 95%

<Second time of observer B>			Operation or Catheter	
nine of the 19 patients		Stenosis	No stenosis	Total
320-row MDCT	Stenosis	0	0	0
	No stenosis	2	32	34
	Total	2	32	34

Sensitivity 0%, Specificity 100%, Positive Predictive Value 0%, Negative Predictive Value 94%, Accuracy 4%

assigned ratings of "excellent" and "good" for the left upper and lower PV, respectively, at both assessments.

Normal pulmonary veins were misread as stenosis in three patients (Patient nos. 4, 7, and 16) at either assessment. Six sites of 32 normal pulmonary veins were recognized as stenosis by Observer A at the second assessment of the images, and two sites in 72 normal pulmonary veins were recognized as stenosis by Observer B at the first assessment (Table 4). Both observers assigned an image quality rating of "excellent" for these sites.

4. Evaluation of CT image quality and its reproducibility

Observers A and B both assigned scores of 4 (2-4 and 3-4, respectively) for all PV sites in both assessments. A comparison of intra-

Table 5. Weighted κ statistics for detection of pulmonary venous return.

<Inter-observer>	RUPV	RLPV	LUPV	LLPV
First time	0.99	0.97	0.96	0.98
Second time	1.00	0.98	0.96	0.99

<Intra-observer>	RUPV	RLPV	LUPV	LLPV
Observer A	0.92	0.92	0.93	0.93
Observer B	0.98	0.98	0.99	0.99

RUPV=right upper pulmonary vein, RLPV=right lower pulmonary vein,
LUPV=left upper pulmonary vein, LLPV=left lower pulmonary vein

Table 6. Factors affecting scores for image quality.

<Observer A>	Independent variable	Standardized Conffiicient(β)	P
RUPV	Age	− 0.662	0.011
	Intubation	− 0.492	0.024
	DLPe	0.493	0.042
RLPV	Intubation	− 0.525	0.019
	Weight	− 0.519	0.034
LUPV	none		
LLPV	Intubation	− 0.757	0.003
	Height	− 0.944	0.004
	Range	0.651	0.016
	Tube current	0.541	0.022

<Observer B>	Independent variable	Standardized Conffiicient(β)	P
RUPV	none		
RLPV	none		
LUPV	Intubation	− 0.488	0.014
	Tube current	− 0.483	0.015
LLPV	Height	− 2.164	0.031

RRUPV=right upper pulmonary vein, RLPV=right lower pulmonary vein,
LUPV=left upper pulmonary vein, LLPV=left lower pulmonary vein,
DLPe=effective dose length product.

observer image quality scores for each PV site found no significant differences between the first and second assessments by Observers A ($p=0.947$ and 0.608, respectively) and B ($p=0.593$ and 0.461, respectively). The inter-observer image quality evaluation scores for each PV site also did not significantly differ between the first and second assessments of the right upper PV ($p=0.142$ and 1.00, respectively), right lower PV ($p=0.149$ and 0.270, respectively), left upper PV ($p=0.598$ and 0.063) or left lower PV ($p=0.942$ and

Table 7. Corresponding relevant radiation and system setup with effective radiation dose equivalent.

Case	Exposure time (sec)	CTDI (mGy)	DLPe (mGy × cm)	Effective Radiation Dose (mSv)
1#	14.46	65.6	53.9	21.0
2#	5.83	26.0	41.0	1.60
3#	6.69	53.6	38.6	1.51
4	7.50	31.1	63.7	2.48
5#	18.19	100.0	97.4	1.75
6	8.58	44.9	27.6	1.08
7	13.59	90.5	133.3	5.20
8	12.24	68.0	30.2	1.18
9	12.31	20.6	38.4	1.50
10	6.27	28.7	23.4	0.91
11	15.96	48.3	99.5	3.88
12	6.18	38.3	49.1	1.28
13	4.70	18.6	34.2	1.33
14#	10.11	51.5	53.2	2.07
15#	12.86	58.3	23.0	0.90
16	8.50	35.4	23.8	0.93
17	5.03	28.3	192.0	4.99
18	8.48	18.2	20.4	0.53
19	7.69	39.1	25.5	0.99

#intubation, CTDI = CT dose index, DLPe=effective dose length product.

0.317, respectively).

Table 5 shows the results of the inter- and intra-observer reproducibility of the detection of PVR. Inter-observer kappa coefficients as a function of the PV site during the first and second visual assessments were 0.96–0.99 and 0.96–1.00, respectively. Similarly, the intra-observer kappa coefficients as a function of the PV site for Observers A and B were 0.92–0.93 and 0.98–0.99, respectively. These results confirmed the high reproducibility of all values.

5. Analysis of factors affecting evaluation of CT image quality

Table 6 shows the factors that might affect CT image quality. A small physique and spontaneous respiration were both significantly associated with high scores for image quality. The associations between imaging conditions and scores for image quality were inconsistent between observers.

6. Estimated radiation exposure

Table 7 shows the imaging conditions and estimated radiation dose for each patient. The median exposure time was 8.50 sec and the median effective dose was 1.50 mSv. No significant association was observed between imaging conditions and estimated radiation dose. The effective dose determined as a function of disease did not significantly differ ($p=1.00$) between total APVR alone (1.60 [1.51–2.10] mSv; n=3) and total APVR with complicating asplenia syndrome (2.69 [1.18–5.20] mSv; n=4). The duration of exposure was 14.2 (4.5–68.0) seconds and the effective dose was 4.56 (1.50–51.3) mSv in 19 age-, height-, and weight- matched control patients who had been assessed by 64-row MDCT. The duration of exposure was significantly shorter ($p=0.019$), and the effective dose was significantly lower ($p<0.001$) with 320- than with 64-row MDCT.

IV. Discussion

We compared the findings of 320-row MDCT and the results of surgery or cardiac catheterization for 74 PV in 19 pediatric patients with CHD. We investigated the diagnostic accuracy for APVR and PV stenosis and evaluated CT image quality. We then investigated the reproducibility of these findings and determined the amount of radiation exposure. The diagnostic accuracy for the PVR path was excellent, and the image quality was very good, regardless of the target PV site. In addition, both the reproducibility of diagnosis and the image quality of 320-row MDCT were good, although the diagnostic accuracy for PV stenosis was low. The duration of exposure was significantly shorter and the effective dose was significantly lower with 320- than with 64-row MDCT.

Kim et al.[2] used 4-row MDCT to evaluate 14 patients (median age, 2.3 months; range, 3 d–8 m) with total APVR (supra-cardiac-type, n=7; cardiac-type, n=4; infra-cardiac-type, n=1; mixed-type, n=2). They reported visualization rates of 100% for the PVR path with horizontal cross-sectional images and 95–98% with 3D reconstructed images. Kawakami et al.[1] used contrast-enhanced MR angiography to assess 31 patients (median age, 2.1 y; range, 2 d–9 y), 11 of whom had total APVR (supra-cardiac-type, n=5; cardiac-type, n=3; infra-cardiac-type, n =3). They reported 93% sensitivity, 100% specificity, and 97% for each of the positive and negative predictive values and accuracy, respectively. The diagnostic accuracy of 320-row MDCT in the present study was better than that previously reported, and the course of the PV in 3 patients with mixed-type total APVR was also able to be identified.

The two radiologists could not identify stenosis of the normal return in PV of one patient and misread a normal pulmonary vein as stenosis in three patients in either assessment. These PV were narrow, and blood flow on the same side was reduced. The image quality was rated as excellent or good, but evaluating stenosis of a narrow and low-flow PV might be difficult with 320-row MDCT. Oh et al.[5] used 64-row MDCT to assess 23 patients with total APVR aged a mean of 2.5 (range, 1–5) days, and determined the diagnostic accuracy for stenosis of the common PV trunk, the vertical vein, and the site of return of the vertical vein. They found that the sensitivity and specificity were both 100%, but the diagnostic accuracy for stenosis of the normal PV was not evaluated. The present study cohort did not include any patients with total APVR accompanied by vertical vein stenosis, so we were unable to evaluate the diagnostic accuracy for this condition.

The quality of CT images of the PV has not been reported. Two radiologists in the study by Kawakami et al.[1] evaluated the quality of contrast-enhanced MR angiographic images of 31 patients using the methods described herein, and generated a mean score of 3.73. Matsuo et al.[12] assessed 33 patients with suspected APVR aged a mean of 9.3 (range, 1–65) years using non-contrast MR angiography with a fast two-dimensional gradient-recalled-echo sequence and cardiac-triggered segmented acquisition (FASTCARD).

They also evaluated the quality of PV image using the methods described herein. They reported rates of good or excellent image quality of 74%, 90%, 77% and 84% for the right upper and lower, and left upper and lower PV, respectively. Observer A in the present study judged that 89.5%, 94.7%, 94.4% and 94.4% of images of the right upper and lower, and left upper and lower PV, respectively, were of good or excellent quality, and Observer B judged that all four PV sites were of good or excellent quality. Thus, the capability of 320-row MDCT to visualize the PV therefore equals or exceeds that of MR angiography.

Several factors affected image quality scores depending on the PV site. Noise is reduced by a small physique, and we surmised that image contrast would therefore be high. Quality is generally improved by having the patient hold their breath during inspiration at the time of image acquisition, but patients did not hold their breath in the present study. Nevertheless, venous return was increased under spontaneous respiration, and the PV was thus easier to visualize. A higher voltage and current, as well as a broad imaging range, increase exposure, but improve image quality. However, why a low current affected the high quality scores assigned by Observer B, but not those assigned by Observer A, remains unclear.

The reported effective doses of radiation during 64-row MDCT on pediatric patients with CHD range from 2.5 ± 2.1 to 5.0 ± 3.9 mSv [13-15]. Compared with 64-row MDCT, 320-row MDCT has a shorter imaging duration, which allows for less radiation exposure. Al-Mousily et al. [8] reported an effective dose of 0.8 ± 0.39 mSv with ECG synchronization during prospective gating during CT assessment of eight children with CHD and a mean age of 8.1 (range, 0.1-49) months, which is lower than the effective dose of 1.8 ± 0.71 mSv without synchronization. Zhang et al. [9] reported a low effective dose of 0.42 ± 0.06 mSv during CT imaging with ECG synchronization by prospective gating of 22 pediatric patients (mean age, 18 m; range, 14 d-9 y) with complex cardiac anomalies, and the accuracy was also good.

The effective dose was lower in the present study than that in the above reports describing 64-row MDCT, but higher than that reported for 320-row MDCT. The reasons for this might be as follows. We did not perform ECG synchronization by prospective gating. We calculated values using the same conversion coefficient for infants aged from 4 to 12 months and neonates (0.039 mSv/mGy × cm), whereas Zhang et al. [9] used the same conversion coefficient for such infants and children aged 1-4 y (0.026 mSv/mGy × cm). Whereas the present study included one patient in the age range of 4 to 12 months, the report by Zhang et al. does not indicate the number of patients in each age group. Thus, we were unable to compare the effective dose using the same conversion coefficient. Radiation exposure might be further reduced using tube current modulation. Accordingly we recently reduced the Aquilion ONE tube rotation period to 0.275 s, and presently include ECG synchronization by prospective gating. We therefore aim to further reduce exposure to medical radiation [16]. Further investigation into diagnostic accuracy and image evaluation under conditions of reduced exposure is required.

Although stenosis of a narrow PV required very careful evaluation, we were able to accurately diagnose APVR from 320-row MDCT images with excellent image quality and reproducibility, while exposing patients to less radiation compared with conventional 64-row MDCT.

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Conflict of interest: The authors have no conflict of interest to declare.

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320 列 multidetector-row CT による 肺静脈還流異常の評価

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要旨

先天性心疾患 19 例を対象に 320 列 MDCT を施行し, 肺静脈還流異常と肺静脈狭窄の診断尺度, 描出された肺静脈の画質, 画質の影響因子, および被ばく線量を検討した. 10 例の肺静脈還流異常患者と 9 例の正常肺静脈還流患者の計 19 例, 74 本の肺静脈について手術または心臓カテーテルの結果を gold standard として評価した. この結果, 肺静脈還流診断の正診率は 100% であった. 肺静脈狭窄は 2 か所で認められたが, 読影で指摘できなかった. 3 例で正常の肺静脈を狭窄と誤読影した. 画質評価は 1(poor) から 4(excellent) まで点数化し, この肺静脈部位別点数の中央値は 4 であった. 画質の高点数には肺静脈の部位により小体格や, 自発呼吸, 撮像条件が有意に関連していた. 実効線量の中央値は 1.50 mSv であった. 以上のことから, 320 列 MDCT は肺静脈還流異常の診断に有用であるが, 肺静脈狭窄の診断能は低い可能性がある. 被ばく線量は従来の 64 列 MDCT よりも低値であった.