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Patent ductus arteriosus (PDA) in adults evaluated in echocardiography and multi-slice computed tomography (MSCT)

THE INCIDENCE AND CLINICAL PICTURE OF PDA

The congenital circulatory defects are defined as the disorders of the structure and function of the cardiovascular system present at birth, even if the diagnosis is established much later. They result from the defective development of the normal structure in the embryonic and fetal life. It is estimated that 0.8% of neonates are born with developmental defects of the circulatory system, among which the most common ones include: ventricular septal defect (30.5%), atrial septal defect (9.8%) and patent (Botall's) *ductus arteriosus* (9.7%).

Patent *ductus arteriosus* (PDA) is one of the most frequent congenital heart defects, three times more common in women. The condition consists in maintaining the fetal patency between the aorta and pulmonary artery. The arterial duct is a part of the aortic arch connecting the descending aorta with the left pulmonary artery. In the fetal life, about 84% of the pulmonary artery trunk blood reaches the systemic circulation through that duct. Twelve to 24 hours after birth the duct closes functionally due to the contraction of its muscular wall and the anatomical closure occurs between the 1st and 2nd week of life, with the arterial ligament left (1, 2, 6, 8, 9). The reasons resulting in maintaining the patency of the arterial duct are not completely known, the condition is more often observed in children with low birth weight due to prematurity and those with respiratory distress syndrome (6). In the pathogenesis of this defect the role of kinins and prostaglandins is implicated (9). In the fetal life the blood flows through the arterial duct from right to left because of high pulmonary vascular resistance. Shortly after birth the lung changes develop which decrease the pulmonary arterial pressure to 1/4–1/6 of the aortic pressure. This condition reverses the blood flow through the patent duct and results in overcirculation to the lungs, left atrium and ventricle and ascending and arch portions of the aorta, the extent of which varies. After some years an Eisenmenger's reaction to the increased pulmonary flow is likely to develop and the pulmonary vascular resistance may exceed the systemic resistance, which leads to the right-to-left shunt across PDA (2, 6, 7, 9). PDA may occur as an isolated defect or may be accompanied by other heart defects (e.g. pulmonary trunk atresia), compensating them, which enables the patient to survive, or not.

The clinical picture may be extremely variable depending on the size of the duct and the difference between the systemic and pulmonary resistance. A small shunt is often detected incidentally; generally it does not cause hemodynamic derangement or clinical signs, however, it may predispose to endocarditis (9, 11). In an extremely big left-to-right shunt, the development of children is slower, the upper respiratory tract infections and pneumonia are more common. The biggest threat, however, is the

pulmonary hypertension caused by organic changes in the pulmonary vessels, gradual reduction of the shunt and eventually its reversion to the right-to-left one with the presence of cyanosis (Eisenmenger«s reaction (2, 8, 9).

The clinical signs of big left-to-right shunts are similar to those observed in patients with big ventricular septal defects. The physical examinations additionally reveal a big amplitude of the arterial pressure with low diastolic pressure *pulsus celer et altus* similar to aortic incompetence. The machinery murmur is heard in the second left intercostals space, which disappears when the pressures are equalized. Electrocardiography reveals the features of left ventricle hypertrophy and with concomitant pulmonary hypertension the features of right ventricle hypertrophy or ventricular hypertrophy may be observed.

The X-ray picture of the thorax shows the enlarged left atrium and left ventricle, increased vascular markings, the "hilar amputation" picture accompanied by pulmonary hypertension. Normally echocardiography visualizes PDA and reveals the left-right shunt (colour Doppler); another recognized diagnostic method, although rarely used is MRI (11). The invasive examinations facilitate the direct catheterization of PDA, its visualization in the angiogram, oximetric evaluation and assessment of the shunt's size and pressures in the pulmonary circulation (2, 6).

CASE REPORTS

In the majority of patients with wide PDA or other concomitant heart defects, the diagnosis is established in childhood and the patients are subjected to various therapeutic procedures depending on the concomitant defects and clinical evaluation. The patients with slight shunts are usually seen in cardiological outpatient clinics in adulthood due to abnormalities found on X-ray pictures or on auscultation of the heart.

Such a group of patients will be presented in our paper. Amongst the patients seen in the Outpatient Clinic, Medical University of Lublin between November 2002 and October 2003, 3 were diagnosed with PDA as an isolated defect (two women, aged 32 and 50 and one 45-year-old man). The reasons of referral included cardiac murmurs which were not accompanied by any clinical signs. The history was not contributory, both women had two children. In the case of a man the visit was related to the continuation of cardiological care started in his childhood due to indefinite congenital heart defect (lack of earlier medical records). The physical examinations of both women revealed typical continuous machinery murmur, in the third case the auscultation findings were not characteristic. ECG and X-ray of the thorax did not demonstrate any abnormalities. In the first two cases the diagnosis was based on echocardiography, in the third one – on MSCT.

ECHOCARDIOGRAPHY AND MSCT FINDINGS

The echocardiographic studies (Fig. 1–3), (SONOS 5500) with Doppler (pulsating wave and colour imaging) provided the direct visualization of PDA (3, 4, 10). The image was obtained in two positions: 1. Parasternal short axis view at the level of big vessels with the picture visualizing the dilated pulmonary trunk and two branches, the turbulent flow to the pulmonary trunk in the direction opposite to the physiological pulmonary flow was visible from the descending aorta lying below. 2. A suprasternal view visualizing the aortic arch with three branches and the pulmonary artery beneath, moreover, the pathological continuous flow from the aorta to the pulmonary trunk was observed. Both women showed a slight enlargement of the left atrium and left ventricle and dilated pulmonary trunk.

MSCT was performed using an eight-row Light Speed Ultra scanner with the diagnostic console Advantage Windows 4.0 (General Electric Milwaukee). The three examinations presented in our paper constituted 0.87% of all cardiac examinations conducted in one year. The preparations of patients for examinations included earlier laboratory tests (creatinine and TSH levels) and evaluation of arterial

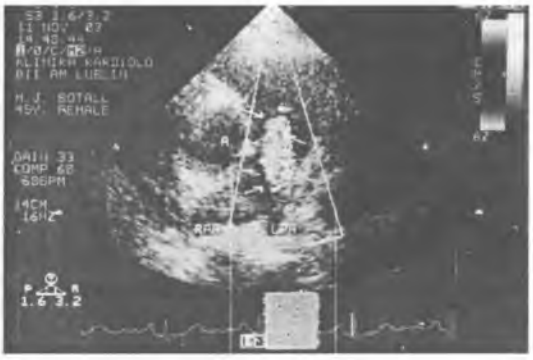

Fig. 1. Transthoracic echocardiogram (TTE). Parasternal short axis view (SAX) at the level of big vessels, arrows indicate the flow (colour Doppler) within the dilated pulmonary trunk, the flow opposite to the physiological one in the pulmonary trunk, A – aorta, RPA and LPA – right and left pulmonary artery, respectively

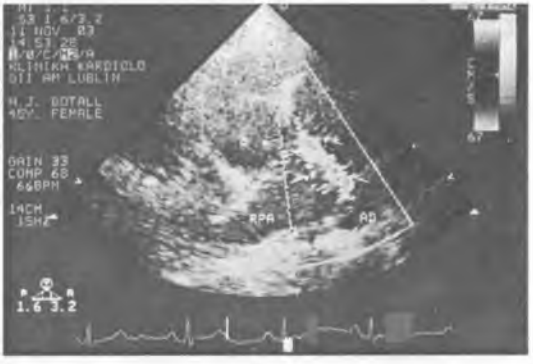

Fig. 2. TTE. Modified parasternal SAX allows to visualize more precisely that the flow starts in the descending aorta (transverse section) and runs to the left pulmonary artery, A – aorta, AD – descending aorta

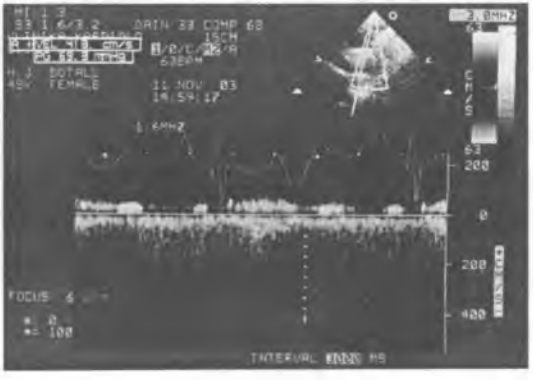

Fig. 3. Transthoracic echocardiogram, suprasternal view, colour Doppler examination of the continuous wave, the continuous flow to the descending aorta visible below the zero line, max. speed 4.18 m/s.; A – aortic arch, AD – descending aorta, RPA – right pulmonary artery

pressure and ECG on the examination day. In two cases a beta-blocker was used to optimize the heart action (oral Metocard, 25 mg, 1.5 hour before the examination). The pre-contrast scanning with ECG gating by means of the axial method in 2.5-mm slices and post-contrast spiral scanning with collimation – 1.25 mm and table feed – 3.5 mm/s were conducted. In two patients the examination was performed in two phases – the first one using the spiral technique in 1.25-mm slices, 0.6-mm overlapping and 13.5 table feed covered the whole lungs and was used to evaluate the branches of the pulmonary arteries (scan delay 10 and 12 seconds). The second stage with ECG gating performed after 10s was confined to the heart region and aortic arch. The optimal scanning time was based on the density measurements taken by the cine option after the administration of the test bolus technique (20 ml, 4 ml/s). The contrast medium (Ultravist 370 Schering) was administered with the power injector in the dose of 130–150 ml with the speed of 4 ml/s. After the examination the native scans were comprehensively assessed – the series of primary reconstructions in the 70% R-R phase and secondary reconstructions in the 15–85% phase in 10% intervals. The analysis of changes was based on 2D multiplanar reconstructions (frontal, sagittal, axial oblique and curved with max. intensity projections, 3D volume rendering images and virtual angioscopy). Additionally, the advanced vessel analysis was used in measurements. In all the patients the quality of CT imaging was found satisfactory and small motor artifacts mainly concerned the right ventricle. In all the cases, PDA of a typical, right-sided localization was observed (Fig. 4, 5). The duct's diameter was 5–11mm and its length 6–10mm. In the male patient the region of calcifications of the aortic wall (Fig. 6) was found in the ostium of the duct's (5, 9). The vessels of the pulmonary circulation in our patients were slightly dilated while the symptoms of severe chronic pulmonary hypertension were not observed. The cavities of the left atrium and left ventricle were slightly dilated. In two patients hypertrophy of the right ventricular muscle was found. It should be stressed that both the arterial duct and changes in the pulmonary circulation were detectable in the vascular option with ECG gating as well as typical spiral technique with bigger pitch, however, the quality of images with ECG gating was significantly higher.

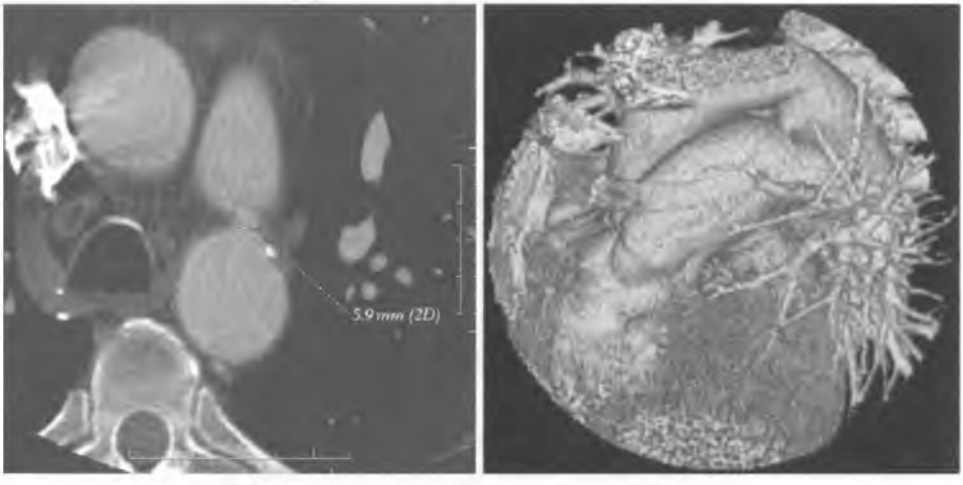

Fig. 4. MSCT in oblique MPR-view (a) and in 3D volume rendering view (b), 7 mm in diameter PDA

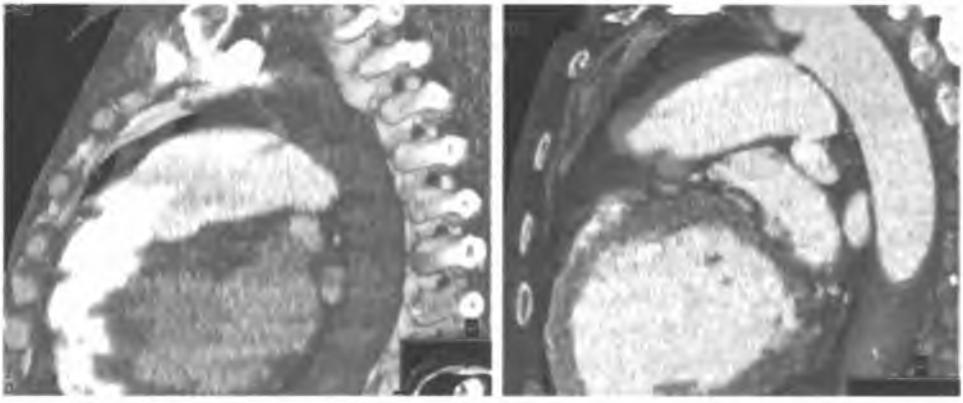

Fig. 5. MSCT – PDA visible in the early (a) and late (b) arterial phase

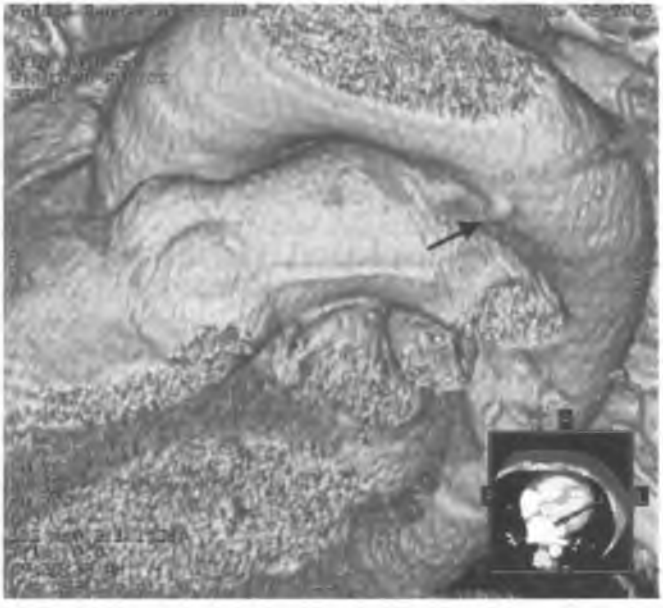

Fig. 6. MSCT – calcifications of the aortal wall in the region of PDA ostium visible in 3D reconstruction

On the basis of the clinical evaluation, echocardiographic findings demonstrating that the shunt flow is the left-right one (in one case also observed on CT), slightly elevated pressure in the pulmonary artery and precise morphological assessment of changes in MSCT, all the patients were qualified for surgical treatment.

DISCUSSION

Despite the lack of subjective symptoms, the diagnosis of even mild PDA is clinically significant since the patients with PDA are at higher risk of endocarditis (the frequency of 0.45/ year); moreover,

5% of them develop Eisenmenger's reaction (2, 8, 9). The rule presently used is that all artial ducts should be closed unless the resistant pulmonary hypertension is observed (6). The results of surgical treatment and interventional percutaneous procedures are extremely good. Although PDA in children may be easily visualized in echocardiography, in adults it is rarely possible and the diagnosis is based on the presence of the pathological flow between the aorta and pulmonary trunk (3, 4, 9, 10). Another, non-invasive diagnostic method used in patients suspected of having PDA is MRI, advantage of which is the lack of patients« exposure to ionizing radiation. The value of this method in older children and adults is stressed by many authors in spite of the fact that it is time-consuming and its resolution concerning the vascular structures of small, 1–2-mm diameters is lower. However, the method is limited by worse possibilities to evaluate calcifications, which is relevant on choosing the method of treatment (with massive calcifications, the percutaneous transluminal procedures are preferable). In the recent years, the dynamic development of various heart MRI techniques is observed, yet the availability of this method is still limited (5). In Poland, MRI of the heart is conducted only in few centres and the number of examinations is highly reduced by administrative regulations. Moreover, it seems that due to its universality and short time needed to perform it as well as very high resolution, MSCT has been widely recognized by clinicians and is gradually becoming the diagnostic standard with the number of available devices rapidly increasing. Our centre performs almost 400 heart examinations a year and the number of patients and the kind of clinical indications (often including not only the coronary diseases but also other types of cardiovascular disorders) are constantly increasing. The possibilities of MSCT were also appreciated by clinicians in our third case in which neither the clinical picture nor echocardiography were sufficient to diagnose the type of heart defect. The CT examination, particularly the two-stage one performed in two patients, provided precise evaluation of the duct's morphology – its dimensions and course in relation to the trachea and facilitated simultaneous comprehensive assessment of the image of the aorta, pulmonary artery and pulmonary veins with their central and peripheral branches as well as pulmonary parenchyma. The visualization of heart cavities in various phases of the action circle and the anatomy of the coronary vessels enabled us to eliminate co-existing developmental anomalies and pathological changes. It is worth stressing that although MSCT is not the basic examination on evaluating PDA and the literature data concerning this issue are very sparse, the radiologist performing MSCT must be familiar with the picture of changes in the course of PDA described above as the defect is not infrequent in adults, usually asymptomatic and therefore is likely to be incidentally diagnosed in patients examined due to other reasons (5).

In conclusion, it should be stated that the diagnosis of PDA in adults should be based on the detection of machinery murmur and on echocardiography with Doppler. In the authors' opinion, apart from MRI which is still mostly unavailable, another valuable non-invasive method may be MSCT, especially with retrospective ECG gating which highly precisely visualizes the anatomical details of the duct and remaining cardio-vascular structures of the thorax and facilitates the PDA diagnosis when echocardiography has failed.

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SUMMARY

The authors presented three cases of patent *ductus arteriosus* (PDA) diagnosed in adulthood as an isolated defect in patients without clinical signs using echocardiography and MSCT. The paper discusses extensively the techniques of both examinations, the use of various reconstructive algorithms in MSCT and possible visualization of the arterial duct as well as concomitant changes in the vessels and heart. MSCT, although not used in PDA diagnosis to date, was found to be a valuable non-invasive diagnostic method of detecting this defect in patients in whom echocardiography failed or in examinations conducted due to non-cardiological clinical indications.

Przetrwały przewód Botalla u dorosłych – obraz w echokardiografii i wielorzędowej tomografii komputerowej

Autorzy przedstawili trzy przypadki przetrwałego przewodu tętniczego, zdiagnozowane za pomocą echokardiografii i wielorzędowej tomografii komputerowej jako izolowana wada w wieku dorosłym u pacjentów bez objawów klinicznych. W pracy szczegółowo omówiono technikę obu typów badań, wykorzystanie różnego typu algorytmów rekonstrukcyjnych w MSCT oraz możliwości wizualizacji przewodu tętniczego oraz współistniejących zmian w naczyniach i sercu. Stwierdzono, że MSCT, choć dotychczas niewykorzystywana w diagnostyce PDA, może stanowić wartościową nieinwazyjną metodę diagnostyki tej wady u chorych, u których na rozpoznanie nie pozwoliła echokardiografia lub w przypadkach badań wykonywanych z niekardiologicznych wskazań klinicznych.