IMPORTANCE OF TURBULENCE OF THE BLOOD FLOW IN THE GENESIS OF THE CARDIAC BRUIT

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UDC 616.12-008.28-02

Analysis of the phonocardiograms of patients with congenital cardiac defects accompanied by pathological currents of blood showed how the intensity of the cardiac bruit depends on the Reynolds number. The Reynolds number was calculated for patients with patent ductus arteriosus for systole and diastole separately, and also for patients with a ventricular septal defect for systole. If the values of the Reynolds number were less than 1200, there was a low-amplitude bruit, a bruit of average amplitude corresponded to a Reynolds number of between 1200 and 1800, and a high-amplitude cardiac bruit was recorded if the Reynolds number was higher than 1800. If the Reynolds number was less than 800, no bruit was recorded.

During the last century, in an attempt to discover the mechanism of the formation of the cardiac bruit, some investigators associated its genesis with the conditions of movement of the blood [2, 5, 6, 7, 11].

In the last two decades, the development of phonocardiographs with various systems of sound filtration have enabled a theory of the cardiac bruit to be developed [1, 3, 9, 10]. An important role in the formation of the cardiac bruit is played by the velocity of the blood flow in the particular segment of the vascular system.

At the end of last century, Reynolds [12] showed that the transition from a laminar type of movement of a fluid into a turbulent type is determined by the ratio of the product of the mean velocity of the fluid in the tube and its radius and the kinematic viscosity of the fluid. This ratio was called the Reynolds criterion or number. At the present time, the Reynolds number is taken to be 2300, and it is assumed that for values less than 2300 the blood flow is always laminar, while for various above 2300 the flow is turbulent [4].

The mean critical number for blood has been found to be 970 ± 80 [8]. In other words, if the Reynolds number is below this value the movement of the blood will be laminar, while if the Reynolds number is higher than this critical value the blood flow is turbulent.

In the investigation described below the cardiac bruit was analyzed and compared with the values of the Reynolds number.

EXPERIMENTAL METHOD

During a surgical operation for patent ductus arteriosus on 150 patients, the pressure was recorded inside the aorta and pulmonary artery, and in 152 patients with a ventricular septal defect the pressure was recorded in the right and left ventricles. The linear velocity of the movement of the blood through the patent ductus arteriosus and through the ventricular septal defect was calculated from the pressure gradient. In addition, during the operation the area of cross-section of the pathological communication was measured. Using the values of the linear velocity of the blood flow and the area of cross section of the

Department of Functional Diagnosis, M. F. Vladimirskii, Moscow Regional Clinical Research Institute. (Presented by Academician V. V. Parin.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 72, No. 10, pp. 50-51, October, 1971. Original article submitted February 16, 1971.

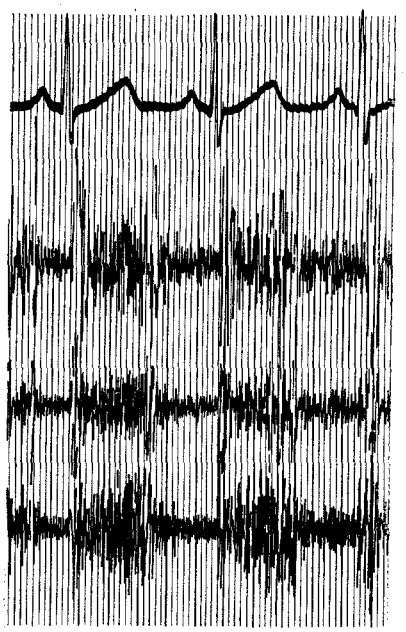

Fig. 1. Phonocardiogram of patient U. E., with patent ductus arteriosus (explanation in text).

TABLE 1. Comparison of Intensity of the Cardiac Bruit with the Reynolds Number for Patients with Patent Ductus Arteriosus (PDA) and Ventricular Septal Defect (VSD)

Reynold's number	Cardiac bruit					
	low-amplitude		average amplitude		high-amplitude	
	PDA	VSD	PDA	VSD	PDA	VSD
800—1000	11	—	—	—	—	—
1001—1200	25	—	—	—	—	—
1201—1400	—	—	89	5	—	—
1401—1600	—	—	76	7	—	—
1601—1800	—	—	63	18	—	—
1801—2000	—	—	—	—	19	39
2001—3000	—	—	—	—	11	57
3001 or more	—	—	—	—	6	26

duct, and taking the viscosity of blood to be constant, the Reynolds number was calculated (for men and women separately) for the flow of blood shunted through the pathological communication.

Before operative closure of the ventricular septal defect and the patent ductus arteriosus, the phonocardiogram was recorded in all patients by means of a type 42-B Mingograph or EKG5-01 apparatus with the FKG-01 phonocardiograph.

In patients with patent ductus arteriosus, the Reynolds number was calculated separately for systole and for diastole, and for patients with the ventricular septal defect, it was calculated for systole.

EXPERIMENTAL RESULTS AND DISCUSSION

The results given in Table 1 show that if the value of Reynolds number did not exceed 1200, a low-amplitude cardiac bruit was present. If the Reynolds number was higher than 1800, a high-amplitude bruit was recorded, while a bruit of average amplitude corresponded to a Reynolds number of between 1200 and 1800.

As an illustration, the phonocardiogram of a patient with patent ductus arteriosus, in whom a loud systolic bruit was heard, although the diastolic bruit was almost completely absent, is shown in Fig. 1. The Reynolds number for this patient was 1262 in systole, i.e., above the critical level for blood, while in diastole it was 890, i.e., at the lower limit of the critical value.

The investigation thus showed that the amplitude of the cardiac bruit recorded on the phonocardiogram is related to the value of the Reynolds number. The onset of a cardiac bruit is due to turbulence of Reynolds number. The onset of a cardiac bruit is due to turbulence of the blood flow taking place when blood is shunted through the pathological communication.

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