Normal First Heart Sounds with Nonfunctional Tricuspid Valve or Right Ventricle

Clinical and Experimental Evidence

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SUMMARY

A case of Ebstein’s malformation of the tricuspid valve with persistent foramen secundum and right bundle-branch block is presented. Preoperative tracings revealed three distinct components of the first sound with normal intervals between them. After resection of a single floating tricuspid leaflet, closure of the septal defect, and insertion of a Starr-Edwards valve, the phonocardiogram again showed three normal components of the first heart sound, followed by a loud closing snap of the prosthetic tricuspid valve. This case demonstrates the occurrence of the three normal components of the first heart sound independently of right ventricular contraction and of tricuspid closure or tensing. In five dogs left ventricular phonocardiograms, made after right heart bypass and destruction of the free ventricular wall, revealed three normal components of the first heart sounds in three animals, and of the first two components, separated by normal intervals in two others. These experiments exclude any participation of the right ventricle or tricuspid valve in the mechanism of origin of the first heart sound. The authors conclude that the three normal components of the first heart sound are of left-sided origin and that the designation “tricuspid” for the second component should be abandoned.

Additional Indexing Words:
Phonocardiography

Wiggers suggested that the views generally propounded for the origin of the heart sounds were decided in society committees and subsequently became so ingrained as to be extremely resistant to experimental or factual questioning. Thus, it was natural for Leatham in his pioneering work to ascribe the first two major components of the first sound to “mitral” and “tricuspid” closure, respectively. Despite much evidence demonstrating three components of the first heart sound, all of left heart origin, the older views continue to resist the evidence for their dynamic origin.

The study of a patient with two congenitally absent tricuspid leaflets suggested a new experimental approach and resulted in the data reported herein.

Report of Case

The patient, a 40-year-old white male, while in the Army in 1952, developed exertional dyspnea and was found to have cardiomegaly. Dismissed from the Army, he has worked since as a mechanic. Occasional exertional dyspnea and precordial pain have occurred 1 or 2 hours after severe exertion for several years and have become more frequent in the last 2 years. He was...
subjected to cardiac catheterization at Fitzsimons General Hospital, where the diagnosis of Ebstein's disease was made.

Physical examination on January 12, 1966, disclosed that there was no cyanosis, that the arterial pulses were normal, and that the blood pressure was normal. Large presystolic pulsations were observed in the jugular veins. The cardiac apex beat was in the sixth left intercostal space at the anterior axillary line. The first sound was of poor intensity. The second sound was widely split. Both a third and a fourth sound were audible; they were prolonged and had a "scratchy" quality. A pansystolic blowing murmur was audible at the apex.

**Electrocardiogram**

A grade 1 atrioventricular block (P-R = 0.32), right bundle-branch block, and intraventricular block (QRS = 0.20) were evident (fig. 1).

**Phonocardiogram**

The tracing recorded at and within the apex showed three components of the first sound; the first started at the time of the R wave, the second occurred 50 msec later, and the third occurred

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**Figure 1**

Electrocardiogram of clinical case of Ebstein's disease. Grade 1 atrioventricular block, right bundle-branch block, and intraventricular block.
was closed. The tricuspid valve consisted of two rudimentary leaflets, inserted very low in the right ventricle, and a third large, floating leaflet inserted at the level of the tricuspid ring. The latter was resected, and a no. 5 Starr-Edwards valve was sutured above the level of the coronary sinus. The clinical course thereafter was uneventful, and the patient had a normal convalescence.

**Postoperative Study**

Auscultation revealed a normal first sound, a split second sound, and loud clicking sounds of the prosthetic tricuspid valve. The electrocardiogram was unchanged (grade 1 atrioventricular block and right bundle-branch block). The phonocardiogram disclosed that the first sound still consisted of three components as follows: the first immediately after the R wave of the electrocardiogram, the second 55 msec later, and the third, 90 msec from the first. Following this triple complex, there was a large, high-frequency sound, obviously caused by closure of the prosthetic tricuspid valve and occurring 160 msec after the beginning of the first sound. The second sound showed two components, the aortic and the pulmonary, separated by an interval of 80 msec. Following these, there was a small sound (possibly a left-sided opening sound) and then, 70 msec after the pulmonary component of the second sound, a large high-frequency sound, obviously an opening snap of the prosthetic tricuspid valve (fig. 4).

**Discussion of the Clinical Case**

This case offers several documented facts which are of importance for the study of the first heart sound. The two major points that should be kept in mind are the following: (a) only one leaflet of the tricuspid valve was present (surgical observation), so that no closure of the valve could take place; and (b) on account of right bundle-branch block and intraventricular block, right ventricular pressure rose 60 msec after the left (catheterization), so that any event related to right ventricular contraction would have followed left ventricular events after a similar delay. In spite of this, the first heart sound had three components recorded, both externally and within the left ventricle, separated by normal intervals, and resembling in configuration the description of the first sound given by Di Bartolo and associates, and Luisada from our group, as well as by van Bogaert and co-workers. This is,

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**Figure 2**

*Same case as figure 1. Phonoangiogram at apex, carotid tracing, and electrocardiogram. Three components of the first sound (a, b, and c) are present; the third component falls during the rise of the arterial pulse. Time lines = 0.04 sec; recording at 100 mm/sec.*

90 msec after the first, at the time of the rise of the carotid pulse (fig. 2). Other tracings revealed both a presystolic and an early-diastolic complex, each lasting about 100 msec.

**Cardiac Catheterization**

The essential findings were the following. Right ventricular pressure was normal. However, the pressure pattern of the right atrium was similar to that of the right ventricle indicating a wide communication between the two chambers in systole. The interval between left and right ventricular pressure rises was 160 msec. Cardiac output was 3.6 L per minute. A left-to-right shunt of 3.6 L per minute at the atrial level was demonstrated. An intracardiac phonocardiogram of the left ventricle showed that three components of the first sound were present in this chamber (fig. 3).

**Angiocardiogram**

This method supplied evidence of tricuspid insufficiency. A large, deformed right ventricle with an indentation in its mid-inferior aspect was noted. The pulmonary vessels were large but the vascular markings were only moderately increased.

The patient was operated on by Dr. H. Najafi on February 4, 1966. The atrial septal defect
Therefore, a conclusive demonstration that the three components had a left-sided origin.

A further demonstration was given by the postoperative findings. After removal of the single tricuspid leaflet and insertion of a prosthetic valve, the first sound still presented three components with the same intervals as before surgery. On the other hand, the prosthetic tricuspid valve gave a loud closing click which occurred 160 msec after the first component of the first sound, thus giving evidence of the delayed timing of right ventricular contraction. This long delay was related to both the right bundle-branch block and the weakness of the right ventricle, as well as the inertia of the prosthetic valve.

**Experimental Study**

This study consisted of obtaining in dogs a complete bypass of the right heart plus a large opening in the free right ventricular wall in order to eliminate any possibility of the right ventricle or tricuspid valve's contributing to the first heart sound. The technique employed proved successful in five experiments (fig. 5).

**Method**

The animals were anesthetized with intravenous sodium pentobarbital (12.5 mg/kg)
FIRST HEART SOUNDS

Same case as figure 1 after surgical repair. The phonocardiograms of apex (6L12) and left base (2L3) still show three normal components of the first heart sound (a, b, and c) separated by normal intervals; these are followed by a closing snap of the prosthetic tricuspid valve (TC). The two lower tracings are the jugular tracing and the electrocardiogram. Time lines = 0.04 sec; recording at 100 mm/sec.

Figure 4

Procedure for right heart bypass in the dog.

Minutes after premedication with subcutaneous morphine sulfate (10 mg/kg). Following recording of an external phonocardiogram, the chest of the dog was opened by a midsternal incision, and a second phonocardiogram obtained from within the left ventricle, together with a left ventricular pressure tracing, by means of an Alard-Laurens (Dallons-Telco) micromanometer. Then the azygos vein was ligated, the two venae cavae were cannulated, and their combined output was introduced by a Sigma-motor pump into the main pulmonary artery, which had been previously cannulated. As soon as the flow became uniform, a large incision was made in the free wall of the right ventricle. This had the purpose of preventing any rise of pressure in the right ventricle and of allowing the blood of the coronary sinus to flow into the chest cavity; from here, it was continuously aspirated and was added to the caval blood for pulmonary perfusion. At this time, the electrocardiogram, the pressure tracing of the left ventricle, and the left ventricular intracardiac phonocardiogram were again recorded.
Results

The tracing presented in figure 6A shows the three normal components of the first heart sound with closed chest. The interval between a and b is 35 msec; that between a and c is 60 msec. The subsequent sections (fig. 6B and C) are examples of cardiac cycles during right heart bypass in the same animal; the intervals between a and b, and a and c are the same as previously.

Figure 7 shows the heart sounds recorded in two other successful experiments during right heart bypass. The first (fig. 7A) shows three distinct components (a, b, and c) separated, respectively, by 40 (a to b) and 75 (a to c) msec. The second tracing (fig. 7B) shows a and b separated by 40 msec.

Discussion

In spite of the unavoidable alteration of left ventricular dynamics caused by the experimental procedure, the existence of either the first two (a and b) or all three components (a, b, and c) within the left ventricle when no right ventricular rise of pressure can occur unequivocally demonstrates the left-sided origin of the three components of the first heart sound.

References


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Figure 7
Experiments in two dogs with right heart bypass. Tracings from above down are electrocardiogram (atrial flutter is present), left ventricular intracardiac phonocardiogram, and left ventricular pressure tracing. Time lines = 0.04 sec; recording at 200 mm/sec. (A) Three components (a, b, and c) of the first heart sound are recorded from the left ventricle. (B) In another experiment, two components (a and b) of the first heart sound are recorded from the left ventricle.
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