The Initial Vibrations of the First Heart Sound

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The major component of the normal first heart sound is that due to valvular closure. Preceding this there occur low frequency, low amplitude vibrations commonly attributed to auricular systole. It has been shown in this study that such vibrations appear invariably even though the auricles are fibrillating, and in heart block when auricular systole is widely separated from ventricular systole. It is concluded that the onset of ventricular contraction itself causes these vibrations through mechanisms unrelated to auricular contraction, and prior to the valvular component.

The HEART sounds, suitably recorded, yield most important information on the sequence of mechanical events that comprise the cardiac cycle. It is essential then that each component group of vibrations of the heart sounds be exactly attributed to the precise mechanical event leading to its production. This paper deals with the first component of the first heart sound and its probable mode of origin, that is, with those few vibrations of low frequency and low amplitude that initiate the first sound.

The first heart sound is composed of vibrations of diverse frequency and amplitude occurring at the onset of ventricular systole. Caeiro and Orias, on the basis of a phonocardiographic study of 20 healthy medical students, divided these vibrations into four component groups. The first of these groups they assumed to be the terminal vibrations associated with auricular systole and termed it the auricular component of the first heart sound. These low frequency, low amplitude vibrations bear a temporal relationship to the P wave of the simultaneously recorded electrocardiogram that is consistent with that of the auricular sound when this is dissociated from ventricular contraction, as in complete or partial heart block. In a phonocardiographic analysis of the normal heart sounds by two of us (Rappaport and Sprague) this interpretation of the origin of the first component of the first sound was accepted; Luisada, Mendoza and Alimurung also are in agreement. However, on the basis of further observations, as described below, we feel that a modification of this interpretation is necessary.

Phonocardiograms recorded at the cardiac apex of 28 patients with auricular fibrillation and 2 with complete heart block were studied with respect to the initial vibrations of the first sound. All recordings were made with a Sanborn Tribeam phonocardiograph. The electrocardiogram and apex cardiogram were recorded simultaneously for reference. Vibrations of low frequency and low amplitude were present at the beginning of the first heart sound in all of the cases with auricular fibrillation (fig. 1, bottom) and in the 2 cases of complete heart block, even when auricular systole preceded ventricular systole by an interval sufficient for the auricular sound to have expended itself (fig. 1, top). The average duration of this group of vibrations was 0.05 second, with a range of 0.03 to 0.06 second, and the average frequency was 35 cycles per second, with a range of 20 to 60 double vibrations.

These values must be interpreted in the light of the technic employed in making the records as described by Rappaport and Sprague in a previous communication: the stethoscopic and logarithmic microphones were employed in all the cases studied. Although the stethoscopic microphone registers low frequency vibrations more efficiently, the initial first heart sound

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vibrations, however, lie within the frequency range of human audibility and are well registered with the logarithmic microphone (fig. 1). They start after the beginning of the QRS complex in the electrocardiogram, which is recorded simultaneously, and with or shortly after the beginning of the rise of the first positive systolic wave in the apex cardiogram.

The main vibrations of the first sound that form its second component, and if we accept, as the evidence would indicate, that the beginning of the main vibrations (that is, second component) of the first sound marks closure of the auriculoventricular valves, then the initial low frequency, low amplitude vibrations (that is, first component) occur during the pre-isometric phase of ventricular systole. Again, the initial group of vibrations coincides with, or follows immediately after, the beginning of the systolic impulse of the apex cardiogram. These observations are consistent with the earlier suggestion of Wiggers that "when the ventricle begins its contraction, its position changes slightly. This may produce the first feeble vibrations of the first sound." More recently this author has accepted the explanation of Caeiro and Orias of the atrial origin of these pre-isometric vibrations of the first heart sound. However, he pointed out that while these

**DISCUSSION**

There is no question that vibrations of auricular origin can frequently be recognized in phonocardiograms, following the P wave and preceding the onset of the QRS complex, and such vibrations maintain their time relationship with the P wave when the P-R interval changes. However, the initial low frequency, low amplitude vibrations of the first sound that succeed the beginning of the QRS do not bear such relationship to auricular systole, occurring even in its absence. On the other hand, they do show a constant relationship to the

![Fig. 1. Phonocardiograms recorded with logarithmic microphone. Top: Complete heart block. Heart sounds at apex with apex cardiogram and electrocardiogram. AS = auricular sound. SM = systolic murmur. The numeral 1 refers to the first component of the first heart sound. Bottom: Auricular fibrillation. Heart sounds at apex with jugular pulse and electrocardiogram. The numeral 1 refers to the first component of the first heart sound.]
sounds begin definitely before the rise of intraventricular pressure, they may continue slightly into the early period of rising tension and those vibrations which do continue represent initial vibrations of the first ventricular sound rather than the termination of the atrial sound.

It is apparent that the vibrations we have described occur with the beginning of ventricular contraction and truly constitute the first component of the first heart sound. They are associated with the development of tension in the ventricular muscle fibers which initiates the rise of intraventricular pressure. Since these vibrations occur before the main group associated with closure of the A-V valves, they must be due directly to slight shortening of the muscle fibers initiating the rise of intraventricular pressure, or to the taking up of slack in the valve leaflets before they become opposed, or, conceivably, to movement of the heart within the thorax.

We feel that in the majority of instances vibrations of atrial origin, which precede the beginning of ventricular contraction, can and should be differentiated from the first heart sound and that the term "first component of the first heart sound" should include only the initial low frequency vibrations associated with the beginning of ventricular systole.

CONCLUSION

1. An initial group of low frequency, low amplitude vibrations of the first heart sound can be recorded in the absence of effective auricular contraction.

2. The evidence indicates that they are produced during the pre-isometric phase of ventricular systole.

3. In normal individuals the initial vibrations of the first heart sound are related to the main vibrations of the first sound rather than to auricular systole, suggesting that they are of the same origin as those that occur in the absence of pertinent auricular contraction.

4. These findings do not apply to the auricular origin of those vibrations that precede the beginning of the QRS or vary with the P-R interval.

REFERENCES

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