Third Heart Sound: Possible Role of Pericardium in its Production

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The disappearance of a third heart sound in a case of calcific pericarditis after surgery together with a quantitative study of the time and frequency relations of the third heart sound in 70 cases suggests that the tensing of the pericardium is a factor in its production. The frequency characteristics of the third heart sound are such that it may be identified in the presence of a diastolic murmur.

The opportunity to study a case of calcific pericarditis with a prominent third heart sound by a quantitative cardiodynamic technique previously described, and the disappearance of the third heart sound after surgical therapy furnished additional information on the possible mechanism of third heart sound production. This data is supplemented by an analysis of time and vibrational characteristics of 70 third heart sound records from our own series.

RESULTS

Fig. 1 and 2 show the heart vibrations 1 day before and 14 days after surgery. They are mounted in proper relation to the six foot projections of the heart outline, the radiographs being taken in the same position and stage of respiration as used for the electrostethograph recordings. In the original charts the heart size is enlarged three times, and the electrostethograph speed is 200 mm. per second, i.e. sufficient to record frequencies up to 1,000 cycles per second. Each electrostethographic strip is one cycle in length, the left border corresponds to the location of the microphone, and the heavy vertical line marks the beginning of the Q wave of the electrocardiograph lead II. In the method used three electrostethographs and the electrocardiograph are recorded simultaneously and the microphones are adjusted to the same sensitivity in dynes per square centimeter. The coordinates are rectangular and labelled in centimeters; the midsternal angle has the value of x equal to 15 cm. and y equal to 0 cm.*

The prominent third sound is distributed widely over the precordium in fig. 1 which corresponds closely with the record made 64 days earlier. This in our experience is an unusually wide distribution of the third sound which ordinarily is confined to the left side of the chest and usually maximal in the region of the left border. In contrast fig. 2 shows only a few remnants of the third heart sound and these are confined to the upper and left portions of the precordium.

Fig. 3 is a scattergraph of 70 cases from our collection comprising normal and diseased hearts from the ages of 2 to 70 years. The dots mark the time interval between the onset of the Q wave of the electrocardiograph and the second (Q-S2) and the third sound (Q-S3) plotted against the time of the cardiac cycle.

In the case reported the Q-S3 time before surgery was .43 second as compared with 0.47 second from the curve in fig. 3. After surgery, the actual time was 0.55 second as compared with a predicted 0.51 second. In another pa-

* The records in fig. 1 and 2 were recorded at 7 dynes per square centimeter per centimeter of deflection on the original record. The frequency-output graph of the equipment used is omitted to conserve space but can be constructed from the following coordinates; 100% transmission at 500 cycles, 90% at 340, 80% at 240, 30% at 90, 20% at 72 and 10% at 53 cycles.

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FIG. 1. HS 677. Before operation. Age 58, female with progressive dyspnea for 15 months, auricular fibrillation for 6 months, and leg edema for 3 months. Transverse diameter of heart within normal limits. The third heart sound is distributed throughout the precordial area even including the upper right substernal area.

tient who died a few days after operation the Q-S3 time was 0.40 as compared with a predicted 0.55 second. In a few cases of published curves of calcific pericarditis it was practical to measure the point of maximum dip in the right ventricular pressure curves and these indicate (1) that the point of maximum dip corresponds closely to the Q-S3 times of our curves, and (2) shows the same shortening in timing before operation and in one case the return to normal afterwards. Eliasch, Lagerlöf and Werko's case illustrated in fig. 1 of their article shows a value of 0.40 second to the point of maximum dip as compared with 0.55 second for our curve prediction.\(^{3}\) Hansen, Eskildsen and Gotzsche's case G. L. K. f. Vp. 714/48 shows a time of 0.44 second as compared with 0.55 second. Their case N. C. L. m. 1118/49 showed 0.28 second as compared with 0.44 second from our curve in fig. 3. After operation these measurements were changed to 0.47 and 0.51 second as compared with 0.48 and 0.49 seconds from our curve in figure 3. Their case P. S. m. 860/48 which had very slight symptoms of a constrictive pericarditis but which had a ventricular pressure curve supporting the diagnosis had values of .44 as compared with 0.48 and another cycle 0.42 as compared with 0.48 second.\(^{8}\) Phonocardiograms were not included in these illustrations but in several cases a third heart sound or a pericardial click was noted.

**DISCUSSION**

Studies on the third heart sound are well summarized by Orias and Braun-Menendez. That it occurs at or near the completion of the filling phase seems well established and Sloan and Wishart have demonstrated excellent phonocardiograms showing its intensification.
with rapid filling. The hampering effect of a constrictive pericarditis upon diastolic filling has been accepted for years. Our data before and after operation suggest that the third sound is produced by the pericardium acting as a limiting factor in diastolic filling. The shortening of the Q-S3 interval noted in our two cases and its lengthening after operation are in conformity with this suggestion. The similar shortening in the time of the point of maximum dip in the cases of Eliasch, Lagerlöf and Werko and Hansen, Eskildsen and Gotzche and its return to essentially normal value in the one case of the latter group after operation is also in conformity.

An analysis of the waveform of the third heart sound gives further evidence of its origin. Fig. 4 illustrates 24 third sound records made by a frequency separation technique in which three frequency channels are simultaneously

**Fig. 2.** HS 677. After operation. The only remnants of a third heart sound are at the level of the second rib in the midline and 5 cm. to the left.

**Fig. 3.** The crossed circles are Case HS 677 before surgery and the clear large circles are after surgery. Plotting Q-S3 against Q-S2 results in a symmetrical distribution about a straight line indicating that the third heart sound is not adventitious but related to the cardiac cycle. Plot on arithmetic probability paper shows that the data is homogenous except for a few observations with long durations.
recorded so that the band from 10 to 1000 cycles per second is recorded. The sounds illustrated in fig. 4 are from the middle channel but an analysis of all three channels show that significant lower frequencies are not present and that high frequency elements i.e. over 150 cycles are quite uncommon in third heart sounds as recorded through the precordium.

It will be noted that the third sound is characterized by (1) a sudden onset, (2) one or two cycles and rarely more, (3) the frequency is estimated to vary between 22 and 42 cycles per second, with over half of the readings between 28 and 36 cycles, (4) a definite tendency for the first wave to be the largest with a rapidly progressing decrement in amplitude. From a vibrational standpoint these characteristics resemble the tensing of a member of limited elasticity such as a pericardial lining and do not resemble what one would expect from turbulent flow or the flapping of a valve leaflet. Furthermore the conformity of the Q-S3 time to the curve illustrated in figure 3 and its relation to other timing curves of components of the cardiac cycle indicate that when the third sound occurs, it appears to be an integral part of the cardiac cycle and not an adventitious sound.

The characteristics described for the third heart sound permit its recognition in the presence of murmurs. Since the third sound is associated with rapid filling its identification in the presence of a diastolic murmur has informational value. Fig. 5 illustrates a third sound in the presence of a murmur due to aortic regurgitation. This identification, as in fig. 5, can be greatly aided by using low frequency band pass amplifier systems. However the frequency separation between the third sound and usual aortic regurgitant murmurs is sufficient that critical electronic filtration is unnecessary, and it can be identified by visual inspection using waveform analysis methods developed in conjunction with the aircraft industry.

**Summary**

A widely distributed third heart sound in a case of calcific pericarditis practically disappeared after operation. The time between the Q wave of the electrocardiograph and the beginning of the third heart sound was decreased in two cases of calcific pericarditis before operation and in one case this time was lengthened after operation. The third sound characteristics are: (1) time of onset, (2) sudden onset, (3) the pattern consists of one or two cycles and rarely more, (4) the frequency is estimated to vary between 22 and 42 cycles per second with over half the readings between 28 and 36 cycles, and (5) a definite tendency for the first wave to be the largest with a rapid decrement in amplitude. From a vibrational standpoint these characteristics resemble the tensing of a membrane of limited elasticity.
such as a pericardial lining. These characteristics can be applied to the recognition of a third heart sound in the presence of a diastolic murmur.

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A Therapeutic Note

It has been found that magnesium adenosine triphosphate in doses of 64 to 256 micrograms per minute can cause as large an increase in blood flow in the arm and hand as can histamine or acetylcholine, without any of the uncomfortable local or general reactions of the latter drugs. Large doses of 1000 micrograms or more per minute occasionally cause whealing.

It is suggested that magnesium adenosine triphosphate is superior to histamine or acetylcholine when it is desired to increase blood flow through a limb by intra-arterial infusion of drugs.

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