Physiologic and Physical Factors that Govern the Clinical Appreciation of Cardiac Thrills

By TIMOTHY B. COUNIHAN, M.D., MAURICE B. RAPPAPORT, E.E., AND HOWARD B. SPRAGUE, M.D.

Palpable cardiac thrills have been considered valuable diagnostic findings. The present study indicates that they add little information to that obtained by careful evaluation of auscultatory findings, and that the quality of cardiac murmurs is a much safer guide in diagnosis than are the palpable vibrations produced by the same mechanism.

Corvisart was among the first to mention and interpret palpable thrills over the precordium as a sign of heart disease. Among the signs of constriction of the orifices of the heart, he mentions "a peculiar rushing like water, difficult to describe, appreciable by the hand applied over the precordium." His pupil Laennec observed that, although such vibrations may be detected by the palpatting hand as a thrill, they were much more easily detected by the ear and that in a majority of cases of valvular stenosis it was possible to hear an abnormal noise that could not be felt at all with the hand.* This early recognition of the superiority of hearing over touch in the detection of vibrations might be expected to have led to the complete replacement of palpation by auscultation for the perception of vibratory phenomena. However, palpation remains a routine procedure and the palpable thrill has become a physical sign of such diagnostic importance as sometimes to sway the diagnosis.

We are here reporting a study undertaken in an attempt to rationalize the significance of the palpable precordial thrill as a physical sign in clinical medicine.

Sensory stimulation is aroused as a result of the mechanical contact of the receptor organ with the medium undergoing vibration. The efficiency of detection is directly dependent upon the type of contact or matching impedance as well as the intensity, frequency and the duration of the source vibration with relation to the receptor threshold. Thus, when a cardiac thrill is to be detected with the fingers in the customary clinical manner, all of these factors must obviously play an important role.

The first part of our study therefore was concerned with the quantitative experimental determination of the sensitivity of the fingers to mechanical vibrations of different frequencies under circumstances designed to simulate those of clinical palpation. In the second part of our study, we measured in quantitative physical terms the main frequency and intensity of heart murmurs in a number of patients who had a variety of forms of heart disease. Some of these murmurs were constantly palpable as thrills, some became palpable after special maneuvers were employed and some remained impalpable during the course of the examination. For the three groups, frequency-intensity values were obtained that bore an expected relationship to the threshold of sensitivity of the fingers.

From the accumulated knowledge of the mechanism of production of vibrations in the
-circulatory system on the one hand, and of human sensitivity to vibrations on the other, we are enabled, in the light of the data derived from our experiments, to subject the physical sign of cardiac thrill to critical scrutiny and to evaluate its clinical import more exactly than hitherto.

PART I. THE SENSITIVITY OF THE FINGERS TO MECHANICAL VIBRATIONS

The Nature of Vibration Sensibility

A voluminous literature exists dealing with the sensibility to vibrations. While we do not wish to give a full account of it or to enter the lists of its many controversies, it is necessary to review in brief some pertinent points.*

Eggers' seems to have been responsible for the widespread acceptance of the view that vibrations were a strictly osseous sensation, a view that has since been amply refuted though it is still encountered in recent literature. Von Frey's meticulous studies showed that the vibratory end organ was closely associated and probably identical with the tactile end organ in the skin. Despite Von Frey's apparently convincing studies, Katz's propounded the view that the sensibility to vibrations was a separate modality, "the vibration sense," and the controversy that soon arose about this question is as yet not settled. Geldard, using greatly superior apparatus and scrupulous technic, stimulated two populations of cutaneous spots, the one pressure-sensitive and the other pressure-insensitive, with sinusoidal mechanical vibrations and showed an intimacy of relationship between the pressure-sensitive and the vibration-sensitive spots. He concluded that there was no ground whatever for the postulation of a separate vibratory sense. Subsequent experiments by Echlin and Fessard demonstrated that stretch-receptors in tendons responded to vibratory stimulation; they recorded from the exposed nerves supplying muscles and tendons afferent discharges synchronized to the rate of the stimulating fork. They point out, however, that it remains to be demonstrated that such nerve-impulses arouse sensations of vibration in consciousness.

It would appear that vibrations can be received by end organs in the skin and deep tissues and that those in the skin are very closely associated if not identical with the tactile receptors while those in the deep tissues probably include stretch-receptors.

Determination of the Sensitivity of the Fingers to Mechanical Vibrations

Apparatus. Our apparatus for evaluating the tactile threshold consisted of a loud speaker arrangement which was driven by means of an adjustable frequency sinusoidal oscillator. The magnitude of vibration of that portion of the loud speaker upon which the fingers were applied (the rim suspension) was measured both optically and by means of a strain gage during the application of the fingers. Interposed between the oscillator and the loud speaker was an attenuator which the subject under test was allowed to adjust for threshold sensation.

The oscillator possessed a total distortion content of less than 0.1 per cent and the distortion present at the loud speaker rim suspension was so small as not to be observable in a cathode ray oscilloscope which was connected to the strain gage element located (directly under the fingers) at the rim suspension. The relative movements of the loud speaker were detected by the subject under test as a result of placing the fingers in such position that they simultaneously contacted the stationary and moving portions of the rim suspension. The rim suspension simulated the ribs and the intercostal spaces of a human being reasonably well.

Material and Method. Four physicians trained in cardiology were investigated to determine the sensitivity of their fingers to vibrations of sine wave form. Conditions resembled those of clinical palpation in that each observer was permitted to find the optimal pressure for him at each frequency of stimulus and to use a generous area of contact between the distal ends of the four fingers and the vibrating medium. The actual amplitude of the vibrations was directly measured at this pressure of

* An excellent account of the history of the controversy and an exhaustive bibliography are given by Geldard.16
the observer’s fingers, so that the variable degrees of damping produced by variations in pressure of contact did not interfere with our results. The area of contact was kept about the same for all observers. Thresholds were approached from below only so that fatigue-adaptation effects would not interfere.

Several threshold determinations were made for each subject at the following frequencies: 7, 10, 15, 20, 40, 70, 100, 150, 175, 200, and 300 cycles per second. The mean tactile threshold curve thus obtained and the average human audiogram (after Fletcher) are shown in figure 1 to illustrate the relationship of the finger tactile sensitivity to that of the ear. The great superiority of sensitivity of the ear is obvious throughout this range of frequencies, excepting frequencies below the auditory range (i.e. below about 16 cycles per second) where the ear is deaf and the fingers are responsive. At a frequency of 250 double vibrations for example, a vibration which is just audible must be increased 2500 times or 68 decibels to make it just palpable; at 40 double vibrations an increase of 180 times or 45 decibels is necessary.

It is also apparent from figure 1 that the threshold curves for hearing and feeling have different forms. In fact human hearing imposes approximately a logarithmic frequency response in this range while the finger tactile frequency response approximates a cube function. This latter finding has a marked bearing on the relationship of the loudness of a heart murmur as heard to its intensity as a thrill when palpated, which will be considered in more detail.

Discussion. The results of our determination of the sensibility of the fingers agree in general with those reported in the literature that were obtained with reliable technics and apparatus. Thus Gilmer, using the apparatus devised by Geldard and Gilmer, found the frequency-intensity threshold for the fingertip to be a concave one from 64 to 2600 double vibrations with maximum sensitivity for four observers at 256 cycles per second and for the fifth at 512 cycles per second. Large individual differences occurred. Sitze pfand, using a relatively large contactor against the fingertip, found sensitivity to decrease somewhat at 50 to 75 cycles per second, but to increase from there rapidly at first and later slowly to 700 cycles per second, between the limits of frequency of 15 to 700 cycles per second. Knudsen found maximum sensitivity of the fingertip at about 256 cycles per second in the range 22 to 1600 cycles per second. Périalhou and Piéron found sensitivity to increase rapidly from the single tactile impulse to about 100 cycles per second and slowly from 100 to 250 cycles per second; to decrease slowly from 250 to 400 cycles per second and rapidly thereafter. The initial increase in sensitivity they found to be effectively a function of the cube of frequency when sinusoidal vibrations are employed. Périalhou later reported similar results but found sensitivity of the fingertip to decrease rapidly at about 550 cycles per second.

While our results are in general accord with those just quoted, exact comparison is not to be expected, inasmuch as we were chiefly concerned with conditions that resembled those of clinical palpation. All the above-mentioned investigators measured sensitivity at the fingertip, which is the region of the body surface most sensitive to vibrations, whereas we employed a larger area of the fingers. Gilmer found in this connection that for vibrations of lower frequency the sensitivity of the fingertip was greater with a larger contactor, but for higher frequencies the area of contact was a negligible factor. Again the findings of Cohen and Lindley that thresholds were lowered by increased pressure on the contactor makes it seem likely that this has introduced another point of difference that makes it hazardous to compare our results with those of others who used fixed pressure of the finger on the contactor.

We confined our investigation of frequency-intensity thresholds to an upper limit of 300 double vibrations because this seemed adequate for the range of frequencies of heart murmurs exhibiting a tactile sense. In our series of phonocardiographic analyses of murmurs to be presented, no “fundamental” frequency above this value was encountered. The upper limit of vibration sensibility is unknown;
Knudsen\textsuperscript{11} found about 1600 double vibrations to be the upper limit but thought that with greater amplitudes than he had available 3000 or 4000 cycles per second stimuli would be perceivable. Gilmer\textsuperscript{8} found a sharp cut-off at 2600 cycles per second. Goodfellow\textsuperscript{14} found frequencies of 8192 cycles per second palpable, but his apparatus was imperfect and this figure seems sufficiently out of line to make it questionable. Gault\textsuperscript{17} found vibrations above 2000 double vibrations palpable by 2 deaf subjects.

The lower limit of frequency of sensible vibrations is logically the single stimulus, but some investigators have reported that the distinctive sensation of vibration is not aroused until higher frequency is achieved. Knudsen\textsuperscript{11} thought this point lay between 12 and 18 cycles per second, and Lalanne\textsuperscript{18} and von Stramlick\textsuperscript{19} found 10 cycles per second as the lowest fusion point. The frequency response of our apparatus was not reliable below 7 double vibrations but at this frequency all observers agreed that a sense of vibration was aroused.

The superior sensitivity of the ear at the frequencies investigated has been discussed, excepting frequencies below about 16 to 20 double vibrations. The ear is also superior in its ability to distinguish small changes in frequency: a change of 1 per cent or less is appreciable by hearing while 15 to 30 per cent change is necessary for appreciation by the fingertip (Knudsen). Dunlap\textsuperscript{10} found a 5 per cent difference of frequency appreciable to the tactile sense at frequencies of 420 to 460 double vibrations but often misinterpreted as a change of intensity.

The ability to detect changes of amplitude with the fingertip closely approaches that with the ear. Knudsen\textsuperscript{11} says that the cochlea and tactile nerves can both just barely distinguish a fractional change of amplitude of approximately one tenth at low intensities and one twentieth at high intensities.

Cold decreases the sensitivity to vibrations\textsuperscript{21} as do age\textsuperscript{21, 22} and certain well known neurologic disorders.\textsuperscript{23} Thresholds are subject to occasional variations in the same individual and may exhibit wide divergence in different individuals.

The effects of fatigue have been studied by Wedell and Cummings\textsuperscript{24} who found that sensitivity to vibratory stimuli applied to the palm of the hand was reduced by 5 to 15 decibels after three minutes' continuous stimulation. Kampik\textsuperscript{25} was able to produce complete fatigue of the vibration sensibility after an hour's vibratory stimulation.

**Clinical Application.** The major portion of the energy of heart sounds and murmurs lies well within the frequency band of 7 to 300 cycles per second and their main vibrations will be palpable if they are of sufficient intensity and duration. The vibratory character of the first and second heart sounds is not ordinarily appreciable by palpation though the intensity may be adequate, because the duration of the main frequency components is too short. Exceptionally, however, it may be so appreciated when the heart sounds last abnormally long, as will be seen later in the phonocardiographic analysis of thrills.

The subjective estimate by hearing of the degree of loudness of a murmur will not exactly parallel the estimate of its intensity to palpation, as is evident from the divergence of the curves of threshold of hearing and feeling (fig. 1). The clinical observer can usually predict by auscultation whether a particular murmur will be appreciable as a thrill, but occasionally two murmurs may seem to the ear to be of equal intensity while only one is palpable as a thrill. Indeed, in such case the impalpable murmur may seem the slightly louder to auscultation. For this reason it is psychologically unsound to employ the palpability of murmurs in their auscultatory grading by loudness. The finding of or failure to find a thrill accompanying a loud murmur thus becomes a matter of academic curiosity.

It is necessary to qualify this conclusion by calling attention to the fact that we have employed pure sine waves in our experiments, while murmurs and thrills are 'noises', that is, composed of a medley of tones of various frequencies and intensities. Whether the threshold of sensitivity of the fingers for noises is very different from their threshold for pure tones is not answered by this study.
PART II. THE PHONOCARDIOGRAPHIC ANALYSIS OF MURMURS AND THRILLS

Forty patients who had heart murmurs of loud intensity were selected for study, irrespective of the type of heart disease from which they suffered. All were first examined clinically and note was made of the grade of intensity of the murmurs and of the presence and grade of thrills. The grading of murmurs was made immediately with the palpating hand. In the 40 patients no grade 6 murmur was encountered and no grade 4 thrill. That the palpating finger is a good analyzer of different grades of intensity has already been mentioned and it is possible to recognize with comparative ease four grades of intensity of clinical cardiac thrills.

Phonocardiograms were then taken on each patient and subsequently analyzed to discover

![Graph showing tactile and auditory threshold curves](https://via.placeholder.com/150)

**Fig. 1.** The mean tactile threshold curve of the fingers of 4 physicians trained in cardiology and the mean auditory threshold curve.

cording to the recommendations of Levine\textsuperscript{26} from six possible grades, without regard to the presence or absence of thrills. The thrills were graded under four heads, from the faintly palpable grade 1, which often required special maneuvering of the patient for its detection, to the very marked grade 4, which is a strong purr often palpable through a light garment. The grade 2 thrill was constant and easily felt without arousing a marked sensation, and the grade 3 was of marked intensity and felt immediately through the main frequency and intensity of the murmur vibrations. The apparatus employed was the Sanborn Tribeam. Stethoscopic registration was employed in the phonocardiographic channel.\textsuperscript{27} The large open bell chest-piece having a diameter of 5 cm. and an internal volume of 12.7 cc., was used throughout. After each recording and without altering the amplification of the machine, a standard signal of 500 double vibrations at 90 decibels at source was sent through the channel and recorded so
Fig. 2. Phonocardiograms of case 36. Stethoscopic records with large open bell chest piece, taken at the following areas: (A) apex, (B) aortic area, (C) pulmonary area and (D) left sternal border in the fifth intercostal space. After each recording from the patient the base line of the sound recording channel is registered and then the standard signal of 500 cycles at the same amplification as the patient-record.
### Table 1 - A Comparison of the Clinical Findings with the Quantitative Measurements Obtained by the Phonocardiographic Method

<table>
<thead>
<tr>
<th>NO.</th>
<th>DIAGNOSIS</th>
<th>POST. RESP.</th>
<th>CLINICAL FINDINGS</th>
<th>PCG ANALYSIS</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>MURMUR</td>
<td>INTENSITY</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site</td>
<td>Timing</td>
<td>Grade</td>
</tr>
<tr>
<td>1</td>
<td>Ventricular Septal Defect</td>
<td>3rd</td>
<td>Systolic</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Ventricular Septal Defect</td>
<td>Apex</td>
<td>Systolic</td>
<td>4</td>
<td>1*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PA</td>
<td>Systolic</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3rd</td>
<td>Systolic</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>Luetic Aortitis</td>
<td>Apex</td>
<td>Systolic</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Congenital Aortic Stenosis</td>
<td>Apex</td>
<td>Diastolic</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>Coar Pulmonalis</td>
<td>Apex</td>
<td>Systolic</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Patent Ductus Arteriosus</td>
<td>PA</td>
<td>Systolic</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td>Aortic Stenosis</td>
<td>Apex</td>
<td>Systolic</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Mitral &amp; Aortic Stenosis</td>
<td>Apex</td>
<td>Systolic</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Mitral Regurgitation</td>
<td>LSB</td>
<td>3</td>
<td>0</td>
<td>170</td>
</tr>
<tr>
<td>10</td>
<td>Ventricular Septal Defect</td>
<td>Apex</td>
<td>Diastolic</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>Pulmonary Stenosis</td>
<td>PA</td>
<td>5</td>
<td>2</td>
<td>150</td>
</tr>
<tr>
<td>12</td>
<td>Mitral Regurgitation</td>
<td>Apex</td>
<td>3</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>13</td>
<td>Ventricular Septal Defect</td>
<td>Apex</td>
<td>3</td>
<td>0</td>
<td>125</td>
</tr>
<tr>
<td>14</td>
<td>Mitral Stenosis &amp; Regurg.</td>
<td>Apex</td>
<td>Diastolic</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>15</td>
<td>Aortic Regurg.; Mitral</td>
<td>LSb</td>
<td>Early</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>Mitral Stenosis &amp; Regurg.</td>
<td>Apex</td>
<td>Systolic</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>Ventricular Septal Defect</td>
<td>Apex</td>
<td>5</td>
<td>3</td>
<td>125</td>
</tr>
<tr>
<td>18</td>
<td>Lutembacher's Disease</td>
<td>Apex</td>
<td>Preystolic</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>Mitral Stenosis</td>
<td>Apex</td>
<td>Mid - Diastolic</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>Aortic Stenosis</td>
<td>Apex</td>
<td>Systolic</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>21</td>
<td>Ventricular Septal Defect</td>
<td>Apex</td>
<td>Systolic</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>22</td>
<td>Luetic Aortitis; A.R.</td>
<td>Apex</td>
<td>Systolic</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td>Mitral Regurgitation</td>
<td>Apex</td>
<td>3</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>24</td>
<td>Mitral Stenosis &amp; Regurg.</td>
<td>Apex</td>
<td>Systolic</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td>Mitral Stenosis</td>
<td>Apex</td>
<td>4</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>26</td>
<td>Congenital Heart Disease</td>
<td>Apex</td>
<td>Systolic</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>27</td>
<td>Luetic Aortitis &amp; A.R.</td>
<td>Apex</td>
<td>Early</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>A-V-Anurysm Pulmonary</td>
<td>Apex</td>
<td>Systolic</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>29</td>
<td>Congenital Aortic Stenosis</td>
<td>Apex</td>
<td>Systolic</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>Patent Ductus Arteriosus</td>
<td>Apex</td>
<td>4</td>
<td>1</td>
<td>125</td>
</tr>
<tr>
<td>31</td>
<td>Aortic Stenosis</td>
<td>Apex</td>
<td>Systolic</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>32</td>
<td>Ventrology of Fallot</td>
<td>Apex</td>
<td>4</td>
<td>+</td>
<td>150</td>
</tr>
<tr>
<td>33</td>
<td>Luetic Aortic &amp; Regurg.</td>
<td>Apex</td>
<td>3</td>
<td>0</td>
<td>138</td>
</tr>
<tr>
<td>34</td>
<td>Mitral Sten. &amp; Regurg.</td>
<td>Apex</td>
<td>Presystolic</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Aortic Sten. &amp; Regurg.</td>
<td>Apex</td>
<td>Systolic</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apex</td>
<td>Systolic</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apex</td>
<td>Systolic</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apex</td>
<td>Systolic</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apex</td>
<td>Systolic</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>35</td>
<td>Aortic Stenosis</td>
<td>Apex</td>
<td>Systolic</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>36</td>
<td>Aortic Sten. &amp; Regurg.</td>
<td>Apex</td>
<td>Systolic</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>?Pulmonary Stenosis</td>
<td>Apex</td>
<td>Systolic</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>37</td>
<td>Aortic Regurg.</td>
<td>LSB</td>
<td>3</td>
<td>0</td>
<td>125</td>
</tr>
<tr>
<td>38</td>
<td>Complete Heart Block</td>
<td>Apex</td>
<td>Systolic</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>39</td>
<td>Mitral Stenosis</td>
<td>Apex</td>
<td>Diastolic</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>Pulmonary Stenosis</td>
<td>PA</td>
<td>Systolic</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

722
as to provide a standard against which to measure the intensity of the murmur. An il-
standard signals were measured from the records. The ratio between amplitude of the main

tative record is shown in figure 2. The frequencies and amplitudes of the main vibrations
of the murmurs and the amplitudes of the
deflections of the murmur and the amplitude
of the deflections of the standard signal was cal-
culated in each record and correction made for

---

![Image](http://circ.ahajournals.org/)

**Fig. 3.** A graphic representation of palpable and impalpable thrills as judged clinically with relation to the tactile threshold curve of the fingers of 4 physicians trained in cardiology.

![Image](http://circ.ahajournals.org/)

**Fig. 4.** Stethoscopic phonocardiogram at apex of subject with syphilitic aortitis and aortic regurgitation. The first sound increases in duration and intensity when a ventricular extrasystole occurs. An atrial sound and a systolic murmur are present. Normally no thrill was noted, but with each extrasystole the component vibrations of the first sound became clinically palpable as a brief thrill-like phenomenon superimposed on the thrust of the apex beat.
the stethoscopic response. This derived voltage ratio is directly convertible into decibels, and gives the quantity in decibels by which the murmur exceeds or falls short of the intensity of the standard signal, which in all cases was set at 90 decibels. The decibel scale here employed refers to a reference of zero decibels which represents a sound pressure of 0.0002 dyne per square centimeter applied to the ears.

The data pertaining to the 40 subjects are presented in table 1. It may be seen that in some subjects the intensity of the murmur was significantly altered by certain maneuvers of the patient and that a thrill could sometimes be elicited in certain postures of the patient and not in others. In such cases phonocardiograms were taken in these various positions and in different phases of respiration, and the results are presented. The table also shows the diagnosis of the causative lesion in each case.

In figure 3, the results of phonocardiographic analysis are related to the curve of threshold sensitivity of the fingers as experimentally determined. It may be observed that the palpable murmurs fall on the one side of the threshold curve, while those that were impalpable fall on the other. The deciding factors in determining their palpability, therefore, were the frequency-intensity values of the vibrations and not the nature of the causative lesions.

It will be recalled that in addition to the frequency-intensity value of vibrations, their duration is a determining factor with regard to palpability. The duration of all murmurs studied except one was sufficient to render them palpable as thrills when the frequency and intensity were adequate. From the analysis of phonocardiograms, it became apparent that the intensity and frequency of the first heart sound were often such as to render it probable that their main component vibrations should be palpable as a brief "thrill"; but on clinical palpation no such "thrill" could be felt except in one case in this series. This case seems worthy of individual description.

During the clinical examination of the patient, who had syphilitic aortitis, premature beats were noted occasionally in an otherwise normal rhythm. There were a grade 3 aortic diastolic murmur and a grade 2 systolic murmur at the base of the heart, and a grade 2 systolic murmur at the apex, with no thrill in any region. The apex beat was not unusual and during the regular sinus beats the component vibrations of the first sound were not palpable; but with each premature beat a short thrill became palpable superimposed on the apex beat. On auscultation, the first heart sound was not unusual except that each premature extrasystole was accompanied by an unusually loud and prolonged first sound. A phonocardiogram was taken and the stethoscopic record at the apex is shown in figure 4. When the mechanism is of sinus origin the first sound has a frequency of 100 cycles per second and an amplitude of 107.7 decibels and lasts about 0.12 second; the extrasystolic first sound is of the same frequency but is of greater intensity (115.7 decibels) and of longer duration (0.20 second).

It is not uncommon to find first heart sounds of sinus rhythm equal to those produced by ventricular extrasystoles, but in such a case the duration of the first sound is generally shorter. Therefore the increased duration appears to be the factor which made the vibrations palpable. It is possible that the single impulse of the apex beat may exercise a masking effect upon the higher frequency sound vibrations, but the present case suggests that the chief factor is the brevity of duration of the main frequencies of the normal first sound.

Certain other cases require mention individually.

It will be noted from table 1 that the murmur in case 12 falls into the expected range of palpability, having a main frequency of 100 cycles per second and intensity of 104.5 decibels, but no thrill was felt. The main frequencies here were of this intensity for only 0.06 second and of much less amplitude during the rest of systole. Here again it seems probable that their duration at ample intensity was insufficient for the clinical palpation of a thrill.

Case 3/ (fig. 5) illustrates the effects of variations of posture and respiration on the intensity of murmurs and thrills and the clinical necessity of employing these maneuvers in such cases in order to elicit a thrill. It will be noted also in this case that the duration of the presystolic murmur (0.08 second) was probably alone too short for its appreciation as a thrill, and that the perception of the thrill depended on feeling the presystolic vibrations plus the main vibrations of the first sound (duration 0.12 second). It is probable that this is true of the presystolic murmur in general: that neither its own duration nor the duration of the first sound alone are sufficient to render either palpable, but that the sum of both is responsible for the effect of a thrill.
However, when the A-V interval is abnormally long, as in case 18, (P-R interval 0.21 second), the presystolic murmur itself may be of sufficient length to arouse the sensation of a thrill.

5; a thrill of grade 2 intensity was felt in this location. At the apex the murmur was considered to be less intense and was graded 4, with a thrill of grade 1. The phonocardiogram showed that a considerable

The phonocardiograms of case 35 are demonstrated in figure 6. A thrill was felt only when the patient leaned well forward, as is common in aortic stenosis.

Case 10. This patient had congenital heart disease probably with an interventricular septal defect. A systolic murmur was audible all over the precordium and was considered loudest at the left sternal border in the third intercostal space where it was graded

difference of frequency existed between the murmurs at both locations, that at the left sternal border having a main frequency of 185 cycles per second and the apical murmur a frequency of 110 cycles per second. The actual intensity of the apical murmur was 106.8 decibels and that of the murmur at the left sternal border 104 decibels despite the clinical impression of greater loudness of the latter and of greater intensity of the thrill at the left sternal
border. This subjective error is attributable to the higher frequency of the vibrations at the left sternal border and is readily understandable by reference to the threshold curves of hearing and feeling. This condition will not arise when a single murmur maintains its frequency at different locations of conduction and a possible advantage that the physician may gain in the search for the cardiac thrill by pressing his fingers into the intercostal spaces was lost to our instrument because the diameter of the chest-piece did not allow of its being so inserted between the ribs. Attention has already been called to the possibility that the sensitivity of the fingers to vibrations may not be quite the same for complex noises as for pure tones. Stethoscopic registration permitted only the main vibrations of the murmurs to be quantitatively studied and it is conceivable that a harmonic analysis would modify somewhat the end result.

**Discussion**

While the intimate nature of the mechanism of production of murmurs and thrills in the

**Fig. 6.** Phonocardiogram of case 35 (aortic stenosis) showing the effect of posture on the intensity of the vibrations of the aortic systolic murmur as recorded at the aortic area. Breath was held at the end of normal expiration throughout, with the following alterations of posture: (A) 25 degrees above horizontal (intensity of murmur 107.3 decibels), (B) 80 degrees above horizontal (intensity 107.3 decibels) and (C) 120 degrees from horizontal, that is, leaning forward (intensity 109.1 decibels). A slight thrill became palpable in the last position.

It is necessary to point out certain shortcomings in our experiment. The modifications of frequency response introduced by the large open bell chest-piece are not accounted for,
heart and blood vessels remains the subject of some speculation, a large body of evidence exists to show that the vibrations are produced by eddies in the stream of blood. Eddy formation occurs by election at the site of an obstruction and the configuration of the obstruction, as well as the velocity of flow, viscosity of the fluid and caliber of the vessel or chamber, exerts an important influence on eddy formation. Eddies may, however, form to a marked extent in the absence of distinct obstruction in tubes of even bore; in such instance fluid flow is streamlined below a certain velocity but may become turbulent and form eddies when the critical velocity is exceeded. Such eddies may give rise to vibrations that are audible and palpable, as in the collaterals in coarctation of the aorta.

Our study has been concerned with elucidating the factors that determine the palpability of vibrations that originate from the turbulent flow of blood in the circulatory system. Their palpability, like their audibility, depends on certain physical properties of the vibrations: frequency, intensity and duration; but the threshold values for the sense of touch are higher than those for hearing and it follows that when a superior sensory mechanism (hearing) is available for the perception of the same physical phenomenon it should replace the inferior (palpation) in the clinical examination of the patient. We have not encountered murmur vibrations below about 16 cycles per second where the human tactile sensation is keener than the audible. Actually, 50 cycles per second was the lowest murmur frequency encountered which is well above the lower limit of about 16 cycles per second.

The truth of this has been increasingly realized in clinical medicine and no reluctance is now felt, for example in diagnosing aortic stenosis without feeling, the classic thrill, and it has become obvious too that the diagnosis of ventricular septal defect must frequently be made from the murmur and other features in the absence of a thrill, though the latter will often be found if sought for. On the other hand, the finding of a thrill accompanying a murmur does not immediately stigmatize the murmur as belonging to a sinister category. It is possible to discover an 'inorganic' thrill, as in cases of cor pulmonale without valvular disease of the heart, when it must be interpreted as being no more sinister nor more 'innocent' than the murmur, since both are but different percepts of the same physical phenomenon.

Summary and Conclusions

1. A study was undertaken to estimate the significance and value of the cardiac thrill as a physical sign in clinical medicine.
2. The threshold of sensibility of the fingers of 4 physicians to vibrations in the range of frequency of the main cardiac vibrations was experimentally determined, under conditions resembling those of clinical palpation.
3. Forty patients who had loud or moderately loud cardiac murmurs were examined clinically and the murmurs and thrills were graded. Phonocardiograms were then taken and analyzed to discover the frequencies and intensities of the vibrations.
4. The ear appreciates the intensity of murmur vibrations as a degree of loudness that approximates but does not exactly parallel the impression of intensity of thrill as detected by the fingers.
5. The sensitivity of the fingers to vibrations in the range of cardiac murmurs is so far inferior to that of the ear that the elicitation of a cardiac thrill becomes a matter of academic curiosity and yields no information of diagnostic import that is not obtained by auscultation. The perception of a thrill depends on the sensitivity of the fingers of the observer and on the physical properties of the vibrations, namely their frequency, amplitude and duration, and tells no more about the nature of the underlying lesion than can be learned by the ear from these same properties.

References

The Vibration Sense and Other Lectures. University of Maine Studies, s. 2, No. 14, 1930.
—, and ——: The standardization of intensity of heart sounds and murmurs. In preparation.
Physiologic and Physical Factors that Govern the Clinical Appreciation of Cardiac Thrills
TIMOTHY B. COUNIHAN, MAURICE B. RAPPAPORT and HOWARD B. SPRAGUE

Circulation. 1951;4:716-728
doi: 10.1161/01.CIR.4.5.716
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1951 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/4/5/716

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/