Precordial Vibrations
Clinical Clues from Palpation

By E. Grey Dimond, M.D.

Some wise man has said that one advantage of the stethoscope is that its use forces the physician to come within at least an 18-inch radius of the patient. Palpation reduces the remoteness to zero: the physician must touch the patient.

A further enthusiasm for palpation develops after the total vibrational energy of the cardiac cycle is analyzed and it is demonstrated that approximately 90 per cent of this energy occurs in a frequency range that is subaudible. Stated differently, the great clinical usefulness of the stethoscope has been accomplished with but a 10 per cent sampling of the heart’s vibrational energy. The remaining subaudible 90 per cent is becoming useful, quantitative information also.

In none of my comments do I wish to imply that other workers have neglected to appreciate the possible clinical value of precordial vibrations. Both remotely 1–5 and currently 6–15 skillful clinicians have been active in this field.

The value of inspection and palpation to discern the heave of left ventricular hypertrophy, the apical tap and thrill of mitral stenosis, the diffuse lower left parasternal lift of right ventricular hypertrophy, the bulge of right ventricular outflow tract hyperactivity, the vibrations of the closure and splitting of the second sounds at the second and third left parasternal interspace—these are but a few of the clinical clues from precordial movement that are now well accepted and widely used.

An area of potential clinical usefulness now developing relates to the recording of these high-energy subaudible vibrations. In the same relationship that the stethoscope has had to phonocardiography, these subaudible vibrations have already proved their usefulness to the palpating hand of the bedside clinician and are now being quantitated and correlated with cardiac dynamics. As with any evolving field, a considerable amount of time is spent in development of technics and discussions over nomenclature. A useful means of understanding these present problems and their potential is to review briefly ballistocardiography.

The record of the recoil or countermovement of the body with the heart functioning as a ballistic device and thrusting blood—this is a simple definition of ballistocardiography. The definition becomes complicated when various instruments are utilized—high-frequency, low-frequency, and ultralow-frequency beds, stools, shin bars, torsion bars, mercury beds, etc.—and then becomes further confounded when the movement of the body is recorded as various functions of simple displacement, of velocity, of acceleration. Ballistocardiography reaches a real level of complexity when it becomes apparent that the movement of the heart and blood does not cause a simple countermovement of the body but that the actual final recorded motion is a

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Figure 1
Reproduced, with permission, from Sir James Mackenzie’s book, The Study of the Pulse,2 published by J. Pentland Young, 1902. The top tracing is obtained on the smoked drum and Mackenzie’s polygraph device. The similarity to the subsequent tracings in this article is apparent.
mixture of many mechanisms—of the coupling, of the resistance, of the elasticity of the heart, the lungs, the chest, the muscles, the fat, the skin, and the blood vessels, etc.

In spite of these many artifacts and arguments of technic, ballistocardiography continued to create a recurrent theme in the literature, namely, that regardless of the instrument there seemed to be some relation between an abnormal ballistocardiogram and coronary disease and that this crude wave form, with all of its limitations, could be used to detect occult coronary insufficiency. This possibility alone should serve to keep alive interest in body vibrations secondary to the heart thrust.

It would seem logical to move from the ballistic record of the total body to a precordial position. This would at least bring the recording device closer to the primary source of the energy, and instead of measuring a recoil of the body, attempt to sample chest wall vibrations set in motion by the heart cycle. This would narrow the possible sources of artifact due to tissue coupling, and make it likely that any influences of great vessel rigidity, of shifting center of gravity, etc. could be diminished.

However, in moving from ballistocardiography to the recordings of the heart-created vibrations from the precordium, the same problems of instrumentation and technic were.

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**Figure 2**

*Apex cardiograms obtained from the same patient but with four different pick-ups (Sanborn, Infraton, Schwarzer, and Electronics for Medicine)*

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Apex cardiogram of the left ventricle in normal subject, showing the identification of its components. A small a wave coincides with the atrial component of the first heart sound. Both mitral and tricuspid components of the first heart sound precede the E point in the apex cardiogram. A middysystolic click occurs in the descending limb of the systolic wave. The aortic component of the second heart sound precedes the O point. MA, mitral area; LF, low frequency; MSC, middysystolic click; ACG, apex cardiogram; IC, isometric contraction; IR, isometric relaxation; RFW, rapid filling wave; SFW, slow filling wave; DN, dicrotic notch; CT, carotid tracing; VT, venous tracing.

inherited. Consequently, the practitioner finds himself again reading of wave forms, recorded as displacement or velocity or acceleration, from a multitude of chest wall locations, and with diverse instruments and nomenclature.

There is real promise, however, that bona fide clinical advances will be made from the study of these low-frequency vibrations of the chest wall, and that the latent hints of ballistocardiography may find logical answers in this more direct approach. To demonstrate this potential, I would like to take one single technic, apex cardiology, the method with
which our group has had experience,* and discuss it in some detail. Other groups, using other methods, have been productive in this field and I do not claim primacy or priority.6-15

Apex cardiography can be defined as the recording of the apex thrust as a simple displacement curve. This is the oldest of the methods, dating back to Marey in 18771 and thoroughly used by Mackenzie2 with his polygraph. Figure 1, from Mackenzie’s book, The Study of the Pulse, illustrates the apex cardiogram much as it is observed today.

Professor Hartman of Leiden, in a superb exhibit before the European Congress of Cardiology in Stockholm in 1956,9 demonstrated not only the apex cardiogram of the left ventricle, but, in subjects with right ventricular hypertrophy, a reproducible vibration from the right ventricle.

Simultaneous cardiac catheterization, phonocardiography, and apex cardiography make it possible to demonstrate convincingly that the apex cardiogram reflects bona fide events in the cardiac cycle and is therefore a reliable reference tracing. The apex cardiogram is simple to obtain. The patient is in the left lateral recumbent position. The palpating hand locates the point of maximal impulse and, with the patient’s breath held in mid-expiration, the character of the movement is contemplated. With experience, practically all of the vibrations illustrated here can be discerned: the sustained lift of left ventricular hypertrophy; the double systolic lift occasionally seen in aortic stenosis; the rapid filling of the ventricle in mitral regurgitation; the slow filling of mitral stenosis; the presystolic thrust of atrial systole in ischemic heart

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* My close associate in the study of the apex cardiogram has been Dr. Alberto Benchimol.

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Figure 4

Same patient, before (above) and after (below) mitral valvotomy. Apex cardiogram and phonocardiogram at left, electrocardiogram and left atrial pressure curve at right. Reproduced from the American Heart Journal, with the kind permission of The C. V. Mosby Company.

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Figure 5

Comparison between two patients. Mitral stenosis on left, mitral regurgitation on right. MA, MF, mitral area medium-frequency phonocardiogram; P. Wedge, pulmonary “wedge” pressure; ACG, apex cardiogram; SFW, slow filling wave; RFW, rapid filling wave.

disease, in aortic stenosis, in hypertension, in myocardopathy; late systolic bulges of ischemia and infarct, etc. Next, a suitable microphone is placed over this area and, again with the patient’s breath held in midexpiration, a recording of this movement is obtained.

The simple crystal microphone pick-up (no. 374) used for pulse tracing recording with the Sanborn twin-beam was used for most of our work. However, this microphone did not consistently give a flat response in the very low frequency range (0.1 to 4 c.p.s.) and we are now using the Schwarzer pick-up (Z 101/37). Any device that gives a flat response from 0.1 to 20 or 30 c.p.s. (i.e., subaudible range) is adequate. The apex cardiogram from a normal subject, as obtained with four different pick-ups, is illustrated in figure 2. With the Infraton, the Schwarzer, and Electronics for Medicine, the records are practically identical. The Sanborn pick-up no. 374 did not consistently, from model to model, maintain the late systolic vibration (X) at the level of the other three pick-ups, while at the same time it accentuated the filling wave.

Characteristics of the Normal Apex Cardiogram

The normal apex cardiogram (with a pick-up with a flat response and a filter eliminating vibrations above 20 c.p.s.) is recorded dependably in approximately 90 per cent of the population. It can be described as consisting of a sharply rising systolic limb, which is initiated at approximately the beginning of isometric contraction and which terminates at an apex (E point), which closely approximates the opening of the aortic valve. A fall-off of this systolic limb next occurs with a secondary sustained wave persisting throughout systole, terminating with the end of systole (second heart sound), then a diastolic
collapse of the wave reaching a low point (O point) at which point the mitral valve opens, and a positive wave due to rapid filling (RFW) occurs. The cycle is usually terminated by a slight upward vibration associated with atrial systole, the a wave (fig. 3).

What other evidence is there that these waves reflect accurately the cardiac events? Natural experiments devised by disease offer considerable support. In the next several pages, natural experiments of pathology, pharmacology and physiology will be used as evidence.

Evidence That the Rapid Filling Wave Is Related to Opening of the Mitral Valve and Flow from Atrium to Ventricle

In figure 4, the apex cardiogram from a patient with mitral stenosis (above), the slow inflow through the stenotic valve is confirmed by both a left atrial pressure curve demonstrating a slow y descent, and an apex cardiogram demonstrating the simultaneous event as recorded on the chest wall. Below is the same patient, after mitral valve fracture, now with a rapid y descent in the atrial curve and a rapid ventricular filling as defined by the apex cardiogram.

Figure 6
Simultaneous apex cardiograms from left ventricle and right ventricle, same patient. Diagnosis: mitral stenosis and tricuspid regurgitation. Reproduced with the kind permission of The British Heart Journal.
Figure 5 demonstrates two contrasting patients, (a) with mitral stenosis, (b) with mitral regurgitation. Here, simultaneous wedge pressures, apex cardiograms, phonocardiograms, and electrocardiograms are recorded. Note the clear correlation between the O point (opening of atrophicventricular valve) and the apex of the v wave; note also the correlation between the rate of y descent and the diastolic filling wave of the apex cardiogram.

Figure 6 is a useful illustration of the validity of this approach in discerning separately the left ventricle and right ventricle. This patient had severe mitral stenosis and tricuspid regurgitation. Note the very slow filling wave over the left ventricle, with onset coincident with an opening snap and the greatly exaggerated filling wave over the right ventricle, reflecting tricuspid regurgitation. I have previously pointed out that Professor Hartman described this discerning value of the precordial tracing.

To summarize and add briefly, the diastolic filling wave of the apex cardiogram offers a useful, dependable means of confirming the time-location of an opening snap and of estimating the rate of inflow into the ventricle; thus it is an effective index of the degree of stenosis or regurgitation through the mitral valve and tricuspid valve. It is useful for preoperative selection of patients for surgery and

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in postoperative evaluation. Restenosis can be accurately identified. The data are reliable and can be obtained with ease. There is no advantage in transthoracic, transseptal, or "wedge" curves. The precordial vibration accurately correlates with intracardiac flow rate through the mitral and tricuspid valves.\(^{16, 17}\)

**Further Evidence That Precordial Vibrations at the Apex Accurately Reflect Intracardiac Events**

Figure 7 was obtained from a patient with atrial flutter. The phonocardiogram, electrocardiogram, apex cardiogram, and venous

![Image](image-url)

**Figure 8**

*Patient with atrial tachycardia and subsequent ventricular pause with carotid pressure. Note close correlation between P wave and precordial atrial vibration.*

![Image](image-url)

**Figure 9**

*Patient in whom ventricular activity is controlled by an electrical pacemaker. Atrioventricular dissociation. Note time relationship between P waves and a wave of apex cardiogram.*

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Figure 10

Simultaneous apex cardiogram and left ventricular pressure curve (recorded via catheter). The patient suffered from easily provoked angina. On the left are the resting curves; on the right, 1 minutes after bicycle ergometer exercise. Reproduced with the kind permission of The British Heart Journal.

Figure 11

Same patient as in figure 10. Curves on left obtained during angina; curves on right 5 minutes after sublingual nitroglycerin. Reproduced with the kind permission of the British Heart Journal.
tracing are recorded. Note the exact correlation between F waves in the electrocardiogram, the venous tracing, and the apex cardiogram.

Figure 8 was obtained from a patient with supraventricular tachycardia and first-degree atrioventricular block. Carotid sinus pressure resulted in ventricular arrest, then resumption of normal rhythm. The evidence for the relation between the electrical P wave, the fourth heart sound on the phonocardiogram, and a precordial vibration is substantial. Note also the dependable, reproducible pattern of the apex cardiogram, including atrial component, systolic spike, O point, and rapid filling wave.

Figure 9 was obtained from a patient in whom the ventricles were controlled by an intracardiac pacemaker and the atria main-

![Figure 12](http://circ.ahajournals.org/)

Curves above obtained while patient was having spontaneous angina; below, with angina provoked by exercise. Reproduced from the American Heart Journal with the kind permission of the C. V. Mosby Company.
tained a separate cadence. Again, note the precordial vibration resulting from this atrial systole.

**Is There a Relation Between Left Ventricular Pressure and the Apex Cardiogram?**

Figure 10 illustrates simultaneous curves: phonocardiogram, apex cardiogram, and left ventricular pressure. Note the time correlation between the fourth heart sound, the atrial component of the left ventricular pressure curve, and the a wave of the apex cardiogram, and the direct correlation between the amplitude of the a wave of the apex cardiogram and the left ventricular end-diastolic pressure. Compare, for example, the very large a wave and the end-diastolic pressure of

![Figure 13](image-url)

*Figure 13*

Three patients, all with angina. Left, control, baseline curve; right, after nitroglycerin.

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30 mm Hg mercury at 1 minute after exercise with the absence of the a wave and the left ventricular end-diastolic pressure of approximately 8 mm Hg 5 minutes after nitroglycerin (fig. 11).

Figure 11 can be used to illustrate another area of possible clinical usefulness of the apex cardiogram. We have already demonstrated the value of the diastolic filling wave in estimating rate of flow through the mitral and tricuspid valves and of identifying an opening snap. Figure 11 demonstrates the interesting fact that the height of the a wave may have a direct correlation with the left ventricular end-diastolic pressure. This we have confirmed in seven patients (ischemic heart disease and left heart catheterization). The fact that the atrial component of the apex cardiogram also may be large in aortic stenosis, hypertension, coarctation, myocardial infarction, pulmonary stenosis, pulmonary hypertension, etc. must also be emphasized and in these conditions it eventually may be proved that the amplitude of the a wave has definite clinical significance. For the moment, however, I want carefully to delineate that I am not referring to any of these conditions nor to congestive heart failure, but am confining this immediate discussion to ischemic heart disease and, in the cases presented here, specifically angina pectoris.

Figure 12 (upper tracing) was recorded from a patient with a reliable history of angina pectoris. During the control period (a) an apex cardiogram demonstrated a typical contour, except that the a wave was slightly larger than normal. At this moment, the patient spontaneously developed angina (top center) and the a wave became huge, the diastolic filling wave exaggerated. No medication was given; the pain subsided spontaneously and 5 minutes later (top right), the apex cardiogram was relatively similar to the resting tracing. The next day, the same patient was restudied (lower tracings). A control record was similar to the previous one. Exercise was carried out to the point of angina and the lower, center tracing was obtained. Note the similarity to the tracing obtained during spontaneous angina.

Other examples of the possible value of the study of the apex cardiogram in ischemic heart disease have been reported. 18-20

Possible Usefulness of the Apex Cardiogram in Evaluating Therapy for Ischemic Heart Disease

Figure 13 illustrates the results obtained in
three angina patients, following sublingual nitroglycerin. The left-hand column illustrates the contour of the apex cardiogram (note the $a$ wave) during angina. The right-hand column illustrates the effect of nitroglycerin. Note the marked diminution of the $a$ wave.$^{18}$ Skinner et al.$^{21}$ have reported similar observations with the kinetocardiogram.

**Usefulness of the Apex Cardiogram in Evaluating Other Agents in the Presence of Ischemic Heart Disease**

One may recall the studies of Dock and others,$^{22}$ who identified the fact that smoking could provoke an abnormal ballistocardiogram in individuals with occult coronary disease. Figure 14 illustrates a possible explanation for this observation and at the same time demonstrates how well the precordial vibration lends itself to research methods. The patient had angina pectoris. Note the prominent $a$ wave in the control curve and the left ventricular end-diastolic pressure of approximately 10 mm Hg. A cigarette was then smoked, quietly, and after 2 minutes, the left ventricular end-diastolic pressure rose to approximately 20 mm Hg and the $a$ wave increased. Six minutes after the patient stopped smoking the left ventricular end-diastolic pressure fell to 15 mm and the $a$ wave decreased.

Figure 15 illustrates these changes in another patient with angina pectoris upon smoking. The control record was obtained after 1 hour supine. Note the effect upon the $a$ wave after 1 and 2 minutes of smoking, and the prompt subsidence when he stopped smoking. I do not suggest that smoking routinely produces this change in all angina pa-

![Figure 15](image-url)

*Figure 15*

*Demonstration of effect of smoking in this specific patient. History of angina. No pain during test. Reproduced from the American Heart Journal, with the kind permission of the C. V. Mosby Company.*
One patient, three sequential experiments. Comparison of venous tourniquets, abdominal binder, and nitroglycerin.

Figure 16

tients. It does so frequently enough, however, to suggest that here may be a means of studying the effect of smoking on the cardiovascular system.

Figure 16 illustrates information obtained by comparing the effect of four limb venous tourniquets, a tight abdominal binder, and nitroglycerin in the same patient with angina pectoris, sequentially. Note the similarity of response elicited by these three approaches. The a wave is reduced by approximately 50 per cent by each procedure. We have carried out this same study and simultaneous left ventricular pressure curves in three patients with angina. The same general pattern results, namely, in a decrease in the
a wave and a simultaneous decrease in the end-diastolic pressure. I should add that although the three approaches—tourniquets, binder, and nitroglycerin—all lower the end-diastolic pressure, nitroglycerin is the most dependable and effective of the three, in our studies. It is interesting to recall the article by Kerr, Cannon, and Lagen in 1939 who found a definite beneficial effect from a tight abdominal binder in angina patients. They suggested at that time that the binder perhaps aided venous return and thus cardiac output. From our own studies, the close similarity of result for four limb venous tourniquets and abdominal binder suggests that the binder impedes venous return and perhaps “unloads” the heart.

Other distinct characteristics of precordial vibrations deserve equal discussion; however, I will only comment briefly on the observations of Harrison of late systolic bulges over the left ventricle in ischemia and infarct and

![Figure 17](https://circ.ahajournals.org/)

_Simultaneous curves from single pick-up, but different sequence of filters. Note marked change in curve upon removal of low-frequency vibrations, especially below 4 c.p.s._

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the work by Agress and others, on the changed time relationships of isometric contraction, etc. in ischemic heart disease.

**What Is the Frequency Range of the Apex Cardiogram?**

With our method we arbitrarily eliminate by filters all components above 20 c.p.s. It is interesting to dissect the remaining vibrations. Figure 17 demonstrates a typical apex cardiogram (0.1 to 20 c.p.s.); also illustrated are the wave forms which would be recorded by utilizing equipment cutting out the very low frequencies (below 4 c.p.s.), and those below 12 c.p.s. Finally, the wave forms obtained with the system responding from 40 to 120 c.p.s. are illustrated. Note the high-energy waves in the low-frequency range and the marked alteration produced by removing vibrations from 0.1 to 4 c.p.s. To record the wave form of the apex cardiogram, as we have discussed it here, requires equipment giving a flat response from 0.1 to at least 20 c.p.s. If the system is sensitive to higher frequencies it will not interfere but we have chosen to record these higher frequencies separately with standard phonocardiograph equipment.

**Summary**

The low-frequency precordial vibrations originating at the point of the apex beat, and especially those in the subaudible range, seem to offer considerable clinical usefulness. In this paper I have briefly outlined some of the physiologic, pathologic, and pharmacologic evidence to support this impression. The instrumentation we have used is crude and undoubtedly we have been misled on occasion by artifacts. However, there is sufficient validity in the technic, reproducibility of result, and correlation with intracardiac events to warrant intensive study.

**References**


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Caleb Hillier Parry on Medical Knowledge

The most dangerous state incidental to the human mind is a calm acquiescence in the accuracy and extent of its own attainments. Knowledge is at once the origin of morals and the road to happiness; and precisely in proportion as we acquire it, we advance, though still at the most humble distance, towards the perfection of the Divine nature. . .

With this view, he who would aspire to a just character for professional eminence, ought to have an adequate knowledge of the properties of number and figure; of the laws of mechanics and hydraulics; of the general principles of botany and chemistry; and a still more minute acquaintance with the anatomy of man and other animals, and with metaphysics, or the properties of mind.

These acquisitions, necessary and multifarious as they are, can still be considered as only the introduction to the more immediate knowledge of his profession; in which he must, as far as possible, learn the structure and uses of the different parts of the animal machine, their various dependencies on each other, their movements and affections in a state of health, and the symptoms of deviation from that state. On these important subjects it would greatly improve the accuracy of his conceptions, were he to compare all the phenomena which occur in the human race with those of other animals, and even of the vegetable kingdom itself. He must also inform himself of the powers which disturb and restore the healthy functions, whether of the body or mind.—Preface. Collections from the Unpublished Medical Writings of the Late Caleb Hillier Parry, M.D.F.R.S. Vol. I., London, Underwoods, Fleet-Street, 1825.
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