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ARTICLES

STUDY OF INNOCENT MURMURS IN CHILDREN BY INTRACARDIAC PHONOCARDIOGRAPHY *

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Introduction

The differentiation of murmurs of congenital or acquired heart disease from innocent murmurs is one of the most basic problems of the cardiologist. Modern techniques of surgical treatment of heart disease, making it possible in many cases to restore afflicted cardiac patients to normally active lives, is one aspect of the need for correct diagnosis. More important, however, is the responsibility of the cardiologist to his patient to make a proper distinction between true heart disease and a physiologically sound heart, so that patients with «innocent» murmurs will not be condemned to lives of needless fear of normal physical activity.

Classical textbooks on cardiology and pediatrics use various terms to refer to «innocent» murmurs in children, such as «inorganic,» «accidental,» «physiologic» or «functional.» However, none of these designations is as accurately descriptive of the phenomenon as the term «innocent» murmur, the name recommended by the American Heart Association.

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While innocent murmurs have long been recognized clinically, the etiology of the murmurs, where and how they are produced, has not been established. Harris,[1] Friedman,[2] Messeloff,[3] Lynxwiller[4] and Stucky[5] have made extensive investigations of innocent murmurs from a clinical - diagnostic point of view, but without the study of physiopathological and etiological factors. They emphasize the fact that many patients with innocent murmurs may be diagnosed as patients with rheumatic carditis or congenital heart disease, or even an undetermined heart disease. Rushmer,[6] in his book states empirically that it is possible to have innocent murmurs produced in the main pulmonary artery or pulmonary conus, but he does not refer to any substantiating scientific study to establish his observation.

A review of the literature indicates that an innocent murmur is a frequent finding among healthy children, a fact which makes proper interpretation of the murmur by the general practitioner, pediatrician, or cardiologist essential.

For example, Schwartzmann[7] in 1931 reported that innocent murmurs occured in 44 per cent of healthy children who were examined; after vigorous exercise the percentage increased to 86.6 per cent. Epstein[8] in 1948 found innocent murmurs in 50 per cent of 260 children examined. Lynxwiller[4] reported in 1955 that of 1,706 children examined in their heart clinic, 36 per cent had functional or innocent murmurs. Fogel,[9] in a review of the incidence of innocent murmurs, stated that the lowest figures of 8 per cent to 20 per cent were reported by Rauh and associates, but his own experience showed an occurrence rate of 53 per cent.

In recent years, a number of new techniques and instruments have been developed for the evaluation of heart sounds and murmurs. Among these, the chest phonocardiogram has been used by several investigators to study the character of innocent murmurs. A more recent refinement of this technique, made possible by the development of phonocatheters, has made it possible to record the intracardiac sounds, and this technique, now termed intracardiac phonocardiography, has been utilized in studying patients with a variety of heart diseases including arteriosclerotic, rheumatic and congenital forms. The present study represents the first application of this advanced technique to the study of innocent murmurs in children, and was undertaken in the hope of shedding light on the physical origin of these murmurs. In addition, the technique was used on dogs,

as discussed below, in an attempt to clarify still further the findings in children.

Materials and Methods

Ten children with systolic murmurs, who were otherwise healthy, were referred to our clinic for study. All of them had the following features in common in their past histories:

a. There was no history of viral infection, colds, German measles or anoxia during the first trimester of pregnancy in any of the children's mothers.

b. There was no history of rheumatic fever in any of the children.

All of them had the following studies:

a. Complete physical examination: blood pressure (including legs), abnormal position.

b. C.B.C., sedimentation rate; A.S.O. titration, C. reactive protein.

c. Urine examination.

d. Roentgen-ray examination of the heart (anterior, posterior, right anterior oblique, and left anterior oblique with barium swallow.)

e. Electrocardiography including V_4R and all chest leads.

f. Chest Phonocardiography.

g. Right heart catheterization and intracardiac phonocardiography including recordings of all sounds and murmurs on a tape recorder.

The electrocardiogram was obtained with a Sanborn Model 52. Phonocardiograms were recorded by the Sanborn Twinbeam photographic recorder, and by an «Electronics for Medicine» recorder. Intracardiac phonocardiograms were obtained with an A.E.L. (American Electronic Laboratory) sound catheter and its amplifier.

Technique

Each patient was pre-anesthetized and then catheterized according to the Cournand [10] method. Under fluoroscopic control, the tip of the catheter was introduced into the main pulmonary artery and both the right and left branches. There, any sounds present were picked up by the phonocatheter and were recorded on magnetic tape, and both direct-wiring and photographic phonocardiograms were obtained. Simultaneously, recordings were made of the external heart sounds for subsequent comparison in determining relationships between intra and extra-cardiac sounds. Continuous recordings of intracardiac sounds were obtained as the phonocatheter was withdrawn from the pulmonary artery into the right ventricle, then to the right atrium and finally the venae cavae. It was also possible, by using a double-lumen phonocatheter, to obtain, in several cases, simultaneous recordings of the pressure at the various locations of the catheter tip.

The experiments on dogs were carried out with the animals under intravenous pentothal anesthesia and with the heart made completely accessible by bilateral thoracotomy. The instruments used and the basic technique of catheterization were exactly the same as those employed in the children. However, in order to accomplish the two purposes of this aspect of the study, i.e. to investigate the possibility that the catheter itself might be a factor in the production of murmurs, and to determine whether murmurs occurred on the left side of the heart, four different approaches were utilized and each of these approaches was used in the study of two dogs. Recording of sounds, synchronized with simultaneous electrocardiographic recordings, were obtained as in the children.

The first approach was similar to that used in children though more direct. The phonocatheter was introduced directly through the myocardium into the right atrium, thence into the right ventricle and the main pulmonary artery.

The possible hemodynamic effect of variation of catheter direction was investigated next by introducing the catheter directly into the right pulmonary artery and then pushing it retrograde-fashion, into the main pulmonary artery.

Intracardiac sounds arising in the left side of the heart were investigated first by introducing the catheter into the pulmonary vein and from there into the left ventricle and on into the aorta.

As on the right side, retrograde effects were investigated by introducing the catheter through the right subclavian artery and back into the ascending aorta.

Findings

The findings in the basic clinical and laboratory studies, including roentgen-ray and electrocardiographic studies and right heart catheterization, carried out on all the children were within normal limits except for the presence of the innocent murmur, which was requisite for the study. Auscultation of all these children revealed a grade I or II soft systolic murmur heard in the 2nd, 3rd or 4th intercostal spaces at the left sternal border. In none of these children was the murmur transmitted to the left axillary area although in one of them there was transmission to the pulmonic and aortic area and in another, to the apex. There were usually minor changes in the character of the murmur with variation in the position of the child, but the heart sounds were otherwise entirely normal in quality and rhythm, with no splitting or other sounds present.

External phonocardiograms obtained on these children revealed only the systolic murmur under study. This murmur was consistently of short duration; in none of the children did it occupy more than the first two-thirds of systole. The phonocardiogram clearly demonstrated its character of low frequency and amplitude. No other abnor-

mal sounds, no third or fourth heart sounds, and no splitting of sounds was revealed in these studies.

The intracardiac phonocardiograms on all children revealed no murmurs in the superior or inferior vena cava or the right atrium or right ventricle. A systolic murmur, however, was found to be present in the main pulmonary artery and its main branches in all of these children. When simultaneous external and intracardiac phonocardiograms were obtained, there was a definite correlation in the timing of the externally recorded systolic murmur and the murmur recorded in the pulmonary artery. In both cases, the murmur usually occupied only the first two-thirds of systole although in some cases the intracardiac recording revealed that a low frequency, low amplitude murmur persisted in the pulmonary artery longer than did the murmur on the chest. Undoubtedly the frequency and amplitude of this sound was simply too low to be transmitted as an audible external murmur. (Figs. 1, 2, 3, 4)

External phonocardiograms obtained on the dogs studied revealed that although the first heart sound was of slightly longer duration than the second, (0.02 - 0.04 second), the second sound was of greater amplitude. No murmurs were revealed in these studies.

Intracardiac phonocardiograms obtained on dogs revealed the following findings on the various approaches:

1. Direct catheterization of the right heart: No murmurs were recorded in the right atrium or right ventricle but a systolic murmur was found in the pulmonary artery. (Fig. 6)
2. Retrograde catheterization of the pulmonary artery: A second sound of high amplitude and a barely visible first sound were recorded here along with a clearcut crescendo-decrescendo systolic murmur almost identical to that recorded on the direct approach.
3. Direct catheterization of the left heart: No murmurs were recorded in the pulmonary veins, the left atrium, the left ventricle or in the aorta where a systolic click was present.
4. Retrograde catheterization of the aorta: No murmur was found but a systolic click was seen; again the second sound was of great amplitude. (Figs. 5, 7)

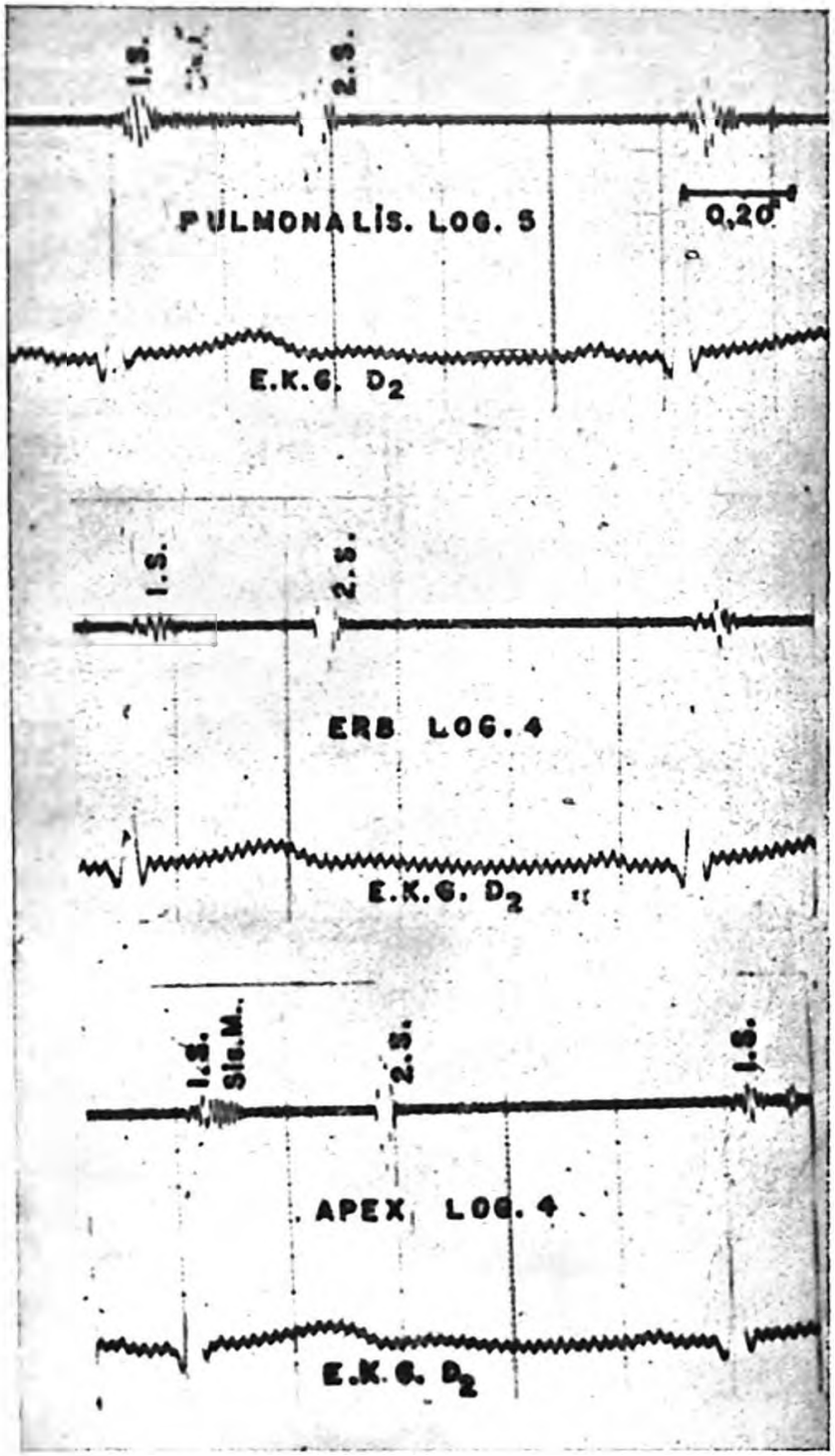

Fig. 1. D. Y., 11 year - old male. (59 - 16425).

Thoracic phonocardiograms from various locations on the chest. There are decrescendo - type systolic murmurs with low amplitude, best seen at pulmonic and apical areas. In each section, upper row is the thoracic phonocardiogram, and the lower row the electrocardiogram. Log. : logarithmic, I. S. : first heart sound, Sis. M. : systolic murmur. Figure after the log. is indicated for phonocardiographic sensitivity for that particular recording.

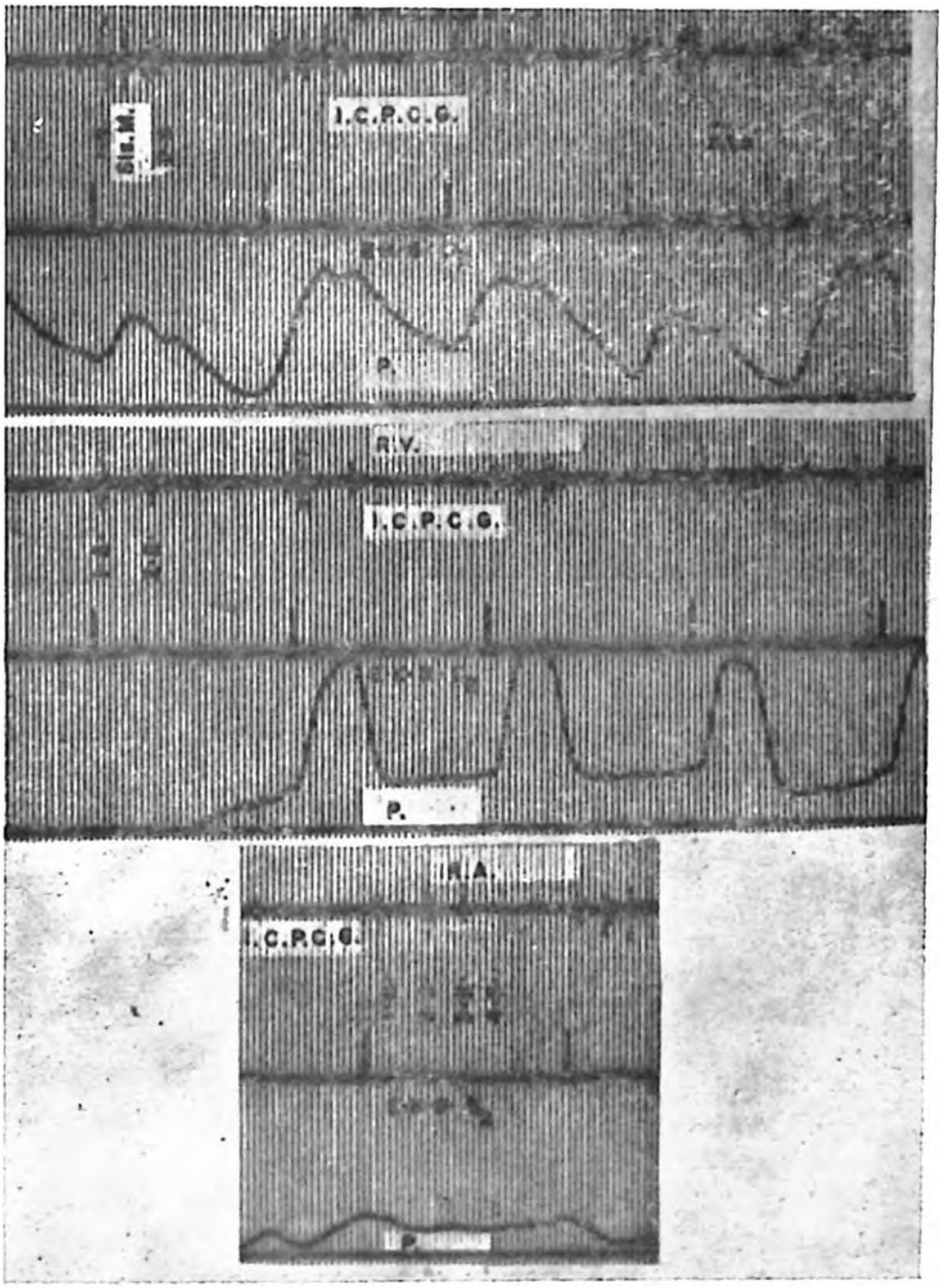

Fig. 2. D. D., 11 year-old male. (59-16425).

Intracardiac phonocardiogram from the various locations in the lesser circulation. For this figure, and for all subsequent figures in each section, the upper row is the intracardiac phonocardiogram, middle row is the pressure in that particular chamber or vessel. Note crescendo-and decrescendo-type systolic murmur in the main pulmonary artery and the complete disappearance of the murmur as the tip of the catheter is withdrawn into the right ventricle.

i.c.p.c.g.: intracardiac phonocardiogram, Sis. M.: systolic murmur, E.K.G.: electrocardiogram, P.: pressure, R. V.: right ventricle, R. A.: right atrium, 1. S.: first heart sound, 2. S.: second heart sound.

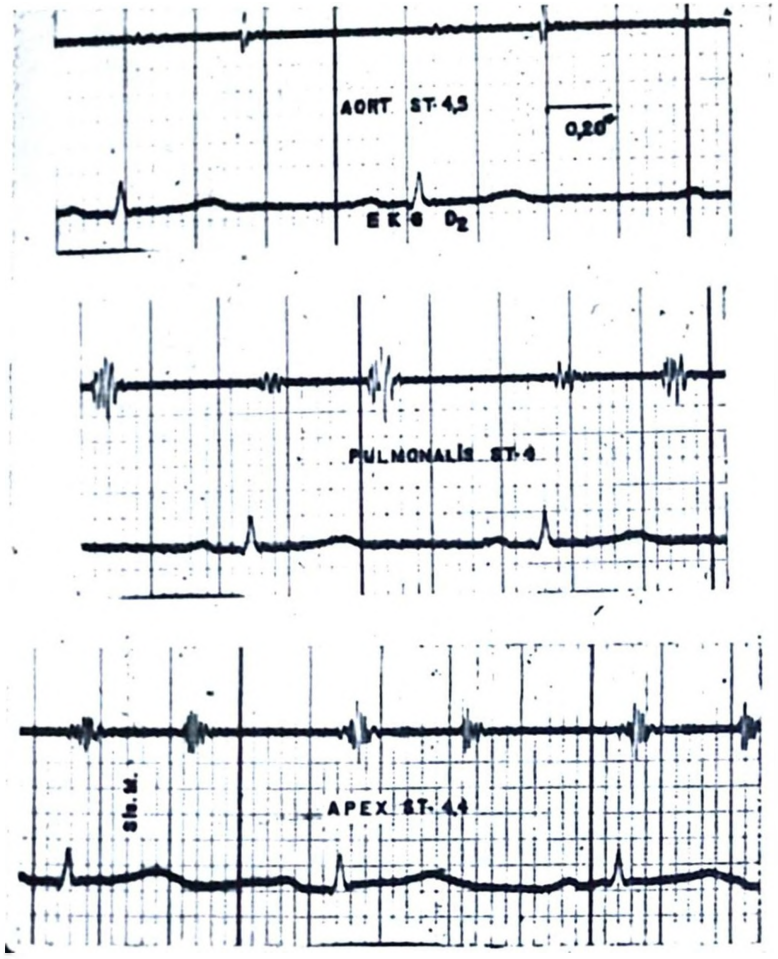

Fig. 3. C. H., 13 year - old female. (60 - 141).

Thoracic phonocardiograms from various locations on the chest. Note a short systolic murmur with low frequency and low amplitude at the apical area.

St : stetho., figures after St. denote the degree of amplification, time marking : 0.20 second between thick lines, Sis. M. : systolic murmur.

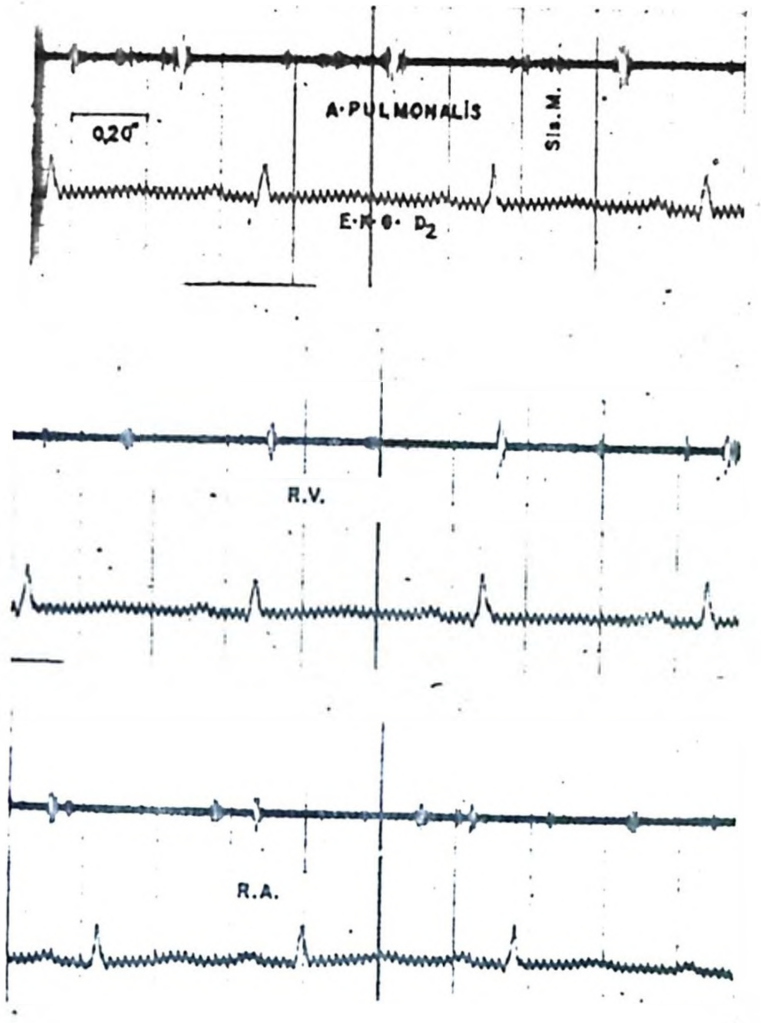

Fig. 4. C. H., 13 year - old female. (60 - 141).

Intracardiac phonocardiogram from various locations in the lesser circulation. Note the decrescendo - and crescendo - type pansystolic murmur in the main pulmonary artery and the complete disappearance of the murmur as the tip of the catheter is withdrawn into the right ventricle.

A. Pulmonalis : pulmonic area, R. V. : right ventricle, R. A. : right atrium.

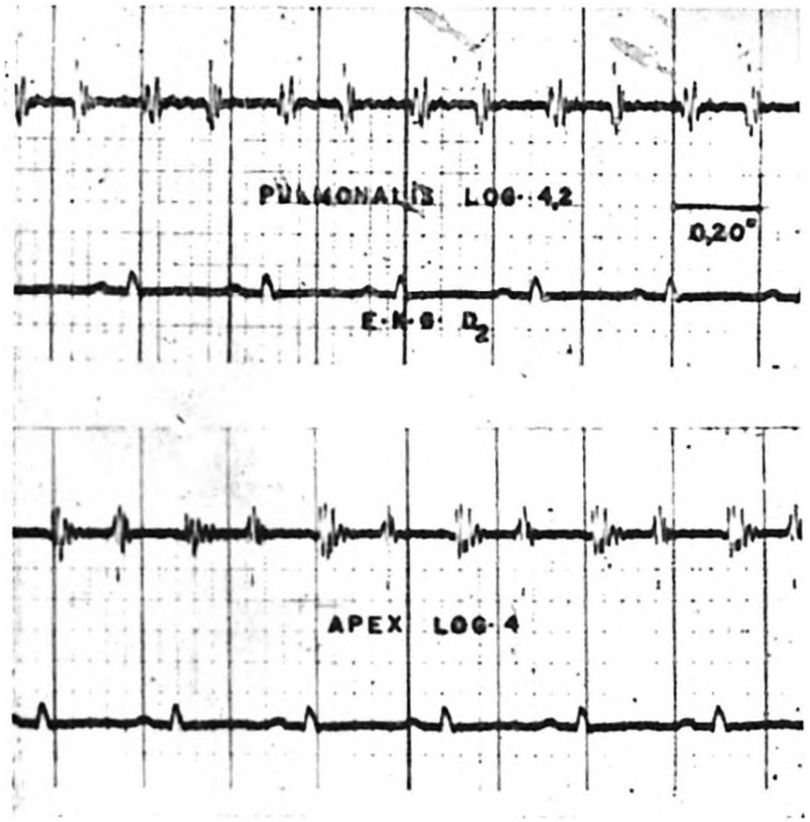

Fig. 5., Dog No. 2.

Thoracic phonocardiogram from pulmonic and apical areas. There is no murmur, and heart sounds are within normal limits for dog.

E.K.G. D_2: electrocardiogram lead II, figures after log. denote degree of amplification.

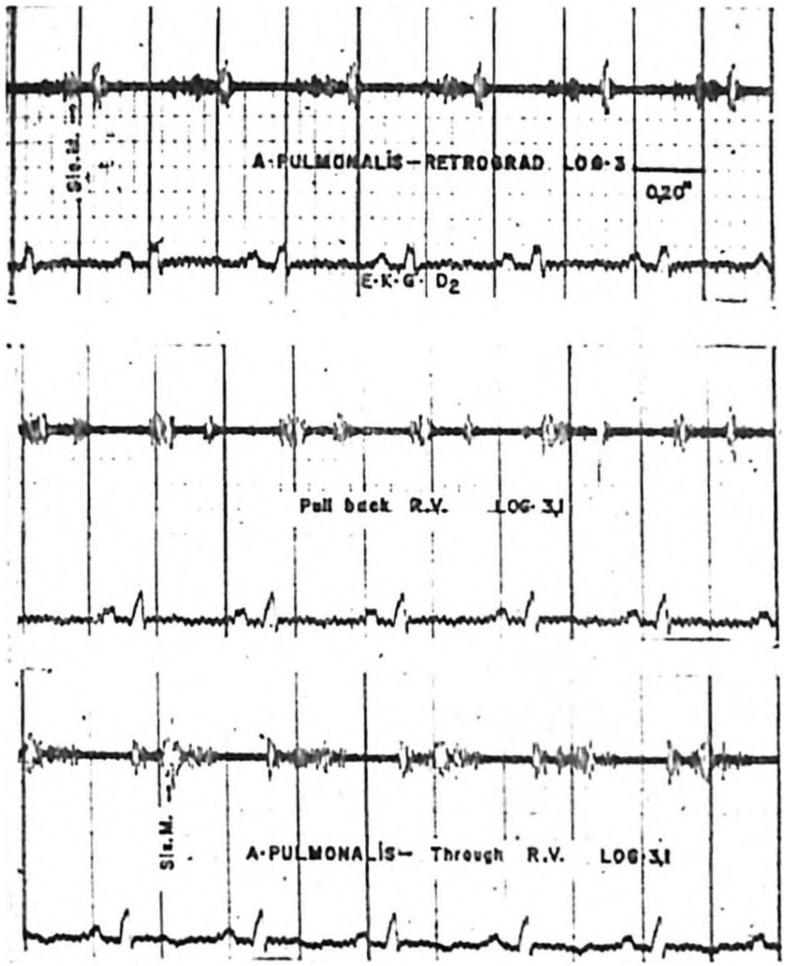

Fig. 6., Dog No. 2.

Upper section, the tip of the catheter is in the main pulmonary artery, introduced retrograde-fashion. Note pansystolic murmur.

Middle section, the tip of the sound catheter is in the right ventricle, introduced via the right atrium. There is no murmur in the right ventricle. First heart sound is louder than the second heart sound.

Lower section, the tip of the sound catheter is in the main pulmonary artery. Note crescendo-and decrescendo-type systolic murmur.

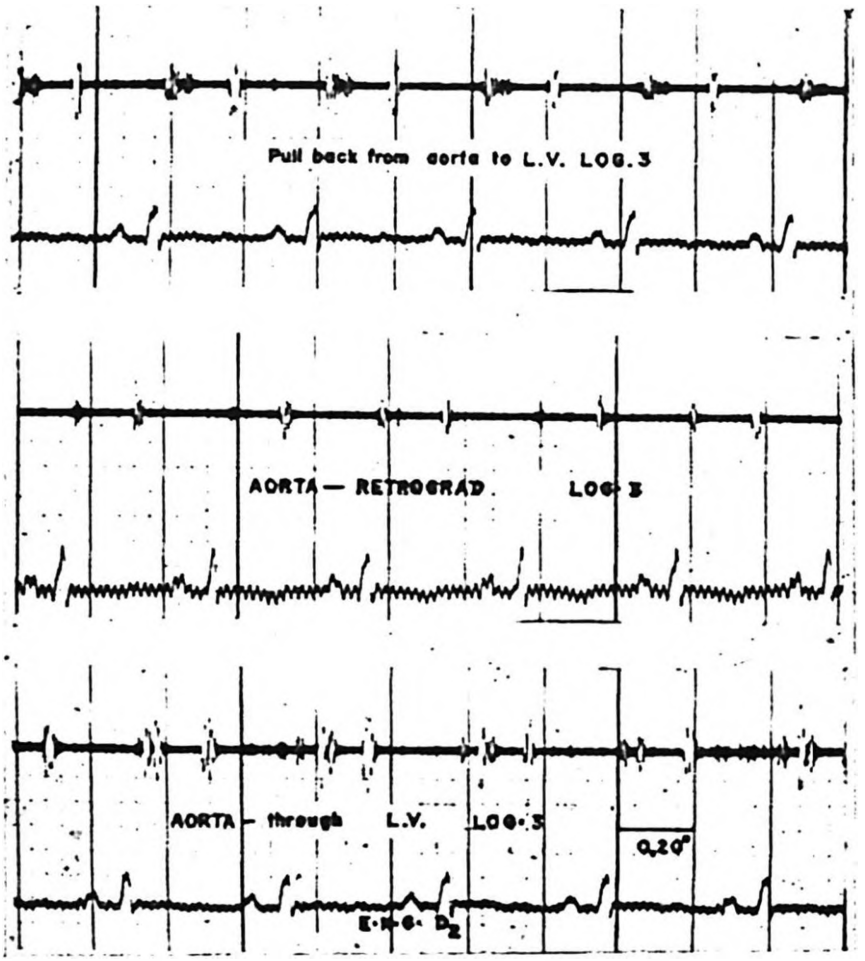

Fig. 7., Dog. No. 2.

Same dog as in figures 5 and 6. In upper section the tip of the catheter is in the ascending aorta introduced via the left ventricle. Note high amplitude of the second heart sound, and no murmur.

In the middle sertion the tip of the catheter is in the ascending aorta as in the upper row, the only difference is catheter introduced retrograde-fashion. Note high amplitude of second heart sound, no murmur at all.

Lower section, the tip of the catheter pulled back from ascending aorta into left ventricle. Note no murmur in left ventricle.

Conclusions

The studies in children otherwise normal except for a murmur, showed simply and clearly that the murmur arises in the pulmonary artery.

The supplementary studies in dogs showed that the murmur found to arise in the pulmonary artery of children is also present in dogs and that the sound is the same whether the catheter is introduced directly or retrograde.

Investigation of the ascending aorta in dogs, both directly and retrograde, revealed no murmurs, thus providing evidence that the murmur found in the pulmonary artery was not produced by the catheter itself since any hemodynamic alterations produced by insertion of the catheter should have been the same in either the main pulmonary artery or the aorta.

Discussion

A previous study showed that a normal person without murmur on the chest may have a systolic murmur in the main pulmonary artery, and the present study demonstrates that the innocent murmurs so frequently found in children occur only in the main pulmonary artery. The question of why these innocent murmurs are only sometimes audible and sometimes not audible on the outside of the chest will be the subject of a further investigation.

In seeking to explain why a murmur might arise from the main pulmonary artery, certain physical aspects of the hemodynamic processes involved offer a possible cause. The main pulmonary artery and the ascending aorta, separated at their origins only by a flexible septum, have approximately the same diameter, and in a given systolic phase, must transport the same volume of blood in order to maintain circulatory equilibrium. The propulsive forces moving a given volume of blood through the two vessels, however, are different.

The left ventricular pressure is significantly higher than that on the right initially. It seems likely, therefore, that during the early portion of systole, at least, the higher pressure of the mass of blood moving through the aortic valve into the ascending aorta would cause the membranous septum between the two vessels to expand toward the pulmonary side, thus distorting and narrowing the lumen of this vessel and this, in turn, could produce sufficient turbulence of the blood flow there to produce a murmur.

Since innocent murmurs are produced in the main pulmonary artery one would expect to hear them over the pulmonic area, namely, in the second intercostal space at the left sternal border. However, some of the murmurs are audible below that area, even at the apex. Because the projection of the valves of the heart on the chest wall is almost at the same level, it is quite possible to have sound or murmur produced in the pulmonic valve transmitted to the left sternal edge or to the apex.

The studies in children demonstrate clearly that innocent systolic murmurs arise in the main pulmonary artery. The precise cause remains unclear.

Summary

Innocent murmurs in children occur sufficiently frequently to make their accurate diagnosis of prime importance to the pediatrician, general practitioner and cardiologist.

Intracardiac - phonocardiography provides a safe and effective method for making possible a differential diagnosis for innocent murmurs and heart disease.

Experiments in ten children and in dogs using phonocardiography have shown that innocent murmurs are produced in the main pulmonary artery. They are heard best at the left of the sternum, in the second, third and fourth intercostal spaces. The sounds are soft and are not transmitted to the left axillary area. They occupy the first two - thirds of the systole.

Innocent murmurs have the character of low frequency and amplitude and they never go into the second heart sound. There is no increase in either the first sound or the second sound.

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