Phonocardiographic Examination used in the Mass Examination of Heart Disease among the Children

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In order to get valuable information for efficient application of PCG and auscultation to mass examination, discussion was made of the characteristics of heart murmurs and sounds of normal children and of congenital heart diseases and acquired valvular heart diseases which are more prevalent among the young.
In the first chapter, the heart murmurs of children, especially functional murmurs are examined by both auscultation and PCG and the role of them in mass examination is evaluated.
In the second chapter, the use of PCG for mass examination is described especially for re-examination.
In the third chapter, discussion is made how to differentiate functional heart murmurs from pathologic ones, whose differentiation is difficult by auscultation.
In the forth chapter, physiologic diastolic murmurs which have not been generally taken into consideration are discussed.

AN EPIDEMIOLOGIC study of rheumatic fever and heart diseases among the school children in Osaka was started by the Department of Public Health, Osaka University, School of Medicine in 1953. It was succeeded by the Field Research Department of the Center for Adult Diseases in Osaka which adopted phonocardiography in a mass examination basis.

During the present study a heart disease control program was started as a part of School Health Administration.

The author's experience reveals that a difficulty lies in the problem of auscultation in carrying out the program. Among the children's heart diseases, the most common are congenital heart diseases and acquired valvular heart diseases (Table I). When they are in the early stage or not serious, they except for a few congenital heart diseases show no clinical symptoms and their typical findings are not obtained in chest X-ray films or ECG. It is frequently required to diagnose heart diseases only by auscultation. Many school children have functional murmurs, some of which are difficult to differentiate from pathologic murmurs. When it comes to diagnosing diseases by auscultation, a considerable experience seems to be required. Besides, the auscultatory findings obtained by individual physicians are subjected to individual differences.

Hence, the advent of a phonocardiographic apparatus. It seems that recently PCG has become rather popular in Japan, proving to be an indispensable means in diagnosing heart diseases as well as physical examination, chest X-ray and ECG. But still it does not seem to have been so widely distributed.

A few years ago the author began to use PCG in mass examination. The heart disease control program system, now the author takes part in, consists of screening, re-examination, further examination, counselling and supervision. The screening is carried out on questionnaires about symptoms, history of heart diseases and

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rheumatic diseases. It is also done on chest X-ray films which is used for pulmonary tuberculosis. Four to eight percent of children screened were re-examined by the staff of the Center on auscultation and questionnaires. Children having suggested abnormalities of heart murmurs and/or sounds and those with the history of rheumatic fever with or without heart diseases as sequelae were further examined. The number of children further examined accounted to 2 to 4% of all the children. In further examination, chest X-ray, ECG and PCG were used and blood examination including serological tests if needed were added. Considering the cost and efficiency, the present screening method seems satisfactory, since it consists of questionnaires, miniature chest films and auscultatory findings by school physicians. However, hence specialists are so much limited in number that they can not cover all those cases which requires re-examination. It is reasonably desired that either such specialists be increased or some other means be adopted. Hence the use of PCG for re-examination as well as for further examination.

In the first chapter, the heart murmurs of children, especially functional murmurs are examined by both auscultation and PCG and the role of them in mass examination is evaluated.

In the second chapter, the use of PCG for mass examination is described especially for re-examination.

In the third chapter discussion is made how to differentiate functional heart murmurs from pathologic ones, whose differentiation is difficult by auscultation.

In the fourth chapter physiologic diastolic murmurs which have not been generally taken into consideration are discussed.

I. HEART MURMURS AND HEART DISEASES IN CHILDREN

§ 1. Introduction

Auscultation is the most sensitive examination for detecting heart diseases in their early stage among the children and it is most frequently used for screening in mass examination. However many children have functional murmurs not a few of which are louder enough beyond Grade 3 (LEVINE 3). On the other hand, not a few of organic murmurs are less than Grade 2. Therefore it is impossible to judge whether murmurs are functional or organic only by their intensity. But it is pretty possible for a well trained physician to differentiate them, referring the pitch, the maximum point of loudness and quality of murmurs. Hence a study was carried out to get some knowledges of heart murmurs among the children. A few factors that had been considered to influence the above points were analysed on both auscultation and PCG and the results obtained were comparatively studied.

§ 2. Methods and Materials

In July of 1962, two physicians with the same diagnostic criteria auscultated 1668 pupils of a primary school in Higashimiyoshi ward, Osaka City.

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### Table II Relations between auscultatory findings and heart diseases

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of cases</th>
<th>No. of children with H.D.</th>
<th>Regions where murmurs are audible*²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Base</td>
</tr>
<tr>
<td>Abnormal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murmurs of Grade 3 or more</td>
<td>22</td>
<td>8</td>
<td>3/7</td>
</tr>
<tr>
<td>Murmurs less than*¹ Grade 2</td>
<td>36</td>
<td>2</td>
<td>0/9</td>
</tr>
<tr>
<td>Subtotal</td>
<td>58</td>
<td>10</td>
<td>3/16</td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional murmurs</td>
<td>54</td>
<td>0</td>
<td>0/37</td>
</tr>
<tr>
<td>No murmurs</td>
<td>21</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td>75</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>133</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional murmurs</td>
<td>159</td>
<td>0</td>
<td>0/98</td>
</tr>
<tr>
<td>No murmurs</td>
<td>40</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>199</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

*1. Cases with murmurs less than Grade 2, but having abnormal quality and/or accompanied by abnormal heart sounds.

*2. Regions of murmurs individually counted, denominator; No. of cases, nominator; No. of heart diseases.

The children were auscultated in a sitting position on a chair or lying in bed if necessary. Besides auscultation, the children's complaints, history and daily life activities were obtained on questionnaires answered by children, parents and teachers, and chest X-ray films were reviewed.

Table II shows the number of pupils who were examined phonocardiographically. In a regular program, the phonocardiographic re-examination is applied only to the pupils showing abnormalities on auscultation by specialists. But in this study 133 children screened at the first stages were examined phonocardiographically (out of 133, 58 were screened by auscultation). As controls, 159 apparently nonpathologic children and 40 children showing no heart murmurs by auscultation were examined phonocardiographically.

The author used the PCG apparatus provided with five kinds of high pass filters, cutting out frequencies below 30, 50, 100, 200 and 400 cps, respectively, with a slope of 18 db/oct, an oscilloscope, an earphone and a recording camera. As a pick up, air conducting type, crystal microphone was used. The PCG examination was carried out in a quiet class room with children kept at a supine position with regular respiration. PCG were checked as to the right and left basal regions, the Erb's region, the lower left sternal border and the apical region. The PCG findings were analysed as to the maximum point, phase, beginning time, duration, shape and frequency of murmurs as well as changes in heart sounds. ECG and chest X-ray were added to the PCG test and if necessary blood examination was made.

The children whose findings were not clear enough to diagnose were examined phonocardiographically again a month later and this examination had a wider coverage than the previous examination allowing the children to take any position, with their respirations briefly stopped if needed.

§ 3. Results

1) The prevalence rate of heart murmurs detected by auscultation.

In 40% of the subjects, heart murmurs louder than Grade I were heard, irrespective of functional or pathologic ones (Fig. 1).

(a) The prevalence rate of heart murmurs in terms of the cardiac region, by sex and age.

Unlike the girls, the boys showed the prevalence rate of heart murmurs decreasing as age advanced. The relations between the region of heart murmurs and age is as follows: the older the children, the less prevalent apical systolic murmurs in both sexes. Unlike the boys, the girls show their basal systolic murmurs becom-
ing more prevalent as they grow older.

Besides the Fig. 1 shows the number of those who needed re-examination by auscultation. This number includes the children whose murmurs proved to be the Grade 3 or more (including functional murmurs of the Grade 3 or more) and those with murmurs less than Grade 2 but with suggested abnormalities of heart sounds and/or murmurs. The number of the children requiring re-examination accounted for 3.5% on an average and no considerable difference was found in both sexes or in two groups (a lower grader group consisting of the 1, 2 and 3 graders and an upper grader group consisting of the 4, 5 and 6 graders).

(b) Heart murmurs reviewed in reference to physical constitution and daily activities.

Fig. 2 shows relations between physical constitution (expressed by Rohrer's Index*) and murmurs. Thin children showing low index in both groups seem to be more subject to murmurs especially in basal murmurs. But such relations between physical constitution and murmurs are not observed among those who require re-examination.

Fig. 3 shows relation between heart murmurs and the children's daily activities. Among the children belonging to the lower grader group,

\[
\begin{align*}
852 & \text{ male children} \\
816 & \text{ female children}
\end{align*}
\]

\[
\begin{align*}
\text{total} \\
\text{basal syst. m.} \\
\text{apical syst. m.} \\
\text{m. at lower left stern border} \\
\text{m. to be re-exam.}
\end{align*}
\]

\[
\begin{align*}
\text{total} \\
\text{basal syst. m.} \\
\text{apical syst. m.} \\
\text{m. at lower left stern border} \\
\text{m. to be re-exam.}
\end{align*}
\]

\[
\begin{align*}
\text{1} & \text{ 2} & \text{ 3} & \text{ 4} & \text{ 5} & \text{ 6}
\end{align*}
\]

\[
\begin{align*}
\text{1} & \text{ 2} & \text{ 3} & \text{ 4} & \text{ 5} & \text{ 6}
\end{align*}
\]

* \( (\text{body weight by gram}) \times 100 \times 100 (\text{body length by cm.})^3 \)

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those whose activities are active have less murmurs throughout the cardiac regions than those who are inactive. But among the children belonging to the upper grader group, those whose activities are active have less murmurs at the basal region and more murmurs at the apical region such relationship is not observed among those who require re-examination.

2) Heart murmurs detected by PCG.

It is evident that murmurs are detected by PCG more easily than auscultation. Undoubtedly PCG exceeds the scope of a stethoscope; 37 out of 40 cases showing no heart murmurs in auscultation disclosed murmurs by PCG in a quiet room with children kept at a supine position.

And normal respiratory splitting of second sound and normal third sound were observed in almost all cases on PCG.

3) Differential diagnosis of heart murmurs

(a) Auscultatory criteria for screening

Children having murmurs louder than Grade 3 or less than Grade 2 but with suspected abnormalities of heart sounds and/or murmurs occupy 58 cases out of 1668 children.

Out of the 22 cases screened because of their murmurs above Grade 3, 8 cases were found to have heart diseases, and out of 36 cases having

* Expressed by Rohrer's index \( \frac{\text{body weight by gram} \times 100 \times 100}{\text{body length by cm}^3} \)
murmurs less than Grade 2, but with suggested abnormalities, 2 cases were found to have heart diseases.

Organic heart diseases were not found by further examination out of the following two groups: one group consisted of 75 children screened by other means than auscultation and a control group consisted of 199 children showing no abnormalities by auscultation.

(b) Phonocardiographic differentiation of heart murmurs which are to be diagnosed only by well experienced auscultation.

Table III shows the results of phonocardiographic examination of 58 cases screened by auscultation. Twenty-two children having Grade 3 or more murmurs are divided into three groups: a group of 7 cases of organic heart diseases, a group of 11 cases of functional systolic murmurs and a group of 4 cases whose diagnoses were left undecided. Thirty-six cases with murmurs less than Grade 2 but having suspected abnormalities of heart sounds and/or murmurs were divided into two groups: a group of 22 cases of functional murmurs and a group of 14 cases whose diagnoses were left undecided.

The right column of table II shows the results of the second phonocardiographic examination performed a month later for 18 cases whose diagnoses had been left undecided. One case previously suspected of VSD was confirmed to be VSD. Two cases suspected of ASD and one case suspected of MI proved to be negative.

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Fig. 3. Influences of daily life activity to heart murmurs among primary school children.

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This second PCG examination revealed that there were 12 cases of diastolic murmurs of unknown cause. These 12 cases consisted of 9 cases whose diastolic murmurs had been left undifferentiated, and 3 cases which had been previously suspected of MS and on second PCG examination considered to be the same as the above 9 cases.

§ 4. Discussion

The prevalence rate of heart murmurs detected by auscultation ranges from about 10% to 80% depending upon reporters. This is because the appearance of heart murmurs is influenced by many factors. Position of the subject is one of factors, and generally speaking murmurs increases their intensity in a lying position over a sitting position.

The present study revealed 40% of the cases have more than Grade I murmurs at least at one region in a sitting position.

It is generally believed that murmurs at the apical or the lower left sternal border become less prevalent as age advances, while murmurs at the basal region becomes more prevalent. The same trend is observed in the present study, especially among the females.

Functional murmurs are more prevalent among the children. A thin chest wall of children seems to play a role of making transmission of murmurs easier. Actually an investigation about relations between physical constitution and murmurs revealed that thin children were more subjected to heart murmurs (especially basal heart murmurs).

It is believed that heart murmurs become louder as heart beat is more accelerated. According to the author's impression, children having loud functional systolic murmurs over the apical or the inner apical region seem to be often overdiagnosed by school physicians as pathologic, but many children with STILL's murmurs over the apical or the inner apical region are active in their daily life. Therefore, further study was carried out in order to clarify whether or not daily life activities influence the prevalence rate of heart murmurs at rest. Among the lower grade group those who were

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**Table II** Results of PCG of children screened positive on auscultation

<table>
<thead>
<tr>
<th>Auscultatory findings</th>
<th>Initial phonocardiographic examination</th>
<th>Diagnosis left undecided</th>
<th>Second phonocardiographic examination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pathologic murmurs</td>
<td>Functional murmurs</td>
<td></td>
</tr>
<tr>
<td>Murmurs of Grade 3 or more</td>
<td>VSD ; 1</td>
<td>ASD ; 1</td>
<td>Normal ; 1</td>
</tr>
<tr>
<td></td>
<td>ASD ; 1</td>
<td>PDA ; 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHD ; 1</td>
<td>M I ; 1</td>
<td>M I ; 1</td>
</tr>
<tr>
<td></td>
<td>MSI ; 1</td>
<td>M S ; 1</td>
<td>Diastolic #2 murmurs ; 2</td>
</tr>
<tr>
<td></td>
<td>M I ; 1</td>
<td>Diastolic #2 murmurs ; 1</td>
<td></td>
</tr>
<tr>
<td>22 cases</td>
<td>Subtotal ; 7</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Murmurs less than Grade 2, but accompanied by abnormalities of heart sound and/or murmurs</td>
<td>0</td>
<td>22</td>
<td>VSD ; 1</td>
</tr>
<tr>
<td></td>
<td>Subtotal ; 7</td>
<td>33</td>
<td>VSD ; 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>58 cases (100.0)</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

* 1. Second examination was carried out a month later of children whose diagnoses were left undecided in the initial examination.

* 2. cf. Chapter 1. § 4.

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active in their daily life showed less prevalence of murmurs at various check points. But among the upper grader group, those who were active in their daily life showed murmurs less frequently at the basal region and more frequently at the apical region.

(2) Phonocardiographic findings

The author's phonocardiographic study revealed almost all children had systolic functional murmurs at a supine position. So it can be said that there are few children without murmurs. Besides, a normal respiratory splitting of 2nd sound was found in all cases if a slight splitting of 2nd sound which was observed only in inspiratory phase was included and normal 3rd sound was also found in almost all cases if the minimal 3rd sound was included.

(3) Differential diagnosis of heart murmurs

(a) Auscultatory criteria for screening

Stethoscopic examination should not be neglected as a means of diagnosing heart diseases in the presence of many advanced means which are available now. For earlier diagnosis, stethoscopic examination is indispensable. With the knowledge of heart sounds and murmurs of children, especially that of functional murmurs, the physicians are able to diagnose almost all heart diseases among children by auscultation. As a screening means, auscultation plays a very important role. Not to overlook pathologic is more required in screening than to confirm cases in diagnosis. Therefore, not only murmurs louder than Grade 3, but also murmurs less than Grade 2 but with possible pathologic qualities of murmurs and/or accompanied by accentuation, weakening or splitting of heart sound were screened positive.

Among the children those who were screened according to the criteria described above accounted for 3.5%. About one sixth of the children screened had heart diseases. The rest five sixths were false positive. Four fifths of heart disease cases were screened by the loudness of their murmurs, and one fifth by other findings than loudness. Therefore, murmurs less than Grade 2 but accompanied by abnormal findings of heart murmurs and/or sounds should be adopted as screening criteria.

(b) Phonocardiographic differentiation of heart murmurs which are to be diagnosed only by well experienced auscultation.

PCG examination revealed that the murmurs of 11 cases of 22 cases which had murmurs louder than Grade 3 were functional. The murmurs of 8 cases of these 11 cases referred to as so called STILL's murmurs were easily diagnosed as nonpathologic by PCG. A considerably trained ear may adequately auscultate such murmurs. But because of their loudness such murmurs are often overdiagnosed as pathologic by many school physicians. Three cases of 11 cases whose murmurs were revealed as functional had murmurs (non musical and loud) accompanied by splitting of 2nd sound at the pulmonic area. So they were difficult to be differentiated from ASD by auscultation. Phonocardiographically, however, they were diagnosed as functional murmurs, because their splitting of 2nd sound was not fixed, and accentuation of II\textsubscript{p} was absent.

One of 4 cases of which diagnoses were left undecided showed diastolic murmurs of unknown cause at the apical region.

Twenty-two cases out of 36 cases screened by other findings than loudness of murmurs were revealed to be nonpathologic but with functional murmurs. Nine cases of these 22 cases had been suspected by auscultation to be ASD, because they were accompanied by splitting of 2nd sound at both inspiratory and expiratory phases. PCG cleared the suspicion by showing that the splitting of 2nd sound was not fixed and the accentuation of II\textsubscript{p} was absent. Other 13 cases revealed to be functional had been suspected of MI because of the quality of their systolic murmurs at the apical region. However, PCG cleared the suspicion by showing that there was a gap between the first sound and the beginning of the murmur and that the shape of murmur was spindle form.

Eight of 14 cases of which diagnoses had been left undecided had middiastolic murmurs on the apical region or the lower left sternal border.

A month later, 18 cases which had not been diagnosed by the first PCG examination were examined again phonocardiographically. One case suspected of VSD with findings at the left sternal border showed on 2nd PCG examination

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typical findings of VSD at the area somewhat inner than in the previous examination. Two cases suspected of ASD with a considerably fixed splitting of 2nd sound at a supine position revealed innocent at a sitting position which clearly made a normal respiratory splitting of 2nd sound. The murmur of one case with suspected MI disappeared when respiration was briefly stopped. As a result, a diagnosis of "cardiorespiratory murmur" was established.

The second PCG examination showed mid-diastolic murmurs in 12 cases. These diastolic murmurs resemble those observed in the early stadium of rheumatic carditis, but they were not accompanied by systolic regurgitation murmurs or by clinical symptoms suggesting active rheumatism. Besides, simultaneous ESR proved normal (Table IV).

<table>
<thead>
<tr>
<th>Table VI Apical diastolic murmurs and ESR</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESR (mm/h)</td>
</tr>
<tr>
<td>Subject</td>
</tr>
<tr>
<td>No. of children with diastolic murmurs</td>
</tr>
<tr>
<td>Healthy children</td>
</tr>
</tbody>
</table>

*2. Selected at random out of normal children who were further-examined.

All 12 cases of mid-diastolic murmurs were examined again phonocardiographically a year later revealing one case and three cases with an increase and a decrease in the intensity of murmurs, respectively; seven cases remained unchanged and one case showed the disappearance of the murmur. ECG and chest X-ray films of these 12 cases showed no abnormalities a year later.

The PCG examination of two years later showed that the murmur of one case which had increased their intensity a year later disclosed a decrease and that the murmurs of two of three cases which had decreased their intensity a year later completely disappeared. Out of seven cases which revealed to be with the same findings as the initial examination a year later, five cases could be followed two years later revealing four cases out of these 5 cases to be with the same findings as the initial examination, and the rest one case revealed no murmurs. No cases of middiastolic murmurs changed to MS during the two years. Therefore, the author considers such middiastolic murmurs are not organic. Such murmurs will be discussed in the chapter IV.

§ 5. Conclusion

(1) About forty percent of the school children studied have some kinds of heart murmurs by auscultation. Murmurs at the basal region become more prevalent and murmurs at the apical region become less prevalent as age advances. Thin children are rather subjected to heart murmurs, especially at the basal region. Active children in daily life have less murmurs at the basal region and more murmurs at the apical region than inactive children at rest.

(2) Almost all the children revealed phonocardiographically to have functional systolic murmurs, normal third sounds and normal respiratory splitting of 2nd sound.

(3) Fifty-eight children (3.5% of all the children studied) were screened positive on auscultatory criteria (murmurs louder than Grade 3, or murmurs less than Grade 2 but accompanied by other abnormal findings as abnormal qualities of murmurs, accentuation, weakening, splitting of heart sounds).

None of the children whose heart diseases had been denied on auscultation were found to be pathologic by further examination.

(4) Forty of 58 children (about 70%) screened positive by auscultation were easily diagnosed by ordinary phonocardiographic examination. Simple improvement or modification in examination such as changing body position or brief stopping of respiration enabled the examiner to accurately diagnose another 10%.

In obtaining the results so far mentioned, no specific knowledges or experience seemed necessary; the techniques of examination stated may be successfully performed by school physicians. Nor was photographic recording of murmurs needed. It is sufficient to employ only an oscilloscope and an earphone. Not necessarily a soundproof room is needed but a
TABLE V  APPEARANCE RATES OF HEART MURMURS SPECIFIC TO EACH HEART DISEASE ON EACH NOMINAL FREQUENCY BAND

<table>
<thead>
<tr>
<th>Classification of heart murmurs</th>
<th>No. of cases</th>
<th>Appearance rates (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nominal frequency bands (cps)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Aortic insufficiency murmurs</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Aortic stenosis murmurs</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>Mitral insufficiency murmurs</td>
<td>62</td>
<td>31</td>
</tr>
<tr>
<td>Mitral stenosis murmurs</td>
<td>39</td>
<td>100</td>
</tr>
<tr>
<td>Murmurs of VSD</td>
<td>58</td>
<td>86</td>
</tr>
<tr>
<td>Murmurs of ASD</td>
<td>30</td>
<td>73</td>
</tr>
<tr>
<td>Murmurs of PDA</td>
<td>12</td>
<td>83</td>
</tr>
<tr>
<td>Functional systolic murmurs</td>
<td>70</td>
<td>33</td>
</tr>
<tr>
<td>Functional diastolic murmurs</td>
<td>30</td>
<td>60</td>
</tr>
</tbody>
</table>

Pick up :  air conducting type, crystal microphone.
Characteristics of filter : high pass filter, different cut-off frequency, same slope of 18 db/oct.

quiet room. If the re-examination, which is now carried out by specialists, were adopted by school physicians with PCG, a heart disease control program could cover more children in mass examination. Besides being contributable to dissemination of the program, the present method may further the effectiveness of auscultation for school physicians.

What’s more, if middiastolic murmurs at the apex or the lower left sternal border were regarded as functional, PCG examination would play a more important role in a heart disease control program among the children.

II. HOW TO USE PCG FOR MASS EXAMINATION

§ 1. Introduction

This chapter deals with the use of PCG for mass examination, especially for re-examination.

The number of examinee subjected to phonocardiography is rather limited. As described in chapter I, PCG examination is to be favorably applied to cases screened by an auscultation. In a heart disease control program as in the present experience, PCG is desirable for re-examination and further examination. PCG adopted for re-examination is chiefly meant to exclude functional murmurs, not to perform so strictly an analysis of pathologic findings. Concerning cardiac examination one of the most common problems is the differentiation of apical functional systolic murmur from MI and basal functional systolic murmur from ASD. In chapter I, it was described that there were not a few cases of diastolic murmurs which would rather have been regarded as functional murmurs. But most of diastolic murmurs are generally believed to be pathologic. Therefore, all cases with diastolic murmurs should be further-examined.

It takes too much time to analyse heart murmurs on all nominal frequency bands. Therefore, the following study was made in order to find out if nominal frequency bands selectively adopted really represented the experimental results.

§ 2. Materials and Methods

One hundred cases were chosen respectively out of cases of aquired valvular heart diseases, congenital heart diseases and functional murmurs which were diagnosed in a routine mass examination for 1962. Since a defect was counted individually in combined cases, acquired valvular heart diseases exceeded 100 in number.

In the present study the author used the same PCG apparatus described in chapter I. The bands

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are divided by filters into five bands, the nominal frequency of which are 30, 50, 100, 200 and 400 cps.

Checking points on the chest for murmurs were also studied.

§ 3. Results

Appearance rates of heart murmurs specific to typical heart diseases are shown in reference to each nominal frequency band in Table V.

All of aortic insufficiency murmurs which referred to as typical high pitched murmurs and all of mitral stenosis murmurs referred to as typical low pitched murmurs were recorded in 200 and 400 cps bands, and in 30, 50 and 100 cps bands, respectively. Therefore, when both 100 cps and 200 cps bands were applied, all of low pitched and high pitched murmurs would be recorded.

§ 4. Discussion

There are many reports made of frequency distribution of heart murmurs\(^{37-42}\). According to Luisada\(^{37}\), the frequencies of normal heart sounds, mitral stenosis murmurs and aortic insufficiency murmurs range from 50 to 150 cps, 40 to 100 cps and 200 to 700 cps, respectively. A recent spectro-phonocardiographic study\(^{43-44}\) reveals that the frequency of an over tone is considerably high pitched, but a chief component is in a range as reported by Luisada.

Both bands of 100 cps and 200 cps nominal frequency of the present PCG record murmurs in a range of 50 to 200 and 100 to 400 cps, respectively. Therefore, only those two bands were sufficient in re-examination. Actually, most of high pitched aortic insufficiency murmurs and low pitched mitral stenosis murmurs were recorded on 100 cps or 200 cps nominal frequency bands satisfactorily.

Normal first and second heart sounds, as well as abnormal heart sound which suggested any kinds of heart diseases, were recorded on either a 100 cps or a 200 cps nominal frequency band. The use of two bands resulted in an increased efficiency in re-examination.

When checking points are limited to five regions; the left and right basal regions, the Erb's region, the lower left sternal border and the apical region, a few heart murmurs localized a small area may be missed. But almost all the pathologic murmurs checked up are accompa
died by abnormal heart sounds, it seems safe to select five checking points in representing general data. It has been revealed that a soundproof room is not always necessary, so long as examination is carried on in a quiet room.

For re-examination the recording of murmurs is not necessary; observations on oscilloscope and check up by earphone are sufficient. An earphone is indispensable in securing the selective ability of sense of hearing. Application of an earphone to an ear (not to both ears) is recommended in controlling outside noise or in avoiding the exhaustion of hearing.

§ 5. Conclusion

When PCG is used for re-examination of a heart disease control program, both 100 cps and 200 cps nominal frequency bands are sufficient and the regions for observation can be limited to the left and right basal regions, the Erb's region, the lower left sternal border and the apical region.

Practically observations on a 200 cps nominal frequency band are first to be carried at the five regions described above and then on a 100 cps nominal frequency band at the apical region.

III. PCG EXAMINATION FOR FURTHER EXAMINATION

§ 1. Introduction

PCG examination is very beneficial in diagnosing heart diseases since it makes up for the limit of hearing and individual differences in auscultation. With PCG one can diagnose complex cases. But as PCG records all the components of heart murmurs and sounds simultaneously, auscultation or an application of an earphone should always be taken into consideration. In a routine mass examination of the program, PCG is applied in diagnosing complex cases.

In this chapter discussion is made how to differentiate non-pathologic changes of heart sounds and/or murmurs from pathologic ones, whose differentiation is difficult by auscultation.

§ 2. Materials and Methods

Seven hundred and twenty-five cases were chosen out of the children who had been suspected of organic heart diseases by auscultation of a routine mass examination for 1962. To evaluate how PCG
### Table VI  Comparison of diagnoses by PCG and by auscultation

<table>
<thead>
<tr>
<th>Diagnosis by auscultation</th>
<th>No. of cases</th>
<th>No. and rate of accordance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No.</td>
</tr>
<tr>
<td>Ventricular septal defect</td>
<td>140</td>
<td>135</td>
</tr>
<tr>
<td>Atrial septal defect</td>
<td>78</td>
<td>65</td>
</tr>
<tr>
<td>Patent ductus arteriosus</td>
<td>34</td>
<td>33</td>
</tr>
<tr>
<td>Undefined type and others</td>
<td>73</td>
<td>65</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>325</strong></td>
<td><strong>298</strong></td>
</tr>
<tr>
<td>Mitral valvular disease</td>
<td>333</td>
<td>208</td>
</tr>
<tr>
<td>Aortic valvular disease</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>Combined valvular disease</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>Undefined type and others</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>377</strong></td>
<td><strong>243</strong></td>
</tr>
<tr>
<td>Congenital or acquired undecided</td>
<td>23</td>
<td>20</td>
</tr>
</tbody>
</table>

*1. No. of cases diagnosed by PCG × 100 (%) / No. of cases diagnosed by auscultation

*2. Diagnoses by PCG of 9 cases were denied on ECG and chest X-ray.

*3. Including cases whose diagnoses were established later on PCG.

### Table VII  Results of PCG examination of cases which were auscultatorily suspected of mitral valvular disease

<table>
<thead>
<tr>
<th>1962 PCG diagnoses</th>
<th>No. of cases</th>
<th>No. of cases followed up</th>
<th>Phonocardiographic diagnoses</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSI</td>
<td>39</td>
<td>28 23</td>
<td>MSI 1 + MS?</td>
</tr>
<tr>
<td>MI</td>
<td>56</td>
<td>39 35 1</td>
<td>MI? MS?</td>
</tr>
<tr>
<td>MS</td>
<td>21</td>
<td>15 14 1</td>
<td>MS?</td>
</tr>
<tr>
<td>MI + MS?</td>
<td>8</td>
<td>5 2 2</td>
<td>MI?</td>
</tr>
<tr>
<td>MS + MI?</td>
<td>3</td>
<td>1 1</td>
<td>MI?</td>
</tr>
<tr>
<td>MSI?</td>
<td>12</td>
<td>9 1 1 1 2 4</td>
<td>MI?</td>
</tr>
<tr>
<td>MI?</td>
<td>26</td>
<td>20 1 10</td>
<td>MI?</td>
</tr>
<tr>
<td>MS?</td>
<td>43</td>
<td>34 4 8 20 2</td>
<td>MI?</td>
</tr>
<tr>
<td>FDM</td>
<td>38</td>
<td>25 4 21 4</td>
<td>MI?</td>
</tr>
<tr>
<td>FSM</td>
<td>87</td>
<td>42</td>
<td>MI?</td>
</tr>
</tbody>
</table>

*Japanese Circulation Journal Vol. 30, April 1966*
examination actually useful in diagnosing heart diseases, the results obtained only by auscultation were compared with those obtained by PCG plus auscultation.

The rate of correspondence was low for a group of mitral type, so that the findings of followed-up 218 cases of mitral type were analysed in 1963.

§ 3. Results

Table VI shows the results of PCG examination of children who had been auscultatorily suspected of organic heart diseases in routine mass examination for 1962. Ninety-two percent of cases which had been auscultatorily suspected or diagnosed as CHD were confirmed by PCG. Those accounting for 96.3% of VSD, 97.0% of PDA and 83.3% of ASD were confirmed phonocardiographically. On the other hand, only 65% of cases of AVHD were confirmed. Of cases with auscultatory diagnosis or suspicion of mitral heart diseases, 63% were confirmed on PCG.

Table VII shows the results of PCG examination of 333 cases which auscultatorily diagnosed or suspected of mitral valvular heart diseases. The right half of the table shows the results of PCG examination for 1963.

It is revealed that some cases of mitral valvular heart diseases were cleared or had their pathologic findings changed in one year.

§ 4. Discussion

(1) Congenital heart diseases

The rate of correspondence in auscultatory diagnosis and phonocardiographical diagnosis proved 92% for CHD. The rates of correspondence for VSD and PDA are 96.4% and 97.0%, respectively, which are significantly high. But the rate of correspondence for ASD was 83.3% which is lower than other types of CHD.

All of the 13 children who were phonocardiographically denied ASD had splitting of second sound in both inspiratory and expiratory phases as well as systolic murmurs at the basal region when they were auscultated. PCG examination revealed that the width of splitting of second sound clearly moved on respirations, that they were not accompanied by accentuation of IIp or diastolic rumble at the lower left sternal border with the three exceptional cases of retracted chest*. Therefore auscultatory diagnosis or suspicion of ASD was denied by PCG 24–28). Out of these 13 cases, there were 3 cases of retracted chest, 4 cases of flat chest and 2 cases of tachycardia with a rate more than 110/min.

Nine cases of 65 cases which were considered to be ASD both by auscultation and PCG revealed to have no heart diseases on chest X-ray and ECG. Out of these 9 cases, there were five cases of flat chest, one case of retracted chest and one case of tachycardia with a rate of more than 110/min. These factors such as, flat chest, retracted chest and tachycardia often lead an examiner to overdiagnose ASD. Besides, the children with a flat or depressed chest often show an enlarged silhouette of heart in a posterior-anterior view of X-ray, often revealing the IRBBB pattern on V1 lead of ECG. Therefore, a diagnosis should be carefully established when children have a flat or depressed chest or tachycardia. But an enlarged silhouette of the heart of cases with a flat or retracted chest is not observed on an oblique position, and it is not accompanied by an increased width or density of hilar branches of the pulmonary artery. In cases of a flat chest, most of the IRBBB pattern of V1 lead have rSr'type (r>r') or slight notching of QRS complex. The V1 lead of a depressed chest case shows the rsr' or qr pattern, and V1 shows low voltage which, however, is tend to increase suddenly in V2 or V5 lead. Mass examination requires a check up of the abnormalities of the chest. Besides, when children are under such conditions as physically activated, emotionally excited, fever, anemia or hyperthyroidism, phonocardiographic findings somewhat resemble those of organic cases17(a)43(a)49(a)7). Therefore, under these conditions no diagnosis should be established without typical and specific findings for disease concerned. And follow-up should be referred to.

Seven cases in a group of 23 cases whose

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* About 60% of children with a depressed chest of moderate degree or more have diastolic murmurs of spindle form and a short duration at the lower left sternal border.

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Fig. 4. A case auscultatorily overdiagnosed as AI. PCG shows protodiastolic extrasounds following a splitted 2nd sound.

A: on 100 cps nominal frequency band,
B: on 200 cps nominal frequency band,
C: on 400 cps nominal frequency band.

Fig. 5. A case of MSI whose murmurs disappeared a year later.

A: on 100 cps nominal frequency band,
B: on 200 cps nominal frequency band,
C: on 400 cps nominal frequency band.
Fig. 6. A case of MSI suspected of rheumatic activity by accelerated ESR and elevated ASLO titer.
A; on 100 cps nominal frequency band,
B; on 200 cps nominal frequency band,
C; on 400 cps nominal frequency band.

Fig. 7. A case of MI whose murmurs disappeared a year later; both 1st and 2nd sounds were within normal ranges, no abnormalities were detected on both chest X-ray and ECG.
A; on 100 cps nominal frequency band,
B; on 200 cps nominal frequency band,
C; on 400 cps nominal frequency band.

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diagnoses had been left undecided congenital or acquired were rather suggestive of MS than of ASD, because diastolic murmurs at the lower left sternal border or the inner apical region were more remarkable than the degree of splitting of 2nd sound or systolic murmurs at the basal region. However, fixed splitting of 2nd sound was confirmed on PCG. So were IRBBB on ECG, and enlarged silhouette of the heart and increased density of the pulmonary artery on chest X-ray. Therefore, these 7 cases were diagnosed finally as ASD or Lutembacher's syndrome.

(2) Acquired valvular heart diseases

The rate of correspondence for aortic valvular heart disease was the highest of the acquired valvular heart diseases tested. Only one case of AI auscultatorily diagnosed showed no correspondence. This case was overdiagnosed by a confusion between protodiastolic extrasounds following a splitted 2nd sound (Fig. 4) and diastolic murmur specific to aortic regurgitation.

Four cases out of 14 cases with combined defects auscultatorily diagnosed did not show correspondence on PCG. They were overdiagnosed by confusing aortic stenosis murmur transmitted to the apical region with murmur of MI in one case and by confusing Austin-Flint's murmurs with those of MS in three cases.

Discussion was made of the problems about mitral valvular heart diseases with a low rate of correspondence by dividing them into two groups.

(a) Confirmed cases of mitral valvular heart diseases.

During the present study it was revealed that several cases of mitral valvular heart diseases diagnosed phonocardiographically were cured or improved a year later. Among young children valvular diseases which are apparently advanced and incurable occasionally turn out to be improving\(^{49-50}\). Not all the cases of mitral valvular heart diseases which showed improvement were not analysed, but the cases which were cleared of their symptoms were analysed.

One case of mitral stenoininsufficiency which was cleared a year later showed a weak first sound followed by rough holosystolic murmur and loud middiastolic murmur the shape of which was cressendo-decrescendo type on the first examination (the duration of diastolic murmur was longer than that of Carey Coomb's murmur) (Fig. 5). Chest X-ray films of this case showed a slight enlargement of heart silhouette. This case might be a so called 'carditis with insidious onset'\(^{49,51}\) and the murmurs could be explained by relative mitral stenoininsufficiency or by organic changes on the mitral valve, which are slight enough to recover\(^{49,52}\). Because three cases out of seven cases of MSI showing the same pattern of murmurs on PCG examination for 1964 showed a high titer on ASLO and increased ESR and were diagnosed as the so called 'carditis with insidious onset' (Fig. 6). When it comes to diagnosing valvular heart diseases of the young, active rheumatic carditis should be always taken into consideration\(^{49,53}\). When the activity was suspected ASLO, CRP and ESR should be applied. However, as there is no practical means for diagnosing subclinical rheumatic carditis\(^{53,54}\), the only way to diagnose subclinical cases is a follow-up observation.

One case of MI showed faint high pitched holosystolic murmur which began soon after the chief component of normal first sound (Fig. 7), it showed no changes on chest X-ray or on ECG. This case was cleared of the MI a year later. Generally, cases of mitral valvular heart diseases with faint systolic murmurs, normal first and second sounds are slight cases showing no abnormalities on chest X-ray or on ECG. These observations suggest that mitral valve will see its lesion improved so long as the involvement is slight.

(b) Cases phonocardiographically suspected of mitral valvular heart diseases

All of the 26 cases which were suspected of MI by PCG had high pitched systolic murmurs at the apical region. These were divided into three groups as to the shape of murmurs. Group 1 consisted of possible holosystolic murmur with a considerably low amplitude. Group 2, loud systolic murmur which began soon after the chief component of first sound with a duration not covering all the systolic phase.

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Group 3, late systolic murmur or high pitched crescendo murmur with obscure beginning. Fourteen cases belonged to group 1, five cases to group 2 and seven cases to group 3 (Fig. 8).

Twenty cases were followed for a year revealing one case in group 2 diagnosed as MI. Six cases out of the followed-up 12 cases in group 1, one case out of the followed-up 4 cases in group 2 and three cases of the followed-up 4 cases in group 3 still remained with suspicion of MI as a year before. The rest nine cases showed no findings suggestive of MI.

The murmurs of cases belonging to group 1 were too faint to be detected in a noisy room. These cases are not accompanied with any abnormal findings on chest X-ray or ECG. No cases changed to obvious MI during the follow up. The problem how to deal with such faint high-pitched murmurs will be discussed in near future. The PCG apparatus is desired which can satisfactorily record faint high pitched murmurs. The murmurs which belong to group 3, especially late systolic murmurs, are often observed soon after rheumatic pericarditis, and it is considered that they are of pericardial origin. Sometimes, they are said to be functional. But some reporters state that late systolic murmurs are of mitral insufficiency. Actually, it is difficult to differentiate group 3 murmurs, especially crescendo type murmurs, from faint high pitched holosystolic murmurs of MI. Therefore, cases with such murmurs are followed up with a suspicion of mitral insufficiency in the present program.

The findings of 34 followed-up cases of 43 cases phonocardiographically suspected of mitral stenosis because of diastolic murmurs at the apical or the lower left sternal border were analysed below. One year later, four cases became mitral stenosis, eight cases still remained with a suspicion of mitral stenosis. Twenty cases decreased their intensity of murmurs (they are classified as functional diastolic murmurs in table 6) and two cases were cleared of their murmurs.

Then initial PCG findings of these 34 cases which had been followed were re-analysed. The findings of four cases which developed into MS were as follows; the duration of murmur was short; no presystolic murmur; no accentu-
ation of first sound; no opening snap of the mitral valve; diastolic murmur consisted not only of low frequency component, but also of high frequency component; three cases showed no third sound, and in one case third sound was almost masked by murmur. Rheumatic activity was not observed during the follow-up for these 4 cases. Therefore, it seems reasonable to diagnose these cases as an incipient stage of MS.

The findings of 22 cases which showed any improvement were as follows: no presystolic murmur; no accentuation of first sound; no opening snap; in 12 cases obvious third sound was observed and 7 cases of them showed a gap between third sound and murmur. Such murmurs are crescendo-decrescendo in shape and regular in wave, short in duration and frequency ranging from 50 to 100 cps. They are sometimes loud enough to be taken for MS. But the characteristics described above differ from those of mitral stenosis murmurs. Therefore, they are considered to be functional diastolic murmurs as those described in the chapter 1. Such murmurs will be discussed in the chapter IV.

§ 5. Conclusion

The rate of correspondence in diagnosis between auscultation and PCG was 92% for CHD on an average. VSD and PDA showed high rates but ASD revealed a relatively low rate. A flat or depressed chest or tachycardia in children often leads to an overdiagnose of ASD. On the other hand, the rate of correspondence for AVHD was 65% on an average.

Of AVHD, the correspondence rate for mitral valvular heart disease was the lowest. Besides, cases of mitral valvular heart diseases which had been diagnosed by PCG often result in the disappearance of the murmurs specific to mitral valvular heart diseases, or in altered findings. Since the children studied are in an age group subjected to rheumatic fever, it is important to check up if children show an insidious onset of rheumatic carditis or unmanifested carditis in diagnosing valvular heart diseases.

Criteria for PCG diagnosis are not yet completed. Therefore, cases on a border line between normals and heart disease cases should be referred to as "possible heart diseases" and a follow-up observation should be performed.

As described above, PCG is not capable of diagnosing all heart disease cases. But PCG is indispensable in diagnosing heart diseases as shown in the following example. Out of 333 cases auscultatorily diagnosed or suspected of mitral valvular diseases, PCG revealed functional systolic murmurs in 87 cases and diastolic murmurs which can be rationally regarded as functional in 38 cases.

IV. PHYSIOLOGIC DIASTOLIC MURMURS

§ 1. Introduction

It has been generally considered that diastolic murmurs are audible only under pathologic conditions. When apical diastolic murmurs were heard in children having no organic changes on the mitral valve, changes in hemodynamics such as described below seem etiologically significant: 1) increased blood flow across a normal mitral valve, 2) blood flow across a normal mitral valve into a dilated left ventricle, and 3) extravalvular causes leading to obstruction of the mitral orifice. It is generally believed that no diastolic murmurs are physiologic. Children loaded with exercise reportedly show diastolic rumble for a while. However, such exercise is out of physiologic conditions and diastolic rumble is considered to be nonphysiologic.

Unexpectedly many children with diastolic murmurs at the apical region or the lower left sternal border were detected by mass examination. Clinical examinations and follow-up observations suggested that more than half of the diastolic murmurs were functional or physiologic (Table VIII). MS is responsible for diastolic murmurs as the cause of organic changes; MI, rheumatic carditis, CHD, anemia etc are responsible for diastolic murmurs of pathologic but not organic origin. On the other hand, there are many diastolic murmurs which showed different characteristics on PCG and they are referred to as functional or physiologic diastolic murmurs in the present study. Among the children with such diastolic murmurs there are a few children with depressed chest which is responsi-

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TABLE VIII  Classification of apical diastolic murmurs detected by mass examination for the young

April—October, 1964.

<table>
<thead>
<tr>
<th>Group</th>
<th>Murmurs No. of cases</th>
<th>Organic MS (MSI)</th>
<th>Organic MS? (MSI?)</th>
<th>Pathologic MI</th>
<th>Carditis</th>
<th>CHD</th>
<th>Others</th>
<th>Abnormalities thoracic cage</th>
<th>Functional Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower grades of primary school</td>
<td>77</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>6</td>
<td>4</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper grades of primary school</td>
<td>54</td>
<td>2</td>
<td>3</td>
<td>7</td>
<td>9</td>
<td>4</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junior high school</td>
<td>73</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>13</td>
<td>7</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>High school</td>
<td>64</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>8</td>
<td>7</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Total (per cent)</td>
<td>268 (100.0)</td>
<td>16</td>
<td>15</td>
<td>17</td>
<td>2</td>
<td>15</td>
<td>24</td>
<td>16 (6.0)</td>
<td>138 (51.5)</td>
</tr>
</tbody>
</table>

MS; mitral stenosis, MI; mitral insufficiency, CHD; congenital heart disease.

* Diastolic murmurs which are audible at the lower left sternal border of subjects with a depressed chest increase their intensity at inspiratory phase; murmurs on PCG differ a little in shape from functional murmurs of subjects without chest deformity.

§ 2. Materials and Methods

In 1964 to obtain the prevalence rate of functional or physiologic diastolic murmurs a few classes out of each grade of a primary school, of a junior high school and of a senior high school in Osaka City were chosen at random (of the primary school lower grades were 251 and upper grades 391, junior high school students were 597 and senior high school students were 590).

All the children chosen were auscultated by a specialist in a sitting and a supine position. Fifty-three children who were auscultatorily suspected of having diastolic murmurs were examined phonocardiographically. Besides, ECG, chest X-ray, and if necessary blood pressure, blood and serological tests were performed in combination with PCG. Twenty-six cases were found with functional or physiologic diastolic murmurs.

Besides 26 cases, 112 cases, of the same kind of diastolic murmurs which were found in a routine mass examination between April and October, 1964 were studied to get the incidence rate of abnormal findings for various examination. Chest X-ray was taken by Odela camera on a 7 cm × 7 cm film with a tube at standard distance of 2 meters from the film. Besides ECG of 12 leads, other leads were studied if necessary. Serological and blood examination were performed if necessary.

To evaluate these diastolic murmurs, a follow-up study was carried out for 91 cases which were found in the routine mass examination for 1962.

§ 3. Results

The prevalence rates of children having various kinds of diastolic murmurs at the apical region or the lower left sternal border were shown in table 9. The prevalence rate of diastolic murmurs on an average was 2.9% which included prolonged third sound and gallop rhythm which were auscultatorily difficult to differentiate from diastolic murmurs.

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It was relatively high as 6.4% for lower graders of primary school. Diastolic murmurs with a duration of over 0.10 sec or showing more than six vibrations on PCG were found in 1.7% on an average, and 4% for lower graders of primary school (Table IX).

Thirty-one cases phonocardiographically found to have diastolic murmurs were classified and shown in Table X. Twenty-six cases (84%) of 31 cases with diastolic murmurs at the apical or the lower left sternal border were phonocardiographically revealed to have functional or physiologic diastolic murmurs.

These diastolic murmurs have common characteristics by which differentiation from other pathologic diastolic murmurs were possible. These diastolic murmurs were further divided into three types, A, B and C by the characteristics of murmurs (Fig. 9). Type A murmurs are entirely different from pathologic murmurs (Fig. 10, 11) on PCG and type C murmurs somewhat resemble pathologic murmurs, while type B murmurs are intermediate.

Table XI shows the incidence rates of abnormal findings for cases with different types of murmurs. The incidence rate for abnormalities on ECG and/or chest X-ray is 9% on an average, which is relatively high for type B and C, but these abnormalities by themselves were too slight to be defined as pathologic. History of rheumatic fever was found in 22% of cases on an average. It was relatively high for type B and C. The abnormal ratios of ESR, CRP, ASLO and tests for cases of anemia were almost equivalent among the three types. ESR was accelerated in 12% on an average, ASLO
TABLE XI  Appearance rates of abnormalities for cases with functional diastolic murmurs detected by PCG.
April……October, 1964.

<table>
<thead>
<tr>
<th>Findings on PCG</th>
<th>No. and rates of cases with abnormal findings on ECG and/or chest X-ray</th>
<th>No. and rates of cases with history of rheumatic fever</th>
<th>No. of cases examined</th>
<th>No. of positive cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of murmurs</td>
<td>No. of cases</td>
<td>No. (per cent)</td>
<td>No. (per cent)</td>
<td>ESR</td>
</tr>
<tr>
<td>A</td>
<td>66</td>
<td>5 (7.6)</td>
<td>10 (15.2)</td>
<td>21</td>
</tr>
<tr>
<td>B</td>
<td>27</td>
<td>3 (11.1)</td>
<td>7 (25.0)</td>
<td>12</td>
</tr>
<tr>
<td>C</td>
<td>45</td>
<td>5 (11.1)</td>
<td>13 (28.9)</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>138</td>
<td>13 (9.4)</td>
<td>30 (21.7)</td>
<td>40 (100.0)</td>
</tr>
</tbody>
</table>

* Anemia; Hb < 70% and/or Ht < 30%, Positive on ESR; > 15 mm/h, Positive on ASLO; ≥ 250 units.

TABLE XII  Changes of the phonocardiographical findings of cases with functional diastolic murmurs

<table>
<thead>
<tr>
<th>Findings of first time</th>
<th>Findings of a year later or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of murmurs</td>
<td>Functional</td>
</tr>
<tr>
<td>A</td>
<td>45</td>
</tr>
<tr>
<td>B</td>
<td>22</td>
</tr>
<tr>
<td>C</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>91</td>
</tr>
<tr>
<td>MS?</td>
<td>3</td>
</tr>
</tbody>
</table>

MS; mitral stenosis.

Fig. 9.  Functional diastolic murmurs at the apical region (on 100 cps nominal frequency band).
A; Type A, B; Type B, C; Type C.
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Fig. 10. Three cases of MS (on 100 cps nominal frequency band).

Fig. 11. Apical diastolic murmurs caused by relative stenosis of mitral orifice (on 100 cps nominal frequency band).

A : A case of active rheumatic carditis,
B : A case of mitral insufficiency,
C : A case of ventricular septal defect.
was elevated in 14% ; anemia was found in 10% ; all cases were negative for CRP. Except one case with anemia, no cases proved positive for more than two tests.

Table XII shows the results of the follow-up of cases with these diastolic murmurs (some of them were once suspected of MS, and later rationally considered to be functional or physiologic and regarded as functional diastolic murmurs) in routine mass examination for 1962. Transition to another type was observed, but no cases changed to true organic mitral stenosis.

The right column of Table XII shows disappearance rates of murmurs. The murmurs disappeared in 23% on an average. The disappearance ratio was lower for type B than for type A, it was lower for C than for B.

The results of the follow-up of suspected cases of mitral stenosis were also shown in table XII for reference.

§ 4. Discussion

The prevalence rate of diastolic murmurs was 1.7% on an average, 4% for lower graders of primary school and 1.4% for senior high school students. It was high among the younger children. Regarding organic or pathologic diastolic murmurs no differences were observed in their prevalence rate. Therefore, differences in the prevalence rate of diastolic murmurs were referable to functional diastolic murmurs. The finding that the younger the children the more frequent these diastolic murmurs supports that these murmurs are not organic but rather functional or physiologic. This percentage 84% (Table X) is higher than 52% (Table VIII) among the cases with diastolic murmurs detected in routine mass examination. The above difference in percentage is reasonably explained by a finding that such functional or physiologic diastolic murmurs were so low pitched that they were overlooked by screening by school physicians resulting in a decreased prevalence rate during routine mass examination.

Those functional diastolic murmurs were best heard at a localized small portion around the apical region or the lower left sternal border especially at the site of apical beat or the spot a little upper from where third sound is best heard. They were also best heard in a supine position, especially soon after changing a position from standing to supine (Fig. 12). These murmurs increased their intensity at the beginning of expiratory phase in many cases. When Valsalva's maneuver was adopted the murmurs increased their intensity a few beats after release of the maneuver.

On the PCG (Fig. 9) the murmurs begin after a little gap after third sound. They are of crescendo-decrescendo type, with a short duration. Their frequency, being regular indi-
vidually, ranges from 50 to 100 cps. Presystolic murmur, accentuated first sound, elongated Q-1 interval or opening snap of mitral valve specific to cases with organic mitral stenosis (Fig. 10) are not observed. Murmurs having such characteristics on PCG are named type A functional diastolic murmurs by the present author. The murmurs are named type B, when their shape is a little irregular or they show no clear gap between third sound and diastolic murmurs. They are named type C, when third sound is covered with murmurs of an irregular shape. Type C diastolic murmurs are somewhat resemble Carey Coom's murmur or shunt rumble (Fig. 11). But type C murmurs are not accompanied by other pathologic findings on PCG.

The incidence rate of abnormalities of these diastolic murmurs on chest X-ray and/or ECG was 9% on an average, and these abnormalities were too slight to be defined as pathologic. Cases with such diastolic murmurs showed no rheumatic activity. But the history of rheumatic fever was found in 22% on an average. As the present study was mostly performed on children chosen by the screening procedure described in chapter 1, it reasonably revealed many cases with history of rheumatic fever. Children with diastolic murmurs of type B and C had more rheumatic history than those with type A murmurs. However many of those with diastolic murmurs were not remarkable as to ESR, CRP, ASLO or anemia. CRP was negative in all cases. With one exceptional case with anemia showing accelerated ESR, no cases were positive in more than two examinations.

Therefore, a follow-up observation was carried out revealing a transition to another type murmurs or disappearance of murmurs. On an average, 23% of the cases with functional diastolic murmurs had their murmurs cleared in a few years. Type A murmurs were easiest to disappear, and type C murmurs were most difficult to disappear. But no cases changed to organic mitral stenosis.

Where and how such murmurs develop is still left unclarified. But when phonocardiographic findings were referred to the physiological and anatomical knowledge of the heart, murmurs especially type A seem to be of left heart origin. Such origin is advocated by the following findings: 1) Type A murmurs were best heard at a localized small spot especially at the spot of apical beat, 2) they were best heard at the beginning of expiratory phase, or a few beats after release of the Valsalva's maneuver. When judged from the frequency of diastolic murmurs, the mitral valve including chordae tendinae and papillary muscles seems to play a great role in the etiology of such diastolic murmurs.

When type A diastolic murmurs were considered to be caused under physiologic hemodynamics, it will be easily assumed that they have some relationship with the rapid filling phase. Therefore, the mechanism of the diastolic murmurs was considered as stated below in connection with the third sound which represents the rapid filling phase.

Generally, the third sound has been considered to occur at the end of the rapid filling phase. Analysis of the curve of left ventricular pressure and its first derivative and analysis of intramural tension certified that the third sound occurs at transition from active relaxation to passive distension. Atroventricular gradient becomes small after the third sound. However, an atrioventricular flow may last by inertia even after atroventricular gradient becomes small. Therefore, type A diastolic murmur which starts after 3rd sound is rationally considered to be caused under physiologic hemodynamics. Namely, an atrioventricular flow by inertia becomes turbulent when it is disturbed by a movement of mitral valve at the end of rapid filling phase, by the intraventricular blood or by vibration of the cardiohemic system which is responsible for the third sound. The turbulence itself can not make murmurs sufficiently audible on the chest wall. But when the mitral valve, chordae tendinae and the papillary muscle have a considerable tension, they resonate with turbulence resulting in the development of audible diastolic murmurs.

It was generally considered that what are caused by resonance are musical murmurs. Therefore, it seems very reasonable to explain type A diastolic murmurs by the resonance of
the mitral valve and its supporting tissue with turbulence.

These murmurs are more prevalent among young children, whose mitral valve, including chordae tendinae and papillary muscles are supposedly more subject to be resonant. As children grow older and lose aptness for resonance, these murmurs often disappear. Therefore, resonance seems reflecting one of the causative factors of these diastolic murmurs.

These murmurs increase their intensity, when the blood volume which passes through the mitral orifice increases. Such increase is often encountered in a supine position, at the beginning of expiratory phase or a few beats after release of the Valsalva’s maneuver. Even children without murmurs at rest apt to have diastolic murmurs soon after changing a position from standing to supine (Fig. 12) or when they are physically activated or emotionally excited. These observations suggest that the volume and speed of blood flow through the mitral orifice play an important role in the development of such diastolic murmurs.

Type B and C murmurs somewhat resemble Carew Coomb’s murmur or shunt rumble on PCG and relative stenosis of the mitral orifice may have some relationship with the development of the murmurs. Therefore, the genesis of type B and C murmurs seems to leave more problems to be further studied.

§ 5. Conclusion

The diastolic murmurs reported in this paper are what are not accompanied with accentuated first sound, with elongation of Q-1 interval, with opening snap of the mitral valve, or with presystolic murmurs which are characteristic to MS. These diastolic murmurs (especially type A murmurs) start after third sound with a slight gap between them. Phonocardiographically they seem to be functional, especially type A to be physiologic. They are not accompanied with such pathologic conditions as MI, rheumatic carditis and CHD which cause a relative mitral stenosis. Moreover, it has been revealed that abnormalities on chest X-ray, ECG, blood and serum tests are uncommon among those cases with such diastolic murmurs. The follow-up revealed no cases changed to MS either.

It is not yet decided how and where such diastolic murmurs are caused, but at least type A murmurs seem to be caused by a resonant vibration of the mitral valve including chordae tendinae and papillary muscle due to the turbulence of an atrio-ventricular blood flow at the end of rapid filling phase.

SUMMARY

Discussion was made of the characteristics of heart murmurs and sounds of normal children and of congenital heart diseases and acquired heart diseases which are more prevalent among the young in order to get valuable information for efficient application of PCG and auscultation to mass examination.

Not without some problems to be dissolved, PCG plays a very important role in mass examination for heart diseases.

In the fourth chapter stress was given to the significance of diastolic murmurs at the lower left sternal border or at the apical region which had often been explained as pathologic. Of such diastolic murmurs there were many cases which should be regarded as functional or physiologic.

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