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From Phonomecanocardiography to Phonocardiography computer aided

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Abstract. Due to lack of training doctors to identify many of the disorders in the heart by conventional listening, it is necessary to add an objective and methodological analysis to support this technique. In order to obtain information of the performance of the heart to be able to diagnose heart disease through a simple, cost-effective procedure by means of a data acquisition system, we have obtained Phonocardiograms (PCG), which are images of the sounds emitted by the heart. A program of acoustic, visual and artificial vision recognition was elaborated to interpret them. Based on the results of previous research of cardiologists a code of interpretation of PCG and associated diseases was elaborated. Also a site, within the university campus, of experimental sampling of cardiac data was created. Phonocardiography computer-aided is a viable and low cost procedure which provides additional medical information to make a diagnosis of complex heart diseases. We show some previous results.

1. Introduction

Some years ago, cardiac auscultation was the way in which physicians, based on the sounds emitted by the heart, diagnosed many diseases from simple to complex one. The tool was just the stethoscope. To correctly interpret what they listened to, it was necessary to submit resident’s doctors to a training, which lasted two years, after completing their studies of general medicine [1].

On auscultation, a physician should detect to be present, not just the two basic sounds that make up a normal heartbeat, their uniformity and regularity, as well as the existence of some other sounds, clicks, or blows, that would indicate a normal or abnormal functioning of the heart and the parts that constitute it [4,7].

1.1. The Phonomecanocardiography and cardiac physicians training

W. Einthoven, 1894, did the first Phonocardiogram in the world [3]. B. Fishleider [2], in the 1950s, created a device, the Phonomecanocardiograph, that made possible, among other things, to graph in paper the sounds emitted by the heart, therefore it was possible to visualize what was heard with a stethoscope. The closer sounds and their intensities, as the so-called splits in Systole or Diastole, which the human ear cannot tell the difference, are clearly visible in a graphic record. The Phonomecanocardiograph served as a great support for the process of educational training of cardiologist’s future. Guadalajara, mentions that the capacity of the resident doctors in cardiology to discriminate different diseases, only using the stethoscope, is 50% [1, 11], that is why the use of the Phonomecanocardiograph was very important.
1.2. Other diagnostic technologies

Unfortunately, with the arrival of new technologies such as the electrocardiogram, echocardiogram, computerized tomography and the magnetic resonance imaging, the use of the Phonomecanocardiograph gradually reduce until its disappearance losing a valuable diagnostic tool.

On the other hand, these new technologies are not only more expensive, they require special equipment and trained staff to use them, moreover their availability is only found in clinics and hospitals in big cities.

2. The interpretation of the PCG and associated diseases

Fishleder, Guadalajara, in Mexico [1, 2], and several other cardiology researchers from different countries, left a legacy of very important information since they related graphs or images of various heart sounds emitted with different heart pathologies [4-10], [12-17]. This is the basis on which can now make the interpretation of the phonocardiograms.

The acoustic analysis of a PCG seeks to respond several aspects: Periodicity. The captured wave recurs on a regular basis? If it is regular, how is it formed? What is the frequency? What additional peaks presented and where are they? What cardiac pathologies can be inferred?

In healthy subjects, the phonocardiogram represents only two basic sounds in a completely regular form, usually called S1 and S2, simulated in Figure 1, [20]. The frequency of the wave is called heart rate or number of pulses per minute. But in non-healthy subjects may appear other sounds added visualized as peaks situated in several places of the wave form.

Taking into account the symbology used to describe phonocardiograms [20], it is possible to make a first classification of 15 possible alterations that may be visible in the graphic wave, and Table I outlined some of the associated pathologies. This is not an exhaustive list.

![Figure 1. Simulation of two beats in a healthy person. The peaks indicate S1 and S2 sounds [20].](image)

1. The S1 peak split, in two tightly together peaks called M and T.
2. The S2 peak split in two tightly together peaks called A and P.
3. If a third sound S3, complex form, after S2, appears.
4. If a fourth sound S4, a narrow peak, before S1, appears.
5. If a click or an additional narrow peak after S2, appears.
6. If a peak of sound after S1, appears.
7. If an intermediate sound between S1 and S2, appears.
8. If high-frequency sinusoidal waves between S1 and S2 are seen.
9. If appears high frequency sinusoidal waves cushioned exponentially immediately after S1.
10. If see high frequency sine wave between S1 and S2, growing exponentially.
11. If see high-frequency sinusoidal waves between S1 and S2, increasing and decreasing exponentially to form a diamond.
12. If high frequency sinusoidal waves appear near to S2, cushioned exponentially.
13. If waves are sinusoidal decreasing exponentially low amplitude and long decay time, between S2 and S1.
14. If high frequency sine waves type immediately before S1, growing exponentially, are seen.

15. If waves are increasing and decreasing high-frequency sinusoidal exponentially forming a diamond, in the time of systole and diastole, absence of S1 and S2.

Table 1. Although the possible associated cardiac pathologies to waveform alterations listed are so many, some are mentioned.

<table>
<thead>
<tr>
<th>Case</th>
<th>Name</th>
<th>Possible Pathology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Split in S1</td>
<td>Myxoma in Atria, atrial septal defect</td>
</tr>
<tr>
<td>2</td>
<td>Split in S2</td>
<td>Aortic stenosis. Hypertrophic cardiomyopathy</td>
</tr>
<tr>
<td>3</td>
<td>Third heart sound</td>
<td>Mitral regurgitation. Ischemic cardiomyopathy</td>
</tr>
<tr>
<td>4</td>
<td>Fourth heart sound</td>
<td>Aortic stenosis. Pulmonary Arterial hypertension</td>
</tr>
<tr>
<td>5</td>
<td>Opening Snap</td>
<td>Mitral stenosis. Tricuspid stenosis.</td>
</tr>
<tr>
<td>6</td>
<td>Ejection Sound</td>
<td>Aortic stenosis. Pulmonary stenosis.</td>
</tr>
<tr>
<td>7</td>
<td>Click Mid Systolic</td>
<td>Hypertrophic cardiomyopathy. Mitral Valve prolapse</td>
</tr>
<tr>
<td>8</td>
<td>Holosystolic Murmur</td>
<td>Mitral and Tricuspid Regurgitation. Severe pulmonary stenosis</td>
</tr>
<tr>
<td>9</td>
<td>Early systolic Murmur</td>
<td>Mitral stenosis. Tricuspid stenosis.</td>
</tr>
<tr>
<td>10</td>
<td>Late Systolic Murmur</td>
<td>Hypertrophic cardiomyopathy. Pulmonary stenosis.</td>
</tr>
<tr>
<td>12</td>
<td>Early Diastolic Murmur</td>
<td>Aortic and pulmonary regurgitation</td>
</tr>
<tr>
<td>13</td>
<td>Mid Diastolic Murmur</td>
<td>Aortic and Mitral regurgitation. Atrial Septal Defect</td>
</tr>
<tr>
<td>14</td>
<td>Presystolic Murmur</td>
<td>Mitral stenosis and aortic Tricuspid regurgitation</td>
</tr>
<tr>
<td>15</td>
<td>Continuous Murmur</td>
<td>Cameral coronary fistula. Pulmonary embolism</td>
</tr>
</tbody>
</table>

3. The Phonocardiograms and data acquisition technology

Due to technological advances in computing and scientific instrumentation, using an electronic stethoscope, like sound sensor, software and a laptop computer now is possible to obtain the PCG of any subject.

As a research project, Phonocardiography, which currently takes place in the Optics Laboratory of the Universidad Autónoma Metropolitana Azcapotzalco, a digital process of cardiac data collection: blood pressure, heart rate, oxygenation and heart sound, in which also has been made phonocardiograms of people in the University community, healthy and diagnosed patients, was implemented. In aleatory form, subjects were selected among pupils, Teachers or Administrative staff.

Using a digital meter of blood pressure and heart rate, Omron model HEM - 7114, the Oximeter Hergom MD300, Littmann Electronic Stethoscope Model 3200, Littman StethAssist and LabVIEW 2013 software, the heart information from the subjects was obtained.

Through a program of computation, data acquisition instruction is given to a laptop that the acoustic signal emitted by the heart and detected by the electronic stethoscope, to be transferred, via Bluetooth. That wave is exported in format .wav. With LabVIEW software, built a program that converts the signal to .lvm format, which allows us to show it as an amplitude vs. time graphic on the PC screen, which can be extended or compressed for display in different time intervals.

4. Image Recognition

Using new computer technology and developing an artificial vision algorithm for pattern recognition, in LabVIEW software, built a program that consists of three routines, which are described below.

The first routine consists of reading of a .wav file, previously obtained with the electronic stethoscope. The program displays the sound wave on the screen and computes the following parameters: the main frequency of the sound, the period with which each peak is repeated times, the number of pulses per minute, the amplitude of the maximum peaks for the characterization of regular and strong or weak sound hearts, the time that it takes to pass the systole and diastole in each cycle and the differences between these times.
The next routine, which converts the .wav to an image format .jpg, the image is analyzed using artificial vision to identify the distance between each wave peak in pixels, thus giving us a relationship with the time elapsed between consecutive pulses.

In the same way as with acoustic analysis, can determine the existence of some type of arrhythmia or tachycardia if the repetition period is not constant over time.

This method can also be used to identify the presence, and time of occurrence, of peaks with abnormal amplitude between pulses. These peaks suggest the presence of an intense sound, which diagnose a possible blow and its type. The algorithm can also measure the vertical distance of the wave, the amplitude of the sound.

Figure 2. Front panel of the LabVIEW program of acoustic and visual Phonocardiograms Diagnostics

5. Results
We have performed about 62 Phonocardiograms of people, randomly chosen, into university community, of several ages, physical conditions, sex, healthy and non-healthy, diagnosed and not.

Important heart functioning irregularities in different ages, apparently healthy individuals, were detected, with ease, without cost, without special facilities and expensive equipment. In another paper will present in detail the respective analysis. In Fig. 3 to 6, shows four cases of PCG displayed in 10 seconds, identifying possible diseases associated to variations of waveforms obtained in comparison with the Table I. The PCG of student 1, Fig. 3 shows the first sound S1, too weak, that means a possible Atrioventricular Block. In the case of the student 2, Fig. 5 the PCG shows a regular waveform, the student is healthy. For the student 3, Fig. 6 the PCG shows a split in S2, which means a possible Aortic Stenosis. And for the student 4 the graph shows split in S1 and split in S2 which means possible Myxoma in Atria and Aortic Stenosis.

Table 2. Data from volunteers who underwent phonocardiograms

<table>
<thead>
<tr>
<th>Voluntary</th>
<th>Gender</th>
<th>Age (year)</th>
<th>Weight (kg)</th>
<th>Height (m)</th>
<th>Blood pressure</th>
<th>Heart rate</th>
<th>blood oxygenation</th>
<th>Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>23</td>
<td>64</td>
<td>1.7</td>
<td>108/66</td>
<td>64</td>
<td>98</td>
<td>Nothing</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>20</td>
<td>48.5</td>
<td>1.57</td>
<td>97/65</td>
<td>72</td>
<td>98</td>
<td>Nothing</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>28</td>
<td>63</td>
<td>1.69</td>
<td>119/71</td>
<td>70</td>
<td>96</td>
<td>Nothing</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>24</td>
<td>54</td>
<td>1.54</td>
<td>105/72</td>
<td>70</td>
<td>97</td>
<td>Lung diseases</td>
</tr>
</tbody>
</table>
6. Conclusions
Looking for an objective method for quickly, by means of sound that emits the heart, obtain important information of its operation, with the aim to develop a procedure to help in diagnostic of heart pathologies, we have developed the technique called Phonocardiography Computer Aided. In it, the sound generated by the heart of people is captured in a laptop computer. Subsequently turning sound into image, it analyzes the image looking for alterations in the waveform, relating them with pathologies.

The research project, Phonocardiography, which currently takes place in the UAM-A has achieved: Implement a digital process of cardiac data acquisition: blood pressure, cardiac frequency, heart sound and oxygenation. Present the sound wave as image in format .lvm, which can be extended or compressed for display in different time intervals. Mathematically simulate the heart sound wave. Build an image recognition program to detect critical areas in the image of the heart sound.

Phonocardiography is an alternative method to diagnose cardiac pathologies. Phonocardiography Computer Aided is a feasible technique, very low cost, which gives immediate objective results and which can be applied in remote populations with limited economic resources.

Thanks to the application of image recognition and acoustic visual techniques, is easy to identify alterations in the sound wave and correlate them with diseases.

7. References
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[10] Leatham A 1987 *Auscultation and phonocardiography: a personal view of the past 40 years* (Br Heart) 57(5) 397-403