METHODS TO EXPLORE THE MECHANICAL ACTIVITY OF THE HEART

There are several methods to investigate the mechanical activity of the heart. The value of these explorations is augmented by multiple traces recorded synchronously and reported to ECG as a reference trace.

**CAROTIDOGRAM (CP)**

Carotidogram (or carotid pulse) represents the graphic recording of volume variations of the carotid artery during left ventricle ejection.

This examination method uses photoelectric plethysmography or mechanical transducers placed near carotid artery (on the internal edge of sternocleidomastoid muscle).

**MORPHOLOGICAL ANALYSIS**

The shape of the arterial pulse curve is represented by two phases:

► systolic phase: starts with the E point, i.e. the opening of the aortic valves and beginning of rapid ejection phase and continues with an upward slope (until B), corresponding to the rapid ejection and a downward slope corresponding to the reduced ejection phase of left ventricle (BC). During the down-slope of the arterial pressure wave the dicrotic notch (I) occurs at the moment when the aortic valve closes. The dicrotic notch indicates end of ventricular systole. This is caused by a short period of backward flow of blood immediately before closure of the valve, followed then by sudden cessation of the backflow.

![Diagram of arterial pulse curve with annotations](image)

Figure no. 95. Synchronous recording of carotid pulse, phonocardiogram and ECG. The graph also shows a possibility to calculate systolic indexes (QZ₂, EJ, PEJ) and the half-rise (Duchosal, 1/2) time.
- *diastolic phase* – consists of the dicrotic notch (see above) and a slow downward slope.

Analysis of the carotid pulse offers us the possibility to calculate:

- Duchosal (half-rise, $t_{1/2}$) time – represents the time until the half of the maximal amplitude of the wave occurs. This is a good indicator of the contractility of left ventricle and correlates with the trans-aortic gradient created by left ventricle ejection. Normal value: 0.04-0.06 seconds.
- Systolic times (or indexes) – see below.

**PHONOCARDIOGRAM (PCG)**

Phonocardiogram represents the recording of heart sound, using a microphone placed on the chest, which detects low frequency sound waves.

Normal heart sounds are vibrations produced by:

- myocardium during contraction and relaxation
- major blood vessel walls
- movement (acceleration and deceleration) of the blood
- movement of the cardiac valves.

This examination method uses piezoelectric microphones, with filters adapted for specific frequencies. These microphones are placed in standard areas on the chest (Figure no. 96):

- the aortic area: 2nd right intercostal space, near the sternum;
- the pulmonary area: 2nd left inter-costal space, near the sternum;
- the tricuspid area: 5th left intercostal space, beneath the sternum;
- the mitral area: 5th left intercostal space, on medium - clavicle line.

![Figure no. 96. Main auscultation areas for phonocardiogram.](image)
MORPHOLOGICAL ANALYSIS

<table>
<thead>
<tr>
<th>Heart sounds</th>
<th>Duration</th>
<th>Loudness</th>
<th>Causes</th>
<th>ECG correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>0.12-0.15 sec</td>
<td>greatly accentuated (30-40 Hz)</td>
<td>-ventricle walls vibrations during isometric contraction -mitral and tricuspid valves closure -pulmonary and aortic valves opening -vibrations of arterial walls during the rapid ejection</td>
<td>appears 0.02-0.04 sec after Q wave</td>
</tr>
<tr>
<td>S2</td>
<td>0.08-0.10 sec</td>
<td>lower than the first sound (50-70 Hz)</td>
<td>-ventricle walls vibrations during the isometric relaxation -closure of aortic and pulmonary valves</td>
<td>corresponds to the descending phase of T wave</td>
</tr>
<tr>
<td>S3</td>
<td>0.02-0.04 sec</td>
<td>weak</td>
<td>-ventricle walls vibrations during fast filling period</td>
<td>after T wave</td>
</tr>
<tr>
<td>S4</td>
<td>0.05-0.10 sec</td>
<td>very weak (in only ¼ of all persons)</td>
<td>-myocardial walls vibrations during atrial contraction which induces the blood inrush into the ventricles</td>
<td>appears 0.02 - 0.04 sec after P wave</td>
</tr>
</tbody>
</table>

Figure no. 97. Synchronous recording of PCG and ECG.

PATHOLOGICAL CHANGES OF PCG

- **doubling of heart sounds** more important with S2; there is a longer period between the aortic and pulmonary components of S2. This can be physiological during inhale, and pathological in pulmonary hypertension.
- **additional heart sounds**: usually low frequency vibrations with very short duration
- **heart murmurs**: vibrations with variable frequency and duration usually longer than 0.15 seconds. These are produced by turbulent blood flow, a reduced valve orifice or
an increase in the speed of the blood flow. Based on the momentum in which they appear these can be:

- **systolic** (between S1 and S2)
- **diastolic** (between S2 and S1)

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**Systolic Times**

Systolic times represent durations of different phases of ventricular systole. These are considered to be important indexes for cardiac performance. They can be determined by combining information obtained by synchronous recording of ECG, PCG and PC (Figure no. 95). Using all these traces we can calculate different intervals:

1. **PEP**: the pre-ejection period.
   \[ PEP = (QS2) - LVEP \]

2. **LVEP**: the left ventricle ejection period (ejection time – ET)
   \[ LVEP = (E - I) \]

3. **QS2**: total electro-mechanical systole

In healthy people systolic times are influenced by many factors, the most representative is heart rate. The ideal values, according to heart rate, are given by Weissler's equations (Table no. 5). Differences over 15% from ideal values are considered to be pathological.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>QS₂</td>
<td>QS₂=546-2.1xHR</td>
<td>QS₂=549-2.0xHR</td>
</tr>
<tr>
<td>ET</td>
<td>ET=413-1.7xHR</td>
<td>ET=418-1.6xHR</td>
</tr>
<tr>
<td>PEP</td>
<td>PEP=131-0.4xHR</td>
<td>PEP=133-0.4xHR</td>
</tr>
</tbody>
</table>

Using systolic times we can calculate several different parameters:

- ejection ratio: \[ 1.125 \times (PEP / LVEP) \times 1.25 \]
- normal hemodynamic index (Blumberger): \[ LEVP / PEP = 2.5-5 \]