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Case Report

Calculation of Cardiac Electrical and Mechanical Efficiencies to Determine Their Correlations and Final K3 Factor of an Individual Patient Using ECG Machine

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Abstract

The Cardiac index is obtained by the ratio of cardiac output to the body surface area of an individual which is between 2.5 to 4L/min/m^2 [1]. The normal cardiac stroke volume ranges from 60ml to 100ml per beat and is give as an index ranging from 33-47ml/beat/ m^2 [2]. The electrical pulse generated by the cardiac is converted to mechanical energy and the net output of the efficiency of the cardiac is given as K^3-factor in this abstract.

Myocardial pulse generated at the SA node is measured and recorded using ECG machine on the test of an individual. The myocardial conversion efficiency (η_{myo}) is 40-50% [3] and is obtained by equation in Figure 1. Another investigation is to obtain mechanical efficiency of the cardiac which is the mechanical heart beat observed. The efficiency (η_{mech}) is obtained by equation in Figure 2. Theoretically, the input and output work done need to be calculated by algebraic sum of all the input vessels flow into the heart and algebraic sum of all the output vessels flow out of the heart as shown in Figure 3.

The correlation between electrical and mechanical efficiency is then determine by equation in equation 1, considering any cardiac energy losses ¢ [4]. The correlation factor (œ) is then obtained and recorded for that patient.

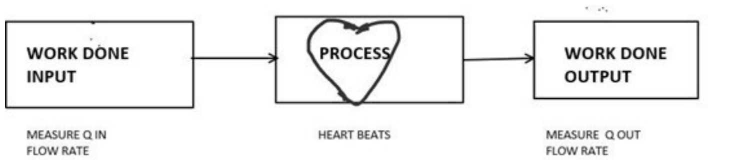
Keywords: ECG; Pulse; Cardiac output; Cardiac index; K3-factor; SA node

$$\eta_{myo} = \frac{\text{work done output(pulse)}}{\text{work done input(pulse)}} x\ 100$$

Figure 1

$$\eta_{mech} = \frac{\text{work done output(heart beat)}}{\text{work done input(heart beat)}} x\ 100$$

Figure 2



$$W_{in} = \sum_{n=1}^{2} \int_{t>0}^{5} Q(t) \qquad W_{out} = \sum_{n=1}^{2} \int_{t>0}^{5} Q(t)$$

Figure 3

η_{myo} = œ η_{mech} + ¢ .... Equation 1

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Introduction

The EEG

An electrocardiograph is an instrument that detects and records the electrical currents on the body's surface, generated by the impulses of the heart [5]. The graphic recording of the heart's electrical impulses is known as electrocardiogram or ECG, and it's characterized by the following components: Deflection Waves: they correspond to the depolarization and repolarization of the heart's chambers. A typical ECG has 3, the P wave, the QRS complex and the T wave. Segment: is a region between two waves. For example, the T-P segment. Interval: which is the region between a segment and one or more waves. For example, the Q-T interval covers the QRS complex, S-T segment and T wave.

EEG 12 -Lead Recording

An ECG recording is performed when an arrhythmia or any other heart anomalies are suspected. It is a painless and non-invasive procedure. Electrodes are attached to the body, usually on the arms, legs and across the chest. They detect the small electrical impulses as described earlier. For diagnostic purposes, the standard is to perform a 12-lead ECG, where there are 12 leads calculated using 10 electrodes [5]. Four are placed on each arm/leg and six on the chest, close to the heart. The 12 leads provide a comprehensive picture to the doctor of the heart's electrical activity. The Lead I, II and III are bipolar since they measure the voltage difference between different limbs; while the other 9 leads are unipolar. Check the Figure below for a typical ECG electrode positioning on the patient.

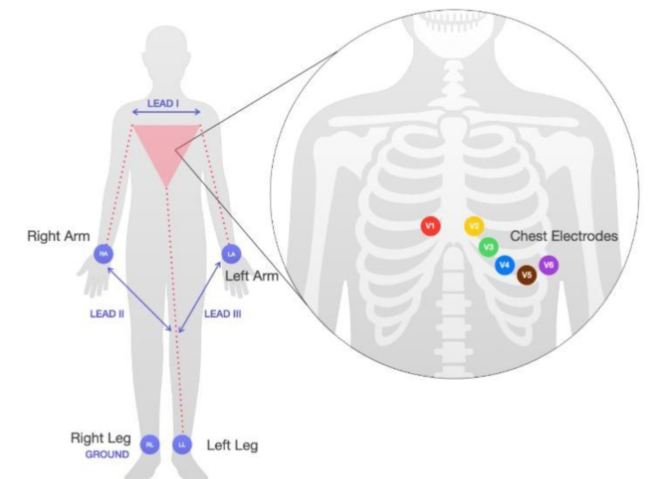

Image source: Tutelft University

Objectives

i) The following are the objectives for this report;To calculate the efficiency of the human heart using EEG and BP machine.

ii) To show the correlation between cardiac electrical signal and mechanical heart beat

Literature Review

Few research as been done how the cardiac heart beat effectively functions or generally the efficiency of the heart. As an mechanical engine, the efficiency of heart can be summarized as the ratio of External Work (EW) and the oxygen uptake of myocardium in a given time, which was initially suggested by Bing et al in 1949 [6]. The definition of Myocardial Efficiency (MEf), in usual clinical and research settings, include only Left Ventricle (LV), while the work and metabolism of right ventricle and atria are neglected. Also, the MEf accounts the EW of LV, but not the potential energy of LV which indicates the work required to expand the LV to its actual minimal volume (LV end-systolic volume). Under these assumptions, the MEf is calculated using the product of EW of LV and heart rate, divided by the product of myocardial oxygen consumption (mVO2) and LV Mass (LVM) Figure 4. The EW, or Stroke Work (SW) indicates the area contained in a pressure-volume loop of LV and can be approximately estimated as a product of Stroke Volume (SV) and end-systolic pressure, or a product of SV and Mean Arterial Pressure (MAP).

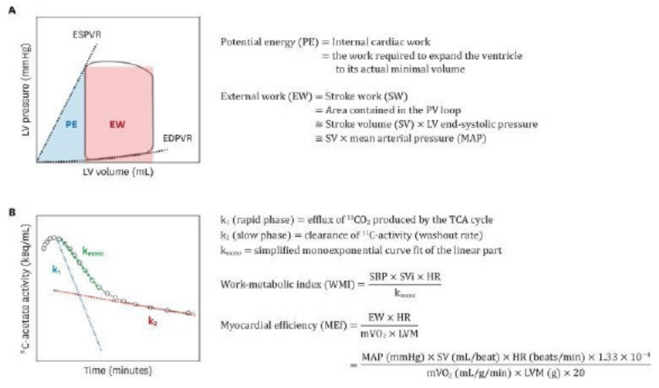

Figure 4

Methodology

The research requires analytical, quantitative and qualitative analysis to obtain the efficiencies of individual patients. The sampling method and Data collection done by randomly selection three patients(individuals). Patient 1 a man aged 30 years, patient 2 a woman aged 26 years and patient 3 a man aged 25 years their measurements are recorded on Table 1.

Data Analysis

Patient Parameters

The following are samples of THREE patients but in our case sample case study of individual randomly picked.

Table 1

Patients	Cardiac Work Input (Win)								Cardiac Work Output (Wout)							
	Electrical (Uv)				Mechanical (Mmhg)				Electrical (Uv)				Mechanical (Mmhg)			
	P1	P2	P3	E IN	A1	A2	A3	Q IN	P4	P5	P6	E OUT	A4	A5	A6	Q OUT
1	2	2.2	3	7.2	20	24	30	74	0.5	0.3	0.2	1	90	100	110	100
2	2.2	4	3.4	9.6	33	28	25	86	0.4	0.2	0.1	0.7	80	110	95	95
3	3.2	3.1	2.6	8.9	30	44	23	97	2.4	2	1.4	5.8	75	88	96	86
				8.6				86				2.5				94

Calculations

Pulse Input = $7.2+9.6+8.93=8.6uV$ Pulse Output = $1.0+0.7+5.83=2.5uV$

$$\eta_{myo} = \frac{\text{work done output(pulse)}}{\text{work done input(pulse)}} x\,100 \qquad = \frac{2.5}{8.6}100 = 29.07\%$$

Mechanical Input = $\frac{74+86+97}{3} = 86mmHg$ Mechanical Output = $\frac{100+95+86}{3} = 94mmHg$

$$\eta_{mech} = \frac{\text{work done output(heart beat)}}{\text{work done input(heart beat)}} x\,100 \qquad = \frac{94}{86}100 = 10.93\%$$

$\eta_{myo} = œ\, \eta_{mech} + ¢$ .... Equation 1

$29.07 = œ * 10.93_{+0.02}$

$Œ = 2.66$

$K^3\text{- factor} = \frac{n_{mech}}{n_{myo}} = \frac{10.93}{29.07} = 0.38$

Assumptions Made

1. The following consideration and assumptions are noteThe mycardial electrical work done is TOTALLY transferred to mechanical work.
2. The average mechanical work input should be less than the mechanical work output
3. The experiment/measurement taken while the patient is at rest or within FIVE (5) seconds
4. The blood flow rate is taken extenarlly at peripheral system (veins and arteries)

Graphical Representation

The final efficiency of the cardiac K3-factor is given in Figure 4 which is obtained by plotting the graphs work done into the heart (y-axis) vs work done out of the heart(x-axis) as shown in Figure 5. The slope K^3 is then expressed as a percentage.

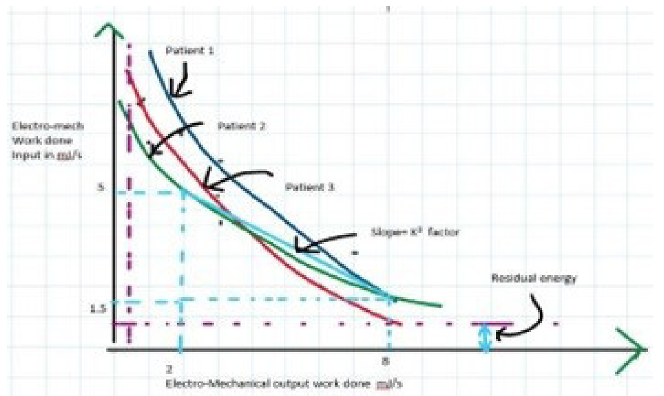

Figure 5

Conclusion

In conclusion, the research will assist the medical personnel in knowing the cardiac parameters of the patient and this factor may be integrated into an ECG machine or a new version of medical equipment may be designed for this purpose.

Recommendations

1. The future opportunities and how the project will assist the medical professions are;In Designing cardiac implants (cardiac valves)
2. In cardiac surgery the parameters can be adjusted on heart-lung machine
3. Medical fitness examination

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