Features of heart imaging in precardiac rheocardiography.

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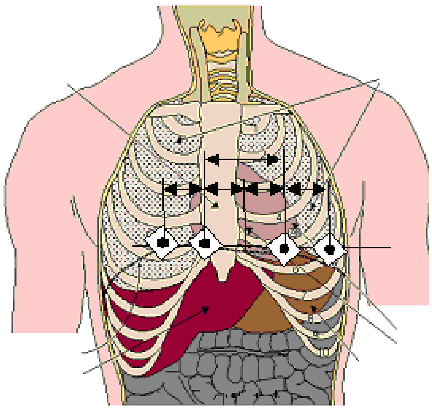
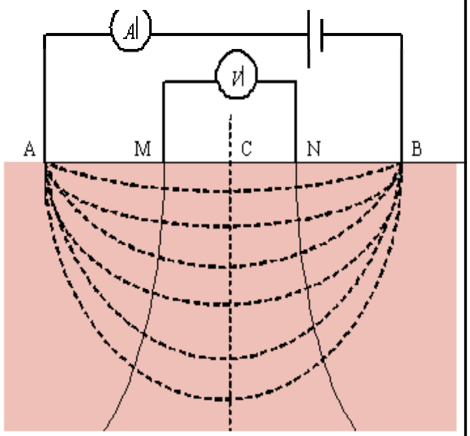
Tasks of Rheocardiomonitoring

- Principles of rheocardiogram forming
- Selection of electrode system
- Direct problem of modeling
- Inverse problem of modeling

Precardiac Rheocardiogram (preRCG)





Direct Problem in PreRCG

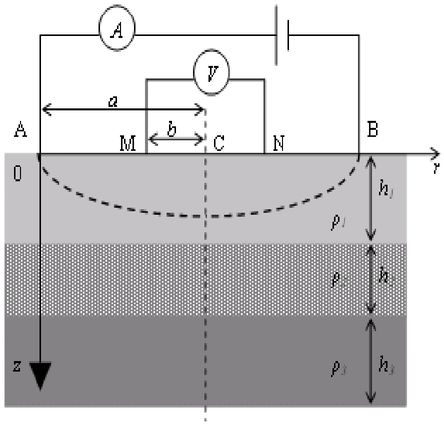
Three-Layered Model

- Muscular tissue |
- Pulmonary tissue | -> $\rho_1 = \langle\rho\rangle$
- Bone tissue | -> h_1= 0.1 m

- Myocardium | -> ρ_2, h_2

- Blood | -> $\rho_3 =$ 1,0-1,5 Ohm*m, h_3 – semi-infinite

Direct Problem for Three-Layered Model



$\Delta\varphi = 0$

Boundary conditions:

$$\varphi_i\Big|_{z=h_i} = \varphi_{i+1}\Big|_{z=h_i}$$

$$\frac{1}{\rho_i}\frac{\partial\varphi_i}{\partial z}\Bigg|_{z=h_i} = \frac{1}{\rho_{i+1}}\frac{\partial\varphi_{i+1}}{\partial z}\Bigg|_{z=h_i}$$

$$\frac{\partial\varphi_1}{\partial z}\Bigg|_{z=0} = 0 \text{, as } \rho_{air} = \infty$$

$$\varphi_{semi-infinite}\Big|_{z\to\infty} \to 0$$

Laplace Equation Solution for Three-Layered Model

$$\frac{\partial^2\varphi}{\partial r^2} + \frac{1}{r}\frac{\partial\varphi}{\partial r} + \frac{\partial^2\varphi}{\partial z^2} = 0$$

$$R(a,b) := \frac{\rho 1}{\pi}\cdot\left[\frac{1}{a^2 - b^2} + \int_0^{100} A1(m)\cdot J0[m\cdot(a-b)]\,dm - \int_0^{100} A1(m)\cdot J0[m\cdot(a+b)]\,dm\right]$$

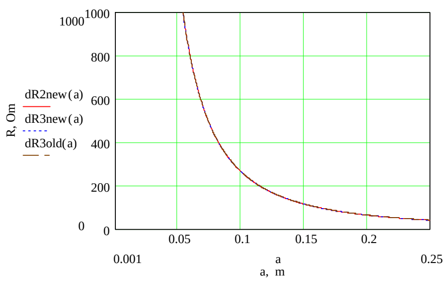
$$A_1(m) = \frac{N}{D_1 + D_2}$$

$$N = (\rho_2 - \rho_1)\cdot(\rho_3 + \rho_2)\cdot e^{-4\cdot m\cdot h_1} + (\rho_2 + \rho_1)\cdot(\rho_3 - \rho_2)\cdot e^{-4\cdot m\cdot h_1 - 2\cdot m\cdot h_2}$$

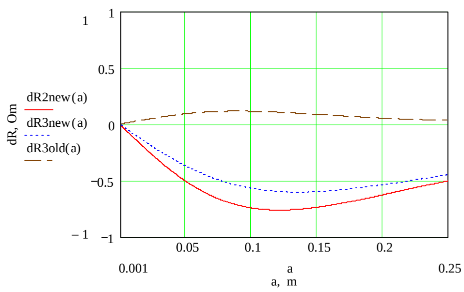
$$D_1 = (\rho_1 + \rho_2)\cdot(\rho_3 + \rho_2)\cdot e^{-2\cdot m\cdot h_1} + (\rho_2 - \rho_1)\cdot(\rho_3 - \rho_2)\cdot e^{-2\cdot m\cdot h_1 - 2\cdot m\cdot h_2}$$

$$D_2 = (\rho_1 - \rho_2)\cdot(\rho_3 + \rho_2)\cdot e^{-4\cdot m\cdot h_1} + (\rho_1 + \rho_2)\cdot(\rho_2 - \rho_3)\cdot e^{-4\cdot m\cdot h_1 - 2\cdot m\cdot h_2}$$

Comparison of Calculated Models



A: **Impedance** vs **a**



B: **Impedance** vs **a**
(without direct component)

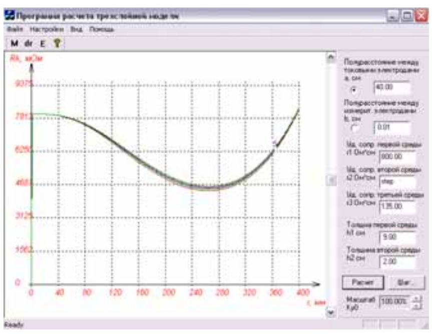
Inverse Problem

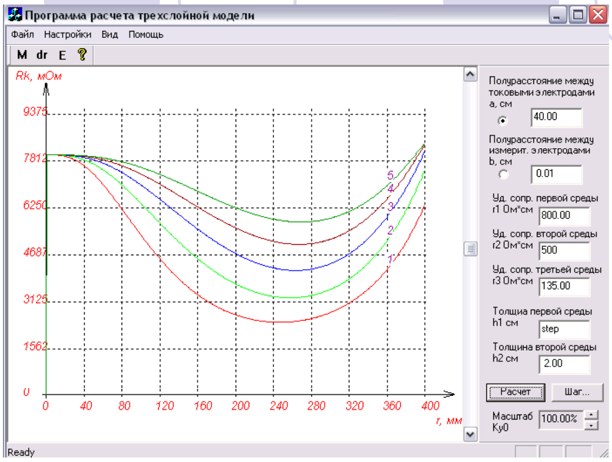
Determined parameters:

- Two-layered model: ρ_1, ρ_2, h_1
- Three-layered model: ρ_1, ρ_2, ρ_3, h_1 h_2

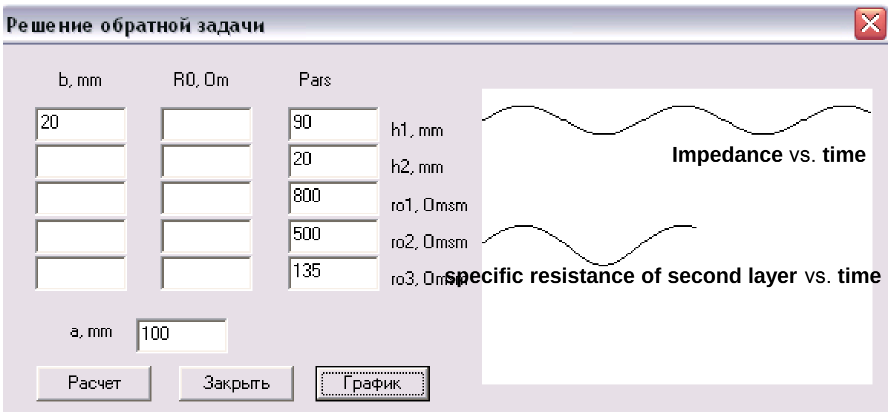
$$\rho \approx \frac{\pi \cdot AM \cdot AN}{MN} = \frac{\pi \cdot (a-b) \cdot (a+b)}{2b} \cdot R_{MN}$$

Apparent resistivity vs. **half interval between current electrodes** (specific resistance of second layer ρ2 is in the range of
400 to 600 Ohm*cm)





Apparent resistivity vs.
half interval between current electrodes
(thickness of first layer h1 is in the range of 3 to 12 cm)



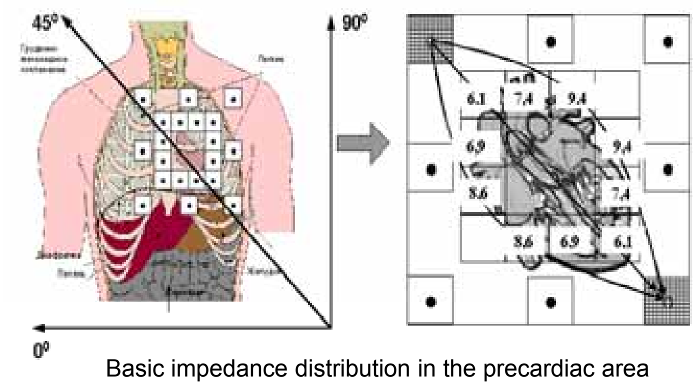
Borders of first and second layers are dynamically changed

Inverse Problem Issue

Precision of model parameter's determination in case of solution of indirect task by using apparent resistivity conception.

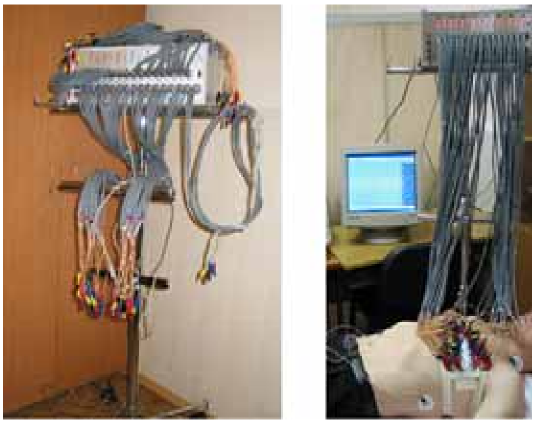
N	ρ_{1gen}, Ohm·cm	h_{1gen}, cm	ρ_{2gen}, Ohm·cm	ρ_{1calc}, Ohm·cm	h_{1calc}, cm	ρ_{2calc}, Ohm·cm	$\delta\rho_1$, %	δh_1, %	$\delta\rho_2$, %
1	750	5	120	749	4.9	131	<0.5	2.0	9
2	820	7	110	819	6.8	134	<0.5	3.0	22
3	760	11	130	760	10.7	160	<0.5	2.7	23
4	750	9	140	750	8.9	150	<0.5	1.1	7
5	770	10	150	770	9.9	159	<0.5	1.0	6

Heart's boundary localization by using precordial signals analysis



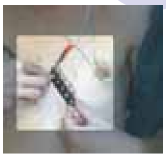
Basic impedance distribution in the precardiac area

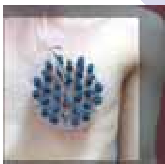
Multi channel system REO-32

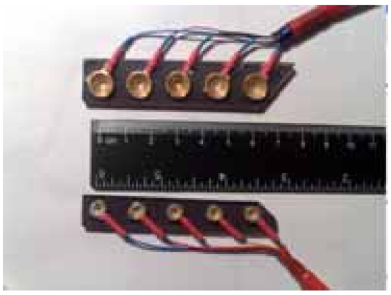


Multichannel system for rheocardioraphy applications

Electrode systems



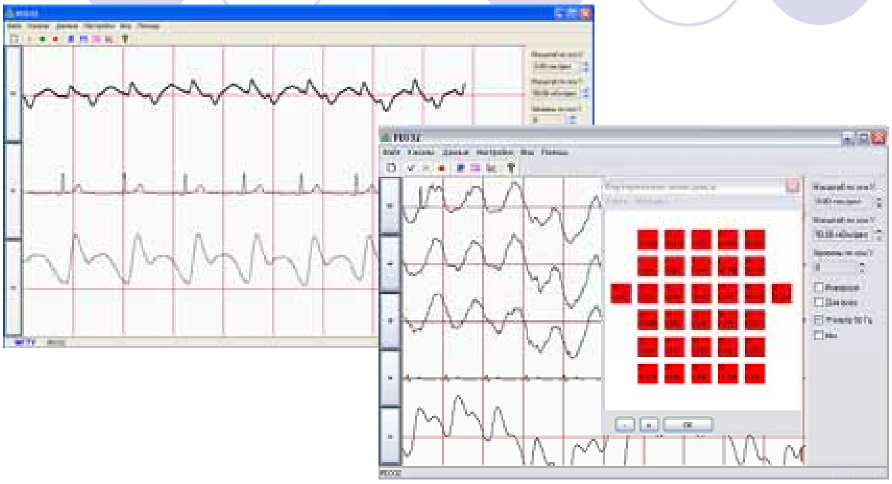




Simple electrode system

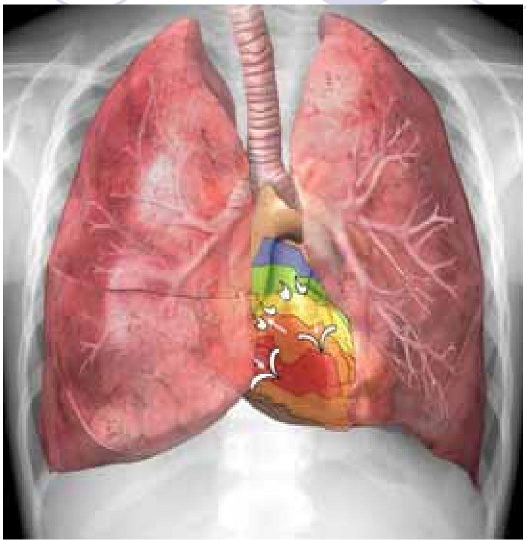
Multichannel electrode system

Software

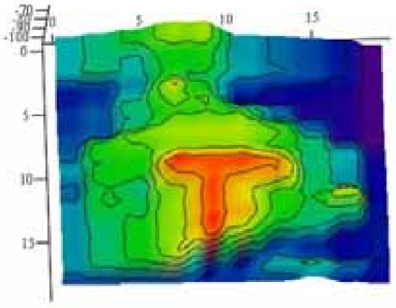


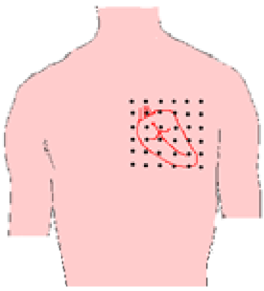
PolyReoDevice. Win32 application for multichannel system

Contouring of the heart



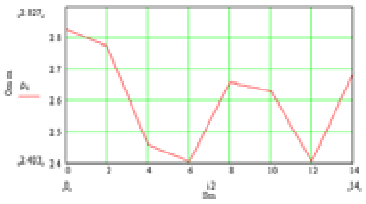
Impedance imaging (model)





Impedance image of the thorax (theoretical, by means of processing RMI data)

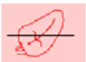
One-dimensional imaging

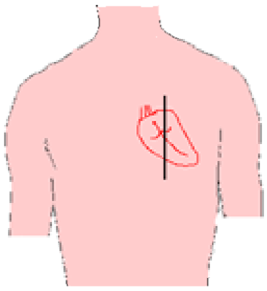


№	Z6, Ом	a, см	b, см	ρ, Ом м
1	100	1,2	0.6	2,82
2	98	1,2	0.6	2,77
3	87	1,2	0.6	2,45
4	85	1,2	0.6	2,4
5	94	1,2	0.6	2,65
6	93	1,2	0.6	2,62
7	85	1,2	0.6	2,4
8	95	1,2	0.6	2,68

ρ0 = 2,6 Ом м

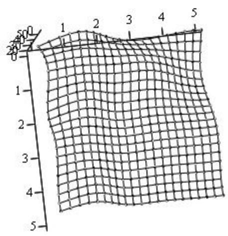
Δρ = 0,29 Ом м (11 %)



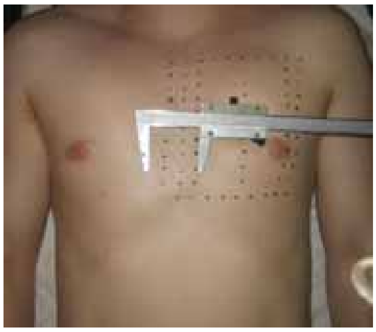


One-dimensional impedance imaging (in direction marked continuous line)

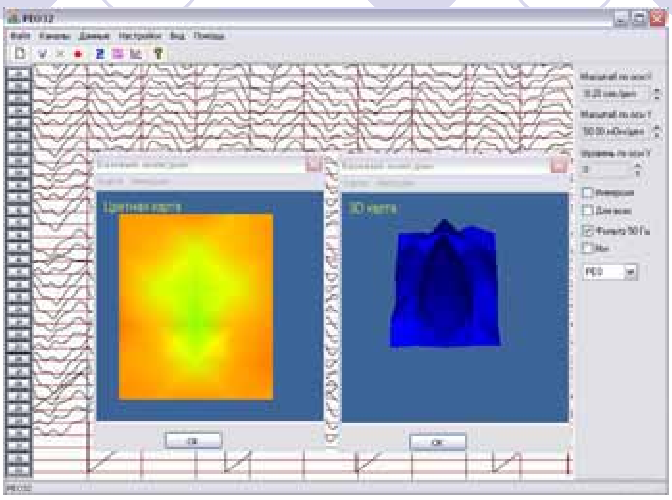
Impedance imaging



Impedance image of the thorax

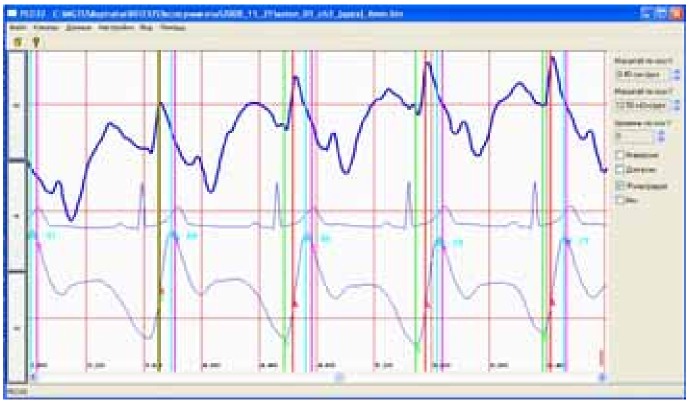


Software



Real-time impedance image, processed data from 32 leads

Signal analysis



Contour analysis of ECG, transthoracic RCG, precardial КСП
Calculate parameters: HR, CI, BR, SV and others

Conclusions

In this paper we took up main features of the pre cardiac rheography technique and examined general poly-layer models to simulate the precardiac area tissues. Solutions for the direct tasks (by solving Laplace's equation by using the boundary conditions) and the determination of model's parameters by solving the indirect task (using apparent resistivity method) are presented. As is shown the miscalculation of the model's parameters determination is less than 1% for parameter $\rho 1$, about 2-3% for parameter h1 and about 20% for parameter $\rho 2$. The lessening of the miscalculation is considered as the next step of the presented work in order to implement this method for human’s biomechanical heart parameters determination.

The multichannel system with the special electrode system and the Win32 application were developed. This complex provides the real-time heart imaging. On this basis the determination of heart boundaries is applied.

Processing of transthoracic rheocardiogram allows to calculate heart parameters such as: heart rate, breath rate, cardiac index, stroke volume and others. Processing precardiac rheocardiogram, registered from right ventricle, makes calculation these parameters more exact.

References

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- Electrical Survey by Using Resistance Technique / by V.K. Khmelevsky and V.A. Shevnin. – Moscow.: MSU, 1994. – 160 p.
- Yakubovsky Y.V., Renard I.V. Electrical Survey. – Moscow.: Nedra, 1991.

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Thank you for attention

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