A Mathematical Model of Radiocardiogram and its Analog Simulation Circuit

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Radiocardiogram is considered as a representation of hemodynamics of inflow into and outflow from right and left hearts of injected isotope. In this paper, it is shown that an analog computer analysis of the hemodynamics simulated by an appropriate mathematical model makes to be able to quantify cardiac output and equivalent volumes of right and left hearts, pulmonary and body blood vessels.

Transportation processes of injected isotope I (μCi) neglecting heart-beat can be approximately represented by following fundamental equations:

$$V_r c_r(t) = F_i \int_0^t c_i(t)dt + F\int_0^t c_b(t-\tau_b)dt - F\int_0^t c_r(t)dt$$

$$V_p c_p(t) = F\int_0^t c_r(t)dt - F\int_0^t c_p(t)dt$$

$$V_l c_l(t) = F\int_0^t c_p(t-\tau_p)dt - F\int_0^t c_l(t)dt$$

$$V_b c_b(t) = F\int_0^t c_l(t)dt - F\int_0^t c_b(t)dt$$

where F (ml/sec) is a mean blood flow rate, V's (ml) and c(t)'s (μCi/ml) represent equivalent volumes and isotope concentration of right and left hearts, pulmonary and body blood vessels, and τ's (sec) represent transportation lags in pulmonary and body systems.

Transportation process at the injected part

$$V_i C_i(t) = \int_0^t \frac{I}{\tau} dt - F_i \int_0^t c_i(t)dt$$

These equations construct a mathematical model of hemodynamics transporting injected isotope.

Cardiac output can be calculated from following equations by using parameter values T's and τ's and mean concentration $C(\infty)$ in steady state.

$$V = V_r + V_p + F\tau_p + V_c + V_b + F\tau_b = I/c(\infty)$$

$$Fc(\infty) = \frac{IF}{V_r + V_p + F\tau_p + V_c + V_b + F\tau_b} = \frac{I}{T_r + T_p + \tau_p + T_l + T_b + \tau_b}$$

where $T_r = V_r/F$, $T_p = V_p/F$, $T_l = V_l/F$ and $T_b = V_b/F$ are time constants of four blood vessels of right heart, pulmonary, left heart and body systems, and $(V_p + F\tau_p)$ and $(V_b + F\tau_b)$ represent pulmonary and body blood volumes.

A generalized mathematical model of cases where are a shunt of left heart to right heart and in inverse shunt of right heart to left heart was developed and a generalized hemodynamics simulation circuit was constructed by using an analog computer on the basis of the above model.

Simulated radiocardiograms obtained from the simulation circuit showed good coincidence with measured ones and calculated cardiac outputs for 20 patients were almost equal to measured cardiac outputs by Fick method.

Heart Pool Scintigram

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In 1958, Rejali et al introduced the radioisotope heart pool scan utilizing ^{131}I labeled human serum albmin. It has been helpful in the differential diagnosis of pericardiol effusion, vascular aneurysms and mediastinal masses.

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Since then, a few litaratures dealing with the heart pool scanning were reported. One of the reasons may depend on other establishing procedures such as angiocardiography, intracardiac catheter and pneumopericardium examinations. The heart pool scintigram has same useful value in the diagnosis of the heart disease notwithstanding harmless and easy procedures, and recent development of instrumentation gives more accurate and valuable informations in the diagnosis. In this paper same considerations of heart pool scintigrams are discussed not only on the distribution of radioisotopes but concentration of its activity.

Enlargement of the cardiac shadow on the chest X-P sometimes can not be differentiated between cardiac enlargement and pericardial effusions. Pneumapericardial or angiocardiographic examinations are very helpful in differential diagnosis, but these examinations are quite elaborate procedures and sometimes result some irreversible prognosis. Therefore, some simpler procedures are preferable. In this point, heart pool scintigram is suitable. About 10 cases which shows caracteristic findings in heart pool scintigrams are exhibited, they are pericarditis, aortic anomalies, aneurysms, etc.

Now we are going to do some dynamic studies on heart pool, utilizing the scintillation camera, specially in the patients who are suspected to have valvular insufficiency as stenosis and shunt of the congestive heart failure.

Problems in Myocardial Scanning

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The scintiscanning with ^{131}Cesium for the visualization of the myocardial infarction has clinically been investigated in Chiba University Hospital since several years ago. Serries of the phantom experiments were performed for checking the size and localization detectable by scanning procedure, and for estimating the contribution of the ribs and cardiac beats to the real image of myocardium. A 10cm plastic ball containing smaller solid plastic ball in it is the phantom used. Cesium chloride ^{131}Cs was infused in 1cm gap just inside the outer wall of the ball phantom. Plastic void of 1 to 3cm diameter is attached in the gap of each phantom, which simulates the myocardial infarction. The ball phantom was baried in the rice-filled box with a piece of human ribs and sternum. Three inch rectilinear scanner with 10cm focusing collimator (37 holes) was the instrumentation. Obtained results are as follows,

1) Voids larger than 2cm were detectable.

2) Any void could be detectable except posterior and postlateral localization.

3) The contribution of ribs were checked lest they should produce the false infarction images in the cardiac siluette. The fear was avoided when the collimation was focused on the anterior wall of the myocardium.

4) Cardiac beats proved to have little effect on the scan images of the 2cm void. Cardiac beats simulation was 65/min at 1cm movement.

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