of the curves caused by the extra-body counting technique, and the validity or even their underlying principles have not yet been established.

An attempt was made in our laboratory for the analysis of radiocardiogram with four scintillation counters and a special purpose analog computor as a radiocardiogram simulator.

The circulation model assumed was consisted of seven compartment (venous part, right side of heart, pulmonary field, left side of heart, arterial part and two of peripheral circulations), and the delay lines connected between these compartments.

The simulated curve was illustrated on oscilloscope and was projected on the recording paper of radiocardiogram.

A justing the appearance times and the rates of empting of the compartments of the model, the simulated curves were matched to radiocardiograms and as the result of this procedure the characterics of circulation i.e., real appearance times and rates of emptying, was shown on the dials of simulator by means of impulse response of the circuit.

In healthy persons, the estimated values of appearance time between compartments and rates of emptying were $46 \pm 8\%$ per sec and $38 \pm 3\%$ per beat for right side of heart, 2.16 sec, $20 \pm 4\%$ per sec, and $16 \pm 4\%$ per beat for lungs and 2.65 sec $50 \pm 7\%$ per sec and $42 \pm 4\%$ per beat for left side of heart respectively.

In the cases of hyperthyroidism the rates of emptying were increased both in per sec and per beat, and the appearance times were shortend, and contrasted to the hyperthyroidism, patients with hypothyroidism showed low rates of emptying and lated appearance times.

Patients with mitralstenosis had low rate of emptying in right side of heart and lung field, and with mitral insufficiency showed low rate in both side of the heart.

Also the abnormal route of circulation was simulated in cases of VSD and T.F. etc.

The arithmetical method of trial and error was obviously rather tendious, and the fitting analysis was easily carried out by means of electronic simulator, and showed usefullness in diagnosis of cardiovascular diseases.

S. Miyamoto

Nihon University School of Medicine, Tokyo

The extracorporeal circulation based on the maintenance of balance of venous and arterial return can be considered to be a state of induced hemorrhagic shock when the perfusion is not adequate. Therefore in order to make better the postoperative results of cardiac surgery, we should study on the pathogenesis of hemorrhagic shock, but up to now only a very limited information about pulmonary circulation in shock is known. According to our recent study, a positive correlation is observed between the circulating blood volume of normal infants and small children estimated by the use of Volemetron with RISA and body length or weight. However the circulating blood volume of infants and small children suffering from congenital cardiac diseases is increased remarkably compared with normal cases and this tendency is observed clearly in the cardiac patients in whom a large intracardiac shunt was found pre- and postoperatively. As a positive cerrelation between the circulating blood plasma volume and body weight, an increase of circulating blood volume is thought to be due to an increase of red blood cell mass. Such a fact indicates that in case of extracorporeal circulation for infants and small children the flow rate of perfusion should be much more than for adults and postoperatively it is necessary to keep more adequate amount of red cell mas than that of blood plasma volume. We measured experimentally the mean pulmonary circulation time and pulmonary blood volume by radiocardio-

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graphy with RISA and got the following results: The mean pulmonary circulation time and pulmonary blood volume is decreased during the duration of two hours of hemorrhagic shock. After the return of extracted blood, the mean pulmonary ricculation time and pulmonary blood volume come to the level slight higher than the preoperative. This fact indicates that the disturbance of pulmonary circulation might be remained after the return of same amount of blood. The circulating blood bolume per Kg of body weight is increased more than the preoperative value after the return of blood and Ht-value is increased during the secondary hour hemorrhagic shock and continues the same state after the return of blood. The circulating blood plasma volume and red cell mass have the same tendency as the blood volume. Thus, there is a marked discrepancy between the cardiac output and the circulating blood volume after the return of blood the former comes to the preoperative level but the latter exceeds the preoperative level. This discrepancy is considered to be due to blood pooling in pulmonary and systemic veins, resulting in pulmonary congestion and peripheral circulatory failure. Therefore it is concluded that an inadequate perfusion in extracorporeal circulation and postoperative treatment for cardiac patients might spoil the result of surgical treatment.

A Mathematical Model Radiocardiogram and its Analog Simulation Circuit

K. Torizuka
Central Clinical Radioisotope Division, Kyoto University Medical School, Kyoto
M. Kuwahara
Faculty of Engineering, Kyoto University, Kyoto

Radiocardiogram is considered as a representation of hemodynamics of inflow into outflow from right and left hearts of injected isotope. This paper deals with 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 blood vessels.

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

$$V_rC_r(t)=F_i\int_0^t C_i(t)dt+F\int_0^t C_b(t-\tau_b)dt-F\int_0^t Cr(t)\,dt$$

$$V_pC_p(t)=F\int_0^t C_r(t)\,dt-F\int_0^t C_p(t)\,dt$$

$$V_lC_l(t)=F\int_0^t C_p(t-\tau_p)\,dt-F\int_0^t C_l(t)\,dt$$

$$V_bC_b(t)=F\int_0^t C_l(t)\,dt-F\int_0^t C_b(t)\,dt$$

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 can be shown as

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

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

Cardiac output can calculated from following equations by using parameter values T's and τ's and mean concentration c (∞) in steady state.

$$V=V_r+V_p+F_p+V_c+V_b+F_b=I/c\ (\infty)$$

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

where $T_r=V_r/F$, $T_p=V_p/F$, $T_l=V_l/F$ and $T_b=$

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