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COMPARTMENT MODELLING STUDY OF STABLE IODINE PROPHYLAXIS IN RELATION TO THE DAILY IODINE SUPPLY

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The aim of our compartment modelling studies is the prognostication of the protective effectiveness of the stable iodine intaken to decrease the radiation damage of the thyroid resulting from accidental radioiodine incorporation. The protective capacity of stable iodine prophylaxis is investigated in relation to the daily iodine supply.

Calculations have been done according to Johnson's modified version of Riggs iodine kinetics model with parameters taken from them and ICRP's Reference Man. In this four-compartment model kinetics of the radioactive and of stable iodine is described by 10 differential equations. According to our model-analysis solutions of 5 equations can be given in analytical forms, thus only a 5-dimensional system should be integrated numerically. Method of Runge-Kutta-Fehlberg was used for this purpose. The radiation burden is characterized by the residence times /cumulative activities/ of 131-I in thyroid gland treated with stable iodine related to control subjects.

According to our results at iodine supply of a quarter of the normal dietary iodine intake (75 μg/day) the residence times of 131-I in the thyroid gland are doubled and the protective effect of stable iodine given in the same large doses and at the same time-intervals are decreased by 30-50 % in comparison with that at normal iodine supply. As another example the elevation of standard iodine supply by 50 % leads to a 30 % reduction of residence times with a 20 % enhancement of protective effectiveness of stable iodine prophylaxis.

Introduction

It is well known that stable iodine compounds provide significant blocking or protective effect on the thyroidal uptake of radioiodine accidentally or purposely intaken [1,2]. According to experimental data of other authors [1-7] as well as to our previous experimental results [8-11] the protective capacity of stable iodine given in large doses - i.e. in doses a few hundred times exceeding the daily need of the organism in iodine - strongly depends on the length of the time-interval between the intake of radioactive and stable iodine, on the average daily iodine supply and depends in a smaller rate on the amount of stable iodine used for thyroid blocking.

The aim of our compartment modelling is to clear whether our program is suitable for the modelling of the experimental observations as well as for the prognostication of the protective effectiveness of large /so called protective or therapeutic/ doses of stable iodine intaken in case of radiation emergency by the nuclear workers and the population at different levels of the daily iodine supply.

Methods

Our calculations have been done according to Johnson's modified version of Riggs iodine kinetics model [12, 13] given in Fig.1. The applied parameters taken from them and ICRP's Reference Man [14] - Table I.

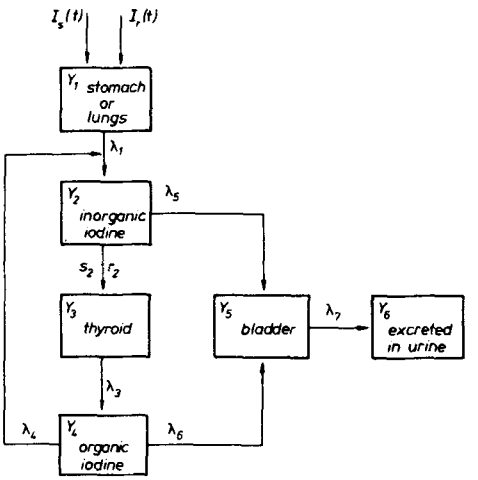

Fig.1. Block diagram of the kinetics of iodine

Table I

Kinetic parameters of iodine in man

$\lambda_1 = 192\ d^{-1}$	$\lambda_4 = 0.053\ d^{-1}$	Ref. man:
$s_2 = 65\frac{M_s}{70}$ /ud	$\lambda_5 = 1.92\ d^{-1}$	M_S= 70 kg body weight
$r_2 = s_2 Y_2^{(r)}/Y_2^{(s)}$	$\lambda_6 = 0.005\ d^{-1}$	M_T= 12 mg iodine in the thyroid
$\lambda_3 = s_2 M_r$	$\lambda_7 = 9.1\ d^{-1}$	I_s= 200 /ug/d daily iodine intake

Note: s - stable iodine, r - radioactive iodine

Besides the normal daily iodine intake of reference man we have also modelled a decreased and an elevated level of iodine supply /75 and 300 /ug/d, respectively/. Protective doses of stable iodine /30, 100 or 200 mg/ were administered within 3 hours following the ^{131}I incorporation.

Solutions of 5 from the 10 differential equations describing the kinetics of the radioactive and of stable iodine in this model can be given in analytical forms according to our model-analysis, To integrate the remained 5 equations the method of Runge-Kutta-Fehlberg was used [15].

The reduction in the radiation burden (fractional dose reduction, FDR) at different schemes of stable iodine prophylaxis and at different levels of stable iodine supply is characterized by the ratio of the residence times (i.e. cumulative activities, τ) of ^{131}I in the thyroid gland treated with stable iodine (τ_i) and of control (τ_c) subjects as follows:

$$\boxed{FDR\ [\%] = 100\,\tau_i/\tau_c}$$

Results

Due to analytical solution of one half of the differential equations of the applied model the running time of the program could be considerably decreased.

At the same daily iodine supply the reduction of the radiation burden of the thyroid gland is more dependent on the time-interval between the intake of radioactive and stable iodine, than on the amount of stable iodine administered at the same time - Table II. The maximal reduction of thyroid dose is calculated for the simultaneous intake of the radioactive and stable iodines /as is shown in Table II/.

Table II

Modelled decrease of thyroid dose by stable iodine given in different doses and time-points at standard iodine supply of 200 /ug/d as compared to the control [in %]

Amount of iodine, [mg]	Dose-ratios [in %] depending on the time of administration of stable iodine versus the time-point of 131-I incorporation, [h]				
	-2	0	1	2	3
30	2.4	2.0	7.3	17.3	26.1
100	0.8	0.7	6.1	16.2	25.2
200	0.5	0.4	5.8	15.9	24.9

At decreased level of dietary iodine intake the residence time of ^{131}I in the thyroid gland increases by a factor of 2 than at normal iodine supply - Table III. Thus, the protective capacity of large amounts of iodine given at the same time-intervals is reduced by 30-50 %. On the contrary, elevation of the daily iodine supply leads to a 30 % decrease of residence time of ^{131}I in the critical organ with a moderate enhancement /up to 20 %/ in the protective efficacy of the iodine prophylaxis as is demonstrated in Table III.

Table III

Effect of daily iodine supply on the residence time of ^{131}I in the thyroid gland and on the effectiveness of stable iodine prophylaxis as compared to the control [in %]

Time of intake [h] of 200 mg iodine following the 131-I incorporation	Residence times [h] /and dose-ratios [in %]/ depending on the daily iodine supply [ug/d]		
	75	200	300
- /control/	71.6	36.4	26.1
1	5.7 /7.9/	2.1 /5.8/	1.4 /5.5/
2	15.6 /21.7/	5.8 /15.9/	3.9 /14.9/
3	24.0 /33.5/	9.1 /24.9/	6.1 /23.3/

Conclusion

The results of our compartment modelling studies have proved the data and tendencies obtained in investigations on volunteers [1-7]. A moderate increase of the daily iodine supply have enhanced the protective capacity of the stable iodine prophylaxis in our numerous laboratory experiments as well as in the present computer modelling [8-11]. Thus, our program is suitable for the prognostication of the effectiveness of stable iodine prophylaxis both in man and experimental animals.

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References

1. L.A. Ilyin, ed.: Radioactive iodine in the problem of radiation safety, Atomizdat, Moscow, 1972. pp.270.
2. NCRP: Protection of the thyroid gland in the event of releases of radioiodine. NCRP Report No. 55, Washington DC, 1977. pp.60.
3. M.Blum and M.Eisenbud, J.Am.Med. Assoc; 200, 1036, 1967.
4. G.Tanaka, in Proc.Symp. "Diagnosis and Treatment of Deposited Radionuclides", ed. H.A.Kornberg and W.D.Norwood, Excerpta Medica Foundation, Amsterdam, 1968. pp.298-315.
5. R.E.Ellis et al, Brit.J.Radiol., 50, 203, 1977.
6. V.Volf, Atomkernenergie-Kerntechnik, 37, 50, 1981.
7. D.V.Becker, Bull. N.Y.Acad.Med., 10, 1003, 1983.
8. I.Turai, Izotóptechnika, 24, 278, 1981.
9. I.Turai, Izotóptechnika, 25, 218, 1982.
10. I.Turai and L.D.Oztanyik, IAEA/HPRA 10, 120, 1983.
11. I.Turai, and M.Toivonen, Radiohygiene of Fission Isotopes of Iodine: Experiments in Rats and Model Studies in Man, Inst. Radiation Protection, Helsinki, STL-A 42, 1983.
12. D.S.Riggs, Pharmacological Review, 4, 284, 1952.
13. J.R.Johnson, J.Radioanal. Chem., 65, 223, 1981.
14. ICRP: Report of the Task Group on Reference Man. ICRP Publication 23, 1974.
15. E.Fehlberg, Low-order classical Runge-Kutta formulas with stepwise control, NASA TR R-315, 1969.