Dose rate distribution on cultured cell exposed to ^{125}I seed in vitro irradiation

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【Abstract】

Objective To study the dose rate distribution on cultured cell plane and establish a reference dose rate table of in vitro cell line ^{125}I seed irradiator.

Methods Thermoluminescence dosimetry (TLD) was used to measure the irradiation dose rate of a single 6711 model ^{125}I seed with apparent activity of 10.323MBq in water at point P. Meanwhile, the theoretic value of the irradiation dose rate at point P was calculated with theoretic formula. The difference between the calculated and observed values within 10% was set as standard to analyze the accuracy of the measurement. The irradiation dose rate of a single 6711 model I^{125} seed was measured in 1mm thick polystyrene + water medium at point P. The value was applied to differential or non-differential proof along with the value from water medium to study the effect of 1mm thick polystyrene on distribution of irradiation dose in water. Finally, by simulating the ^{125}Iseed plane irradiator with nine I^{125} seeds, the distribution table of irradiation dose rate on the cultured cell plane was calculated with theoretical formula.

Results The observed value (n =10) of irradiation dose rate with one I^{125} seed in water at point P was(0. 359 ±0. 023) cGy/h and the calculated value was 0.347 cGy/h, the difference was within 10%. The observed value (n =10) of irradiation dose of one I^{125} seed in 1mm thick polystyrene + water medium at point P was (0. 350 ±0. 027) cGy/h , which showed no statistical difference from the observed value in water under differential and non-differential proof. The reference table on dose rate distribution for cells exposed to I^{125}seed irradiation in vitro was developed.

Conclusions 1mm thick polystyrene gives no significant effect on irradiation dose rate distribution from I^{125} seeds in water. A reference table on the dose rate distribution for cells exposed to I^{125} seed irradiation in vitro has been developed, which can be used to determine an optimal irradiating strategy for future work.

【Key words】 Iodine radioisotopes ; In vitro irradiation; Distribution of dose rate

The previous studies on X-ray biological effect with LD or HD single irradiation were all under restrict dosage control. Implanted ^{125}I particles irradiate the cells continuously with LD, which differs from external irradiation. The in vitro research in mechanism of this irradiation was not reported so far. The reason may be because that ^{125}I irradiation dose distribution was complicated, and reasonable irradiation patterns was unavailable, precise irradiation dosage on in vitro cultured cell plane was beyond control as well or evenly exposed. Therfore , the author simulated the situation of cultured cell exposing to ^{125}I seed in vitro irradiation, analyzed ^{125}I seed irradiation dose distributing rules of in vitro cell plane.

Method and Material

1. Major material and equipment

6711 model ^{125}I seed with apparent activity of 10.323MBq (0.279 mCi), 5% QTd. Thermoluminescence dosimetry (TLD) TLD22000R model (LiF :Mg ,Cu ,P) ,1mm×1mm×1mm cube, 5% QTd from Beijing Institute of chemical defence. Philips MGC320 X-ray machine from Shanghai bureau of measurement can produce 33KV X-ray photon. Thermoluminescent dose meter(TLD) RGD3B, form Beijing Institute of chemical defence. 4cm×4cm polystyrene board is from the bottom of a φ60mm disposable sterilized tissue culture dish, 1mm thick.

2. Thermoluminescent dose meter (TLD) RGD3B calibration

annealed TLD22000R component was exposed to 0.10, 0.25, 0.50, 1.00, 2.00, 3.00 cGy with 0.2mGy/min dose rate, 33kVX X-ray. After exposure, the RGD3B TLD was read under 650V high voltage, M2 range measuring condition (this measuring condition as a routine). The results was input into computer in EXCEL software followed by the analysis of the relationship between the RGD3B TLD and TLD22000R TLD sensor which has been exposed to 33kV X ray, portray and fit a Convert Curve between values and exposure dose, which will be used for measuring the ^{125}I seeds exposure dose convert in later experiments.

3. Theoretical arithmetic of ^{125}I seeds dose rate

according to references, the calculation formula which was used for ^{125}I seeds dose rate in water is as following in calculating ^{125}I dose rate in space P(r,θ). ÛD=1. 27×A ×Λ×g (r) ×.Φan/ r2 (r > L) (1) In formula (1), A represents ^{125}I seeds surface activity (mCi); r represents the distance where spot P to seeds center (cm); L is the length of appropriate active seeds. As for 6711, L=3mm; Λ is a constant of ^{125}I seeds dose rate, as for a specific ^{125}I seed, the constant is fixed; g(r) is a radial dose function, representing the absorption effect and scattering effect along the horizontal axis of seeds. Radial dose function is an equation fitting: g(r)= a0 + a1 r + a2 r2 + a3 r3 + a4 r4 +a5 r5 , a0～a5 is constant. Φan is an anisotropic constant, as for a specific ^{125}I seed, it's fixed. ÛD is dose rate (cGy/ h), when r=1cm, θ= 90°, it can be calculated by formula (2). ÛD=1. 27×A×Λ (2)

4. Measurement and calculation of ^{125}I seeds dose rate

TLD22000R TLD sensor was put at spot P(r,θ) (refer to chart 1), and exposed to single 6711 model ^{125}I seed for 1 hour with apparent activity 10.323MBq in water medium and 1mm polystyrene plate plus water medium separately. After irradiation, the RGD3 TLD meter was read. The value was transferred into irradiation dose according to fitting transfer curve, taken as the measured value of I^{125} seed dose rate. According to formula (2), theoretical value of dose rate at spot P(r, θ) was calculated in the experiment. It was considered as a reliable and precise way to measure disposition of I^{125} dose rate if the difference between measured value and theoretical value of the seed in spot P was within 10%.

5. Researches on ^{125}I seeds dose rate distribution on cultured cell plane

Referring to references [3] a cultured exposure device was set up. nine 6711 model ^{125}I seeds was applied with the same apparent activity (assumed as 37MBa, 1mCi), 8 of which was on a 3cm circle averagely, 1 was in the center. 5 points were set to calculate cell plane dosage (refer to chart 2). The cell plane was 4-10mm to seeds plane 1mm in between. Each cell plane dose rate of 5 points ws measured to set the ratio of maximum and minimum dose rate as content uniformity. The maximum locus was dislodged, the even irradiation dose rate was then calculated.

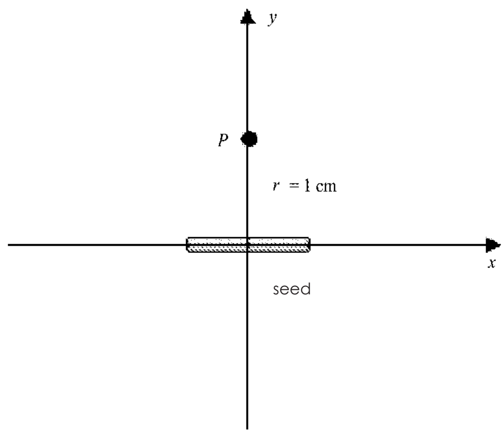
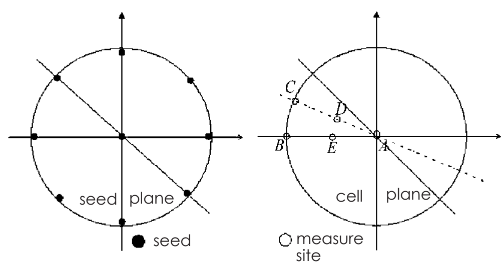


Chart1 Spot P(r,θ) dose rate measuring sketch map



6. Statistical methods

t-test the even of water medium and polystyrene plus water medium, if t-test is not statistically significant, proceed equivalence test is proceeded.

Results

1. RGD3B model TLD meter demarcation: annealed TLD 22000R sensor was irradiated with different dosage by

33KV X ray. The RGD3B value was read, meanwhile, fitting TLD value was a linear curve with dose transfer curve, whose expression was Y =0. 024 X - 0. 002, degree of fitting R2=0.999. This expression was used to measure ^{125}I seeds irradiation dose converting. ^{125}I seeds irradiation dose(cGy)=0.024XRGD3B TLD meter value-0.002(3)

2. The measurement and calculation of 125I seeds dose rate: theoretical value calculation result is based on formula (2), calculating dose rate theoretical value of single 6711 model ^{125}I seed with apparent activity 10.323MBq at point P (Refer to chart 1) is 0.347cGy/h. TLD sensor (n=10) was arranged at point P, irradiated by a single 6711 model ^{125}I seed with apparent activity 10.323MBq in one hour separately in water and 1mm thick polystyrene + water medium. Measure the value of TLD sensor with RGD3B thermoluminescence meter according to formula (3), transfer the value to dose rate at point P of ^{125}I seed as following, (0.359±0.023), (0.350±0.027) cGy/h.

3. because Data analysis: Due to the mean discrepancy of measurement result and theoretical value was 3.3%, meanwhile none statistically significant (t=0.78, P>0.05), equivalence test was adopted.

4. ^{125}I seeds in vitro irradiation dose rate distribution on cultured cell plane calculating: calculate dose rate theoretical value at 5 points on cultured cell plane, set maximum and minimum ratio as dose rate content uniformity, and dislodge the maximum dose rate point calculating mean irradiation dose rate(dose rate mean): results as following(chart 2).

Discussion

^{125}I seeds disintegrate with emitting 35.5, 27.4and 31.4kVγand X-ray. [1, 4] There were many kinds of ^{125}I seeds with size and external structure are in common, though inner fill and attachments are different. Among which, 6711 model ^{125}I seeds, silver rod with surface adsorption ^{125}I are most common. The silver rod irradiates 22.1, 25.5kV X-ray which was stimulated by γand X ray that ^{125}I seeds emitted within spontaneous decay. Therefore the photons which were produced by 6711 model ^{125}I seeds are 28.5kV average energy. It's necessary to demarcate meters for accurate measurements. Abstractly, the standard radioactive source for demarcation was supposed to be the same with planned measurement one in physical characteristics, but as a matter of fact, it's hard. The 33kV X-ray source which was adopted for demarcation was quite similar to 6711 model ^{125}I, but not same. So, error is hard to avoid. It's reported that 31kV X-ray source was adopted for demarcation in abroad. It's considered that the difference between 31kV X-ray source and 6711 model ^{125}I seeds was the main reason leading to error [3].

^{125}I seeds average energy is low, which lead to a "sharp cutoff" dose attenuation in tissue. The Manchester, Paris system which was used for calculating high-energy photon (222Rn, 198Au) was inappropriate for ^{125}I dose rate. [4, 10] In 1995, the AAPM TG43 report set up outlines of various parameters that affect ^{125}I seeds dose distribution in water, calculation formula of ^{125}I seeds dose distribution in water, and analyzed various uncertainties of those parameters, then get total indeterminacy by integral. Finally came the conclusion of 10% uncertainty between theoretical value and measured value. [1] Therefore, the author set the difference within ±10% between theoretical value and measured value as measurement standard. In this experiment, the dose rate of a 6711 model ^{125}I seed with 10.323MBq apparent activity at point P in water (Refer to chart 1) was measured preferentially. The result is 0.359 cGy/h. According to the formula that TG43 report referred, calculated the dose rate at point P 0.347cGy/h theoretical value based on seeds activity, calculation spot. The difference is 3.3% between theoretical value and measured value. It's proved that the procedures and results are accurate and reliable for 6711 model ^{125}I dose rate in water.

The formula that TG43 report recommended uses water as media. It's necessary to cultivate cells in vitro for researching biological effect of ^{125}I seeds that irradiate in vitro cells continuously. The culture flasks and culture dishes that used for culturing cells are glass or polystyrene with a certain thickness, may do some attenuation to ^{125}I seed. Though it's reported that the ^{125}I seed attenuation in polystyrene is similar to that in water, it's unroofed by experiment. The writer studied the practical effect of 6711 model ^{125}I seeds attenuation in 1mm polystyrene to measure the irradiation of ^{125}I seeds to in vitro cells precisely. The results come out with no attenuation affect of dose rate that 1mm polystyrene in water for 6711 model ^{125}I seeds. So, the formula can be applied which TG43 report recommended to calculate cell plane dose rate, with using theoretical value instead of measured value to analyse irradiation rate. Two factors must be considered, dose and dose uniformity on in vitro cells continuous irradiation. The results showed (chart 2), the far the cell plane to seeds plane, the higher cell plane dose rate uniformity are. That means, the more even at different spots on cell plane are on a certain time. The irradiation dose rate dropped down rapidly as long as cell plane got far from the seeds. Theoretically, the irradiation dose rate is tent to uniformity as cell plane are far from seeds plane on a certain distance of a knockdown level. For predetermined irradiation dose rate, the irradiation time and distance where cell plane to seeds plane can be adjusted in the ^{125}I seeds in vitro irradiation experiment according to the results of chart 2 to calculate cell plane dose rate as well as uniformity of dose rate distribution with the actually used 6711 model ^{125}I seeds activity. For instance, apparent activity 27.8 MBq 6711 model ^{125}I is 5mm from the cell plane, the value is 1.48 of uniformity according to the results of chart 2. Cell plane with initial even irradiation dose rate 4.56 cGy/h. The cells were supposed to intake 44.31h irradiation based on decay if 200cGy irradiation was considered. The uniformity will get even meaner as 1.42 if the cell culture dish was twisted 22.5°at halfway of irradiation time.All the theoretical arithmetic that writer used to calculate was based on the TG 43 report recommendation, it's applicable to various ^{125}I seeds. But each seed was different on internal mechanic structure as well as parameters. So, when calculate the dose rate of a specific ^{125}I seed, its own parameter must be adopted. [11] In this report, 6711 model ^{125}I seed was put on to the test, so specificity is advised.

Table 1 Parameters of 6711 type ^{125}I seeds

Radial Dose Functiong(r)	Anisotropic ConstantΦan	Dose Rate ConstantΛ[(cGy/(hr•U)]	Air Ratio kerma IntensionSk(U)
a0 =1.014			
a1 =1.22710X10-1			
a2 =21.730 x 10	0.93	0.98	manufacture provides
a3 =4.024 x 10			
a4 =23.852 x 10			
a5 = 1. 343 x 10			

Chart 2 ^{125}I seeds in vitro irradiation cell dose rate reference pattern list

h (mm)	Point A (cGy/h)	Point B (cGy/h)	Point C (cGy/h)	Point D (cGy/h)	Point E (cGy/h)	dose rate content uniformity	mean dose rate (cGy/h)
10	3.64	2.95	2.88	3.37	3.55	1.264	3.188
9	4.11	3.37	3.25	3.75	3.93	1.264	3.575
8	4.69	3.92	3.69	4.16	4.37	1.271	4.035
7	5.47	4.65	4.21	4.61	4.85	1.299	4.580
6	6.53	5.69	4.81	5.11	5.36	1.358	5.243
5	8.17	7.31	5.52	5.61	5.89	1.480	6.083
4	11.03	10.15	6.31	6.12	6.43	1.802	7.253

Note: 6711 model ^{125}I seeds, apparent activity 37MBa, 8 were on Dia. 3cm circle averagely, 1 was in the centre. h is the distance of cell plane to seed plane(mm).

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