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THE MCNP SIMULATION OF A PARTICLE SOURCE IMPLANTED IN THE HUMAN BODY

Abstract
Radiotherapy has always been the main method for the treatment of malignant tumors, and seed source implantation is a new type of brachytherapy. It has the characteristics of small trauma, accurate dose of tumor target area, and uniform distribution. In clinical treatment of seed source implantation, a scientific and appropriate radiotherapy plan must be formulated, and it is necessary to study the dose field of low-energy seed source. In this paper, the Monte Carlo method is used to simulate the dose field distribution of two specific particle sources I125 and 103Pd, and the exposed source of I125 in the water phantom, and compare and analyze them. Since water can simulate human tissues well, the dose rate distribution in water of the particle source can also be approximated as the dose rate distribution in human tissues.

1. Theory Introduction

(1) Determine the feasibility of the simulation by comparing the simulated value of MCNP5 with the theoretical value, which is the premise for the next step of research.

(2) Simulate the dose field distribution of a single I125 particle source and 103Pd in the water phantom, and add hospital PVC pipes and titanium omentum to the periphery of the source to compare the changes in the dose rate. The dose rate of both is the layer index decline, but the metal titanium mesh has a great influence on the dose rate.

(3) Simulate the dose field distribution of a single bare I125 source (without cladding) in the water phantom, and compare it with the previous cases. It was found that the radial dose first increased and then decreased, and a built-up area appeared.

2. Simulation method

Figure 1. 125I and 103Pd particle sources

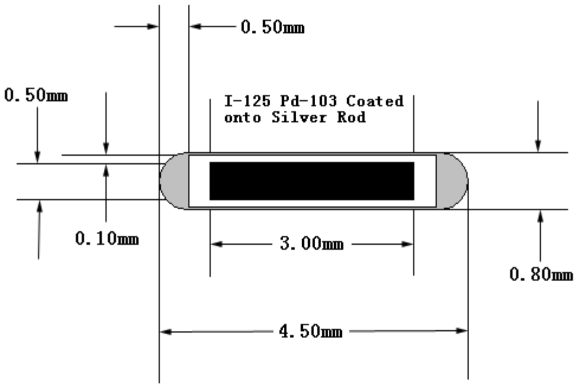

Figure 2. Geometric cross-sections of 125I and 103Pd particle sources

The geometric dimensions of the low-energy gamma particle source used in this article are shown in the figure. This particle source can be used for 125I or 103Pd, with a diameter of 0.8mm and a length of 4.5mm. The outermost cladding is a titanium tube with a sidewall thickness of 0.05mm. The two ends of the cladding are sealed by two titanium hemispheres with a radius of 0.4mm, using argon arc welding sealing technology. Finally, 125I or 103Pd nuclide was deposited on a silver rod with a diameter of 0.5mm×3mm by electroplating. The activity of the radioactive source will decay exponentially with time, and the activity of the low-energy particle source currently in production is generally between 0.4 and 1.0 mC.

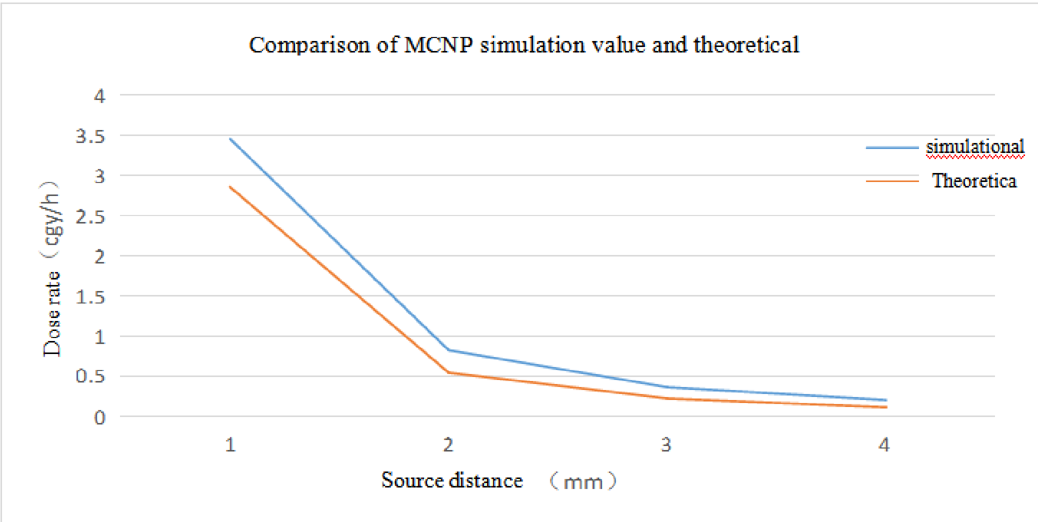

Figure 3. Comparison of MCNP simulation value and theoretical value

We can see from the figure above that the simulated value is always smaller than the theoretical value due to the influence of the cladding. But the overall trend is the same, the radial dose coefficients all decay exponentially, and the simulated values can largely conform to the theoretical values. It can be explained to a certain extent that the MCNP program can simulate the dose distribution of low-energy particle sources more accurately.

3. Results

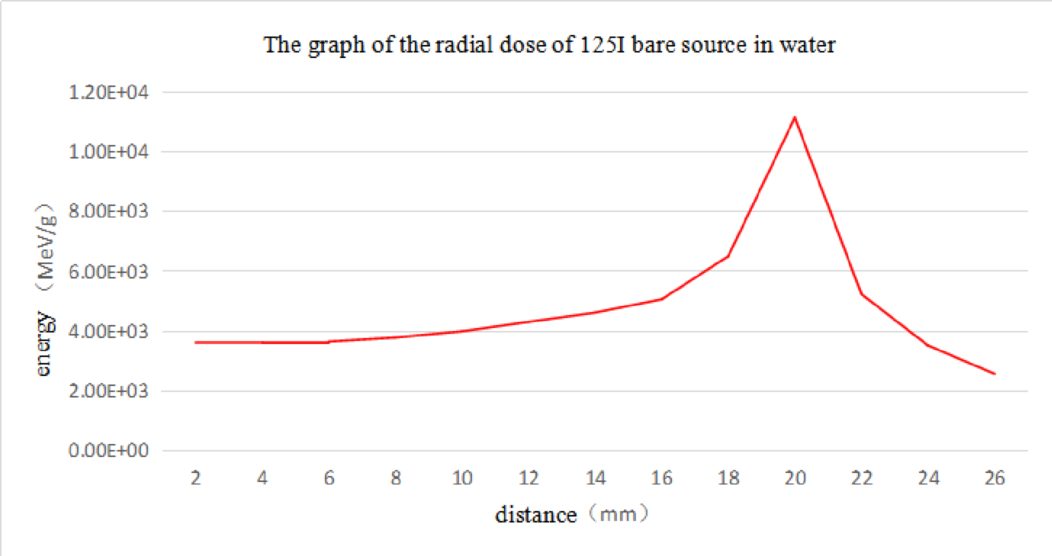

Figure4. The broken line graph of the radial dose of 125I bare source in water

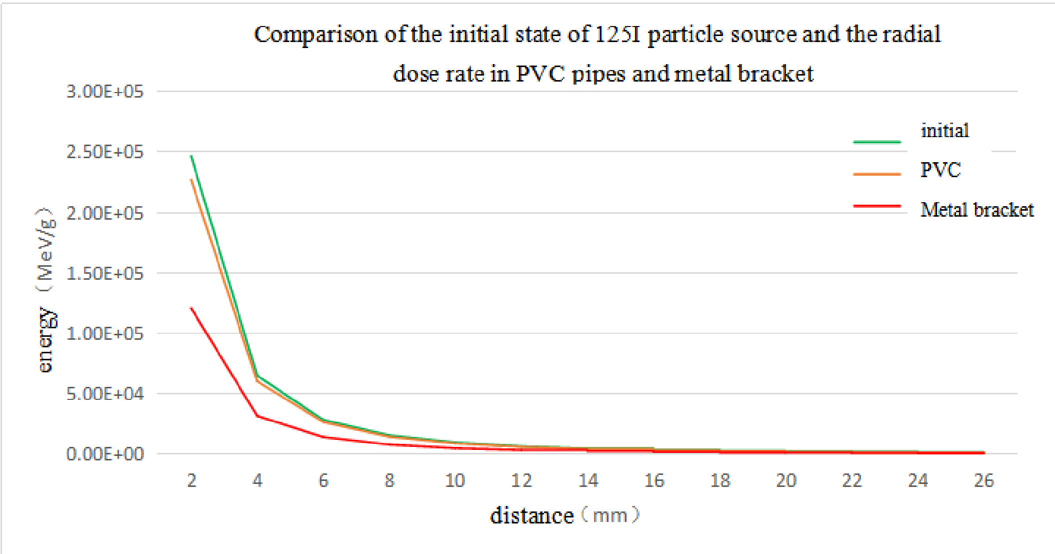

Figure 5. Comparison of the initial state of 125I particle source and the radial dose rate in PVC pipes and metal bracket

4. Conclusion

This paper uses Monte Carlo method and MCNP5 software to simulate the dose rate distribution of two kinds of common particle sources in medical brachytherapy-125I and 103Pd in the water phantom. Because the water phantom can well reflect the actual situation in human tissues, the dose distribution of these two particle sources in human tissues can be simulated.

(1) Use MCNP5 simulation to test the 125I particle source and compare the theoretical value with the actual simulation value of MCNP5. It is found that the simulated calculation data is basically consistent with the theoretical calculation data, but the result is slightly smaller due to the influence of the cladding. But we can still conclude that it is feasible to use MCNP5 to simulate and calculate the dose field of a low-energy particle source.

(2) Simulate the dose rate distribution of the 103Pd particle source and the 125I particle source in the water model, and compare the simulated data and graphs. The space dose rate of the two low-energy gamma particle sources is the square of the distance from the center of the source in the water model. It is inversely proportional, and decays quickly. However, due to the difference in energy and dose rate and decay cycle of the two particles, they are suitable for the treatment of different types of cancer in clinical treatment.

(3) Simulate the dose rate distribution of 125I and 103Pd particle sources in medical PVC catheters and metal (titanium) therapeutic stents in medical PVC catheters. Comparing the simulated data and graphs, it is concluded that the medical PVC catheter has little effect on the dose rate distribution, while the metal therapeutic stent has a great effect on the dose distribution. Especially for the 103Pd particle source, the dose rate distribution under the metal therapeutic stent has been reduced to 1/3 of the original. Therefore, if a metal stent is used in the treatment, the activity of the source should be appropriately increased to increase the dose to achieve the desired purpose.

(4) It is worth noting that when simulating a bare source (without cladding), the dose rate of the 125I particle source in water first increases and then decreases. This is because without the absorption and blocking of the cladding, the energy emitted by the particle source in the water leaves the built-up area. We can see that the maximum dose rate appears at 20mm, which means that the maximum dose rate does not appear in the nearest place, but only after a certain distance. The area in between up to the maximum depth becomes the dose built-up area, which is a property that the enveloped particle source does not have.

REFERENCES

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2. Nath R, etal. Dosimetry of Interstitial Brachytherapy Source: Recommendations of the AAPM Radiation Therapy Committee Task Group // No. 43. MedicalPhy, 1995, 22(2):PP. 209.