

Optimized image acquisition parameters for imaging radioactive iodine-125 seed implantation for cancer treatment

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Abstract

Objective: Objective: Using nuclear medicine imaging, we explored suitable acquisition window parameters for assessing the distribution of iodine-125 radioactive seed implantation. **Subjects and methods:** We studied 30 patients with various tumors (21 of which were liver cancers) who had received iodine-125 radioactive seed implantation and had undergone whole-body scintigraphy. Scintigraphy images were acquired at a magnification of 1.0 in a 1024×256 matrix and at a scan speed of 25cm/min. Energy peaks were set to 29keV or 35keV, and energy window widths were set to 20%, 50%, 70% and 100%, the image data were divided into eight groups. After image processing under the same conditions, the eight groups of whole-body scintigraphy images were assessed by three experienced nuclear medicine physicians. Two acceptable groups of images were selected from the eight groups of images for each patient. The regions of interest (ROI) of iodine-125, background and whole-body scintigraphy images were outlined to calculate the iodine-125 to background ratio of the radioactive counts and the iodine-125 to whole-body scintigraphy ratio of the radioactive counts. **Results:** Through subjective evaluation by three physicians, the percentages of acceptable images of groups 2, 3 and 7 were more than 50%, with group 2 showing the highest percentage. Furthermore, no statistical significant difference was found in the iodine-125 seed target/background ratio and iodine-125 seed target/whole-body scintigraphy ratio among the three groups ($P>0.05$). **Conclusion:** The parameters to yield high-quality images of iodine-125 radioactive seed were chosen to be an energy peak of 29keV, an energy window width of 50% and a scan speed of 25cm/min.

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Introduction

Internal radiation therapy with interstitial implantation of iodine-125 seeds has been widely used in various solid tumors such as prostate cancer, liver cancer, non-small cell lung cancer, pancreatic cancer, and unresectable malignant thymoma, and displays statistical significant therapeutic effects, less trauma, and less damage to normal tissue [1-5]. Iodine-125 radioactive particles exert a therapeutic effect because the particles can be accurately implanted into the target organ. We evaluated the distribution of iodine-125 seeds in the target organs, relying mainly on X-ray or computed tomography (CT). However, these imaging modalities are mostly suitable for local implantation site imaging and cannot display a particle drift away from the lesion site. The iodine-125 seed itself emits γ -rays after implantation into the human body to meet clinical treatment demands. Iodine-125 seeds can also be used as a source in nuclear medicine imaging to detect iodine-125 distribution in the body. Because of the low emitted γ -ray energy of iodine-125, it is unsuitable for conventional nuclear medicine imaging. Thus, no uniform acquisition energy parameters exist. Kono et al (2008) [6] reported that the acquisition parameters could be set up as an energy peak of 35keV and an energy window 70%. However, whether the latter represents optimal imaging conditions has not been determined. The goal of the present study was to explore suitable acquisition window parameters that can be applied to assess the distribution of iodine-125 radioactive seed implantation using nuclear medicine imaging.

Subjects and methods

Patients

From July 2012 to December 2012, 30 patients with tumors (24 men and 6 women;

mean age, 55.7 ± 14.1 years; age range, 31-84 years) agreed to undergo implantation of iodine-125 radioactive seeds (PharmaSeed Model BT-125-1, Shanghai GMS Pharmaceutical Co, Ltd, China), and whole-body scintigraphy on the following day, at Zhongshan Hospital, Fudan University. Twenty-one liver cancer patients accepted iodine-125 seed implantation through a stent in the biliary tract, portal vein, inferior vena cava or by interventional puncture. Two pancreatic cancer patients received iodine-125 seed implantation through a biliary tract stent. Due to obstructive jaundice, iodine-125 seeds were implanted in the biliary stent of patients with gastric cancer, colorectal cancer, colon cancer, and bile duct cancer. The seeds were implanted directly into the tumor bed for each case of lung cancer, prostate cancer and parotid acinar carcinoma. The study was approved by the institutional review board of Zhongshan Hospital affiliated with Fudan University, and all patients gave their written informed consent.

Imaging method and grouping

Whole-body scintigraphy was performed on the day following iodine-125 seed implantation with a dual-head gamma camera single photon emission tomography/computerized tomography (SPET)/spiral CT scanning [Philips Precedence with 16-slice diagnostic CT (Philips, Medical System, Bothell,

WI, USA)]. The camera heads were equipped with a low-energy, high-resolution, parallel-hole collimator. For planar whole-body scintigraphy, acquisition counts from a series of energy windows (20%, 50%, 70% and 100%) and energy peaks (29 and 35keV) were acquired in a 256×1024 matrix and at a scan speed of 25cm/min. A total of eight different data points were collected under the conditions shown in Table 1.

Image processing

The anteroposterior and posteroanterior raw data of whole-body scintigraphy were imported using the Multiviewer processing module program (JETstream WORKspace Release 3.0, Philips, the Netherlands) of the JSWS workstation (xw4400x, HP, USA). The image background was set to white and the cool set to pseudo-color image color. The regions of interest (ROI) of the iodine-125 seed targets, background and whole-body scintigraphy images were outlined to calculate the iodine-125 seed target/background ratio of the radioactive counts and the iodine-125 seed target/whole body scintigraphy ratio.

Image evaluation and statistical analysis

After image processing under the same conditions, eight groups of whole-body scintigraphy images were assessed by three experienced nuclear medicine physicians. A clear iodine-125 seed particle outline and appropriate image contrast were considered acceptable. Two acceptable groups of images were selected from the eight groups for each patient, and then the percentage of satisfaction of each image was calculated. Data on the iodine-125 seed target to background ratio of the radioactive counts and the iodine-125 seed target to whole-body scintigraphy ratio of the radioactive counts were compared among the different groups using one-way analysis of variance. Data analysis was performed by using SPSS 16.0 software (SPSS Inc., Chicago, IL, USA).

Table 1. Division of image parameters into eight groups according to different image acquisition parameters

Groups	Energy peak (keV)	Energy window
1	29	20%
2	29	50%
3	29	70%
4	29	100%
5	35	20%
6	35	50%
7	35	70%
8	35	100%

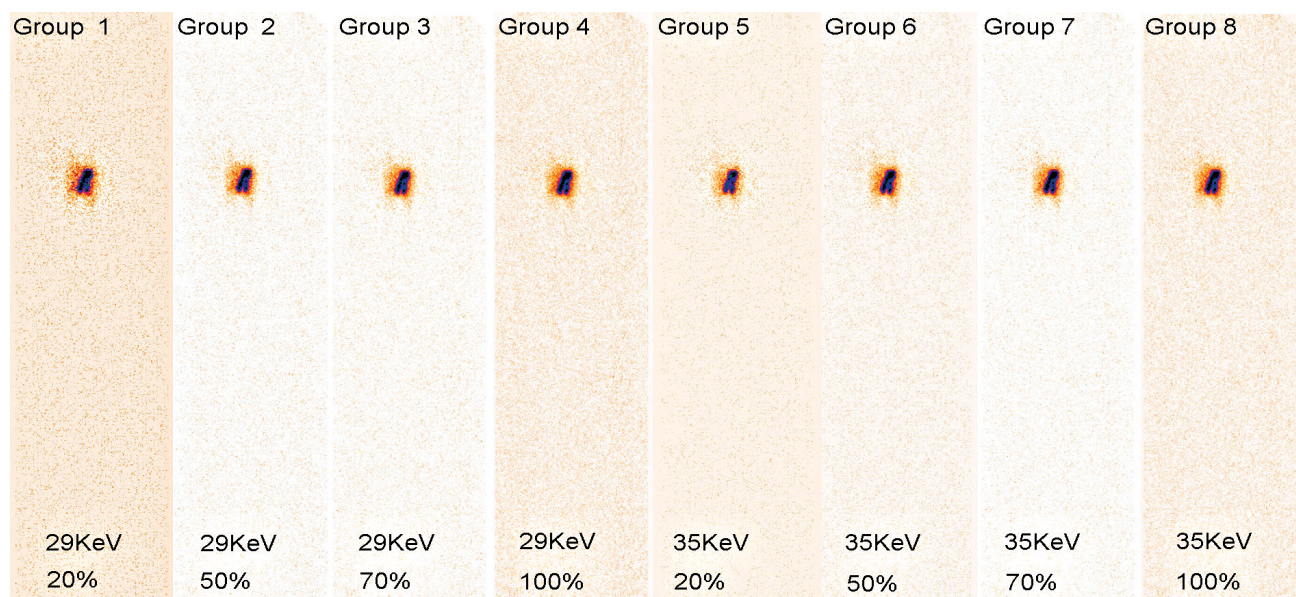


Figure 1. Whole-body scintigraphy images from the eight groups of image acquisition parameters of a patient.

Results

Two acceptable groups of whole-body scintigraphy images were selected from the eight groups (Figure 1) for each patient by three experienced nuclear medicine physicians. The percentage of acceptable image considered by three experienced nuclear medicine physicians was 55.6% for group 2, 50.0% for group 7, 54.4% for group 3, 18.9% for group 4, 11.1% for group 6, 7.8% for group 8, and 2.2% for group 5. Group 1 was unselected. The differences in the iodine-125 seed target/background ratios among the eight groups were statistically significant ($F=7.72$, $P<0.001$). After multiple comparison, no statistical significant differences were found among groups 2, 3, 4, 7 and 8 ($P=0.139$) and among groups 1, 2, 3, 6 and 7 ($P=0.135$) (Table 2). The differences in the iodine-125 seed target/whole body ratios among the eight groups were statistically significant ($F=8.447$, $P<0.001$). After multiple comparison, no statistical significant differences were noted among groups 2, 3, 7, and 8 ($P=0.265$); among groups 1, 2, 6, and 7 ($P=0.249$); among groups 3, 4, and 8 ($P=0.282$); and among groups 1, 5, and 6 ($P=0.096$) (Table 3). Through subjective evaluation by three physicians, the percentages of acceptable images of groups 2, 3 and 7 were more than 50%, with group 2 showing

the highest percentage. Furthermore, no statistical significant difference was found in the iodine-125 seed target/background ratio and iodine-125 seed target/whole-body scintigraphy ratio among the three groups ($P>0.05$).

Discussion

The half-life of iodine-125 seeds is 59.3 days, and its energy includes 27.4keV (X-ray/ γ -photon), 31.4keV (X-ray), 35.5keV (γ -photon), and 22.1 and 25.2keV (fluorescent X-rays from the titanium capsule) [6]. Iodine-125 seeds used in clinical treatment can provide a low dose and persistent exposure of about 200 days. Compared with external beam radiation, iodine-125 seed particles planted directly in the tumor bed has many advantages, such as treatment area positioning accuracy, high target dose, and rapid reduction of the radiation dose outside the range of the particles without increasing damage to the surrounding normal tissue. In the United States, iodine-125 seed implantation treatment for prostate cancer has become one of the standard treatment regimens [7]. In recent years, with the application of imaging-oriented

Table 2. Iodine-125/background ratios of the radioactive counts for each case

Case	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
1	30.1	27.6	21.5	16.7	46.1	39.9	27.6	18.4
2	16.1	13.7	11.6	8.2	27.2	20.5	14.8	9.5
3	38.7	33.3	28.7	21.6	47.9	36.5	32.1	23.6
4	15.1	12.8	11.2	8.2	25.3	19.2	14.6	9.3
5	86.4	59.2	47.9	37.6	95.4	55.9	66.8	43.8
6	48.1	40.9	31.3	26.5	61.3	55.1	44.2	27.9
7	8.3	7.5	5.8	4.8	12.6	10.5	7.1	5.4
8	30.4	22.5	19.5	13.2	38.3	32.3	24.7	16.5
9	14.8	11.7	10.2	7.6	18.6	16.2	11.7	9.0
10	28.1	25.7	23.0	16.9	46.2	3.7	26.9	19.1
11	32.9	26.7	21.0	15.9	42.0	18.1	26.6	18.8
12	57.6	48.2	40.9	28.2	88.9	66.5	46.8	33.7
13	27.7	26.6	21.9	16.3	46.5	31.3	26.6	17.9
14	131.0	110.0	79.2	54.4	152.0	104.0	89.4	59.6
15	57.6	50.6	44.2	38.7	95.9	62.4	58.1	41.2
16	109.0	93.3	74.6	55.2	147.0	120.0	86.8	61.1
17	42.4	39.7	30.6	23.0	70.6	52.4	37.5	26.6
18	105.0	80.3	52.4	41.8	78.6	91.4	71.8	48.7
19	37.4	36.8	31.9	24.8	81.3	48.3	38.0	27.9
20	57.8	47.3	36.8	27.5	50.4	65.7	44.8	34.8
21	42.6	34.1	29.0	20.8	21.0	46.1	36.1	24.3
22	28.4	25.6	22.5	17.6	31.7	39.2	29.6	19.7
23	17.8	15.8	14.1	10.2	35.6	23.4	16.5	11.6
24	18.8	17.5	14.9	10.9	31.9	22.7	17.4	12.5
25	22.7	17.4	14.7	11.2	36.8	23.3	17.6	13.3
26	24.9	21.8	17.8	12.7	51.8	26.5	20.7	14.2
27	47.7	39.9	27.5	21.8	66.2	45.3	41.7	27.9
28	42.0	38.2	31.0	21.6	97.0	46.3	39.7	24.1
29	76.4	62.2	52.5	37.8	39.3	80.1	59.1	41.3
30	35.6	26.5	23.0	16.4		36.4	18.2	18.6

Table 3. Iodine-125/whole-body scintigraphy ratios of the radioactive counts for each case

Case	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
1	0.28	0.24	0.21	0.16	0.36	0.30	0.25	0.18
2	0.19	0.16	0.14	0.11	0.25	0.20	0.16	0.12
3	0.47	0.41	0.36	0.30	0.49	0.46	0.39	0.32
4	0.11	0.09	0.08	0.06	0.16	0.12	0.09	0.07
5	0.56	0.33	0.34	0.32	0.14	0.28	0.51	0.62
6	0.28	0.24	0.21	0.17	0.37	0.30	0.25	0.18
7	0.08	0.07	0.06	0.05	0.12	0.10	0.07	0.05
8	0.27	0.23	0.20	0.16	0.34	0.28	0.24	0.18
9	0.16	0.13	0.11	0.09	0.21	0.17	0.13	0.10
10	0.42	0.37	0.32	0.26	0.51	0.44	0.37	0.29
11	0.29	0.17	0.13	0.15	0.07	0.26	0.28	0.35
12	0.29	0.25	0.22	0.17	0.38	0.32	0.26	0.19
13	0.19	0.17	0.15	0.11	0.26	0.21	0.17	0.12
14	0.46	0.40	0.35	0.29	0.52	0.46	0.40	0.32
15	0.38	0.33	0.29	0.23	0.46	0.39	0.33	0.25
16	0.48	0.42	0.37	0.30	0.56	0.49	0.42	0.33
17	0.36	0.32	0.29	0.23	0.46	0.39	0.33	0.25
18	0.35	0.31	0.27	0.21	0.45	0.38	0.31	0.23
19	0.32	0.28	0.25	0.20	0.41	0.35	0.29	0.22
20	0.43	0.39	0.34	0.28	0.51	0.45	0.39	0.31
21	0.35	0.31	0.27	0.21	0.42	0.37	0.31	0.23
22	0.19	0.16	0.14	0.10	0.62	0.22	0.17	0.12
23	0.13	0.11	0.09	0.07	0.18	0.14	0.11	0.08
24	0.25	0.22	0.19	0.14	0.35	0.28	0.22	0.16
25	0.20	0.18	0.15	0.12	0.29	0.23	0.18	0.13
26	0.22	0.19	0.17	0.13	0.30	0.24	0.19	0.14
27	0.30	0.25	0.21	0.17	0.37	0.31	0.25	0.19
28	0.35	0.31	0.27	0.21	0.43	0.37	0.31	0.24
29	0.49	0.43	0.39	0.32	0.56	0.49	0.43	0.34
30	0.28	0.24	0.21	0.16	0.36	0.30	0.24	0.18

devices, such as those used for ultrasonography (USG), CT, and magnetic resonance, iodine-125 seed implantation has been rapidly developed and has demonstrated good effects for various solid tumors [1-5]. To obtain good results after seed implantation, a perfect radiation dosimetry-based implant program is necessary. More importantly, the seeds must be implanted into the proper position. However, the iodine-125 seeds may deviate or migrate away from the target organ location after implantation [8, 9].

Evaluation of iodine-125 seed implantation is mainly used to understand particle implementation, such as particle distribution, radioactivity distribution, and the implanted particle displacements. X-ray and CT are often used to evaluate iodine-125 seed distribution in the target organ; however, their imaging ranges are limited, and they cannot display the seeds that deviate significantly or migrate to other areas [3, 10, 11]. Using the γ -ray emission of iodine-125 as sources, whole-body nuclear medicine imaging can detect its systemic distribution in the whole body without additional radiation. Moreover, with whole-body imaging, SPET/CT fusion imaging targeted to the lesion can display the specific location of the seeds clearly.

The energy window is the energy range of received or processed X-rays or γ -rays by the nuclear medicine imaging system. The energy window can be used to set the upper and lower energy values. In our clinical work, the actual

measurement value of the energy peak of iodine-125 seeds was 29keV. We used the γ -rays emitted by the iodine-125 seed itself as a nuclear medicine imaging source, at 25 cm/min and chose eight groups of image acquisition parameters (energy peaks: 29keV and 35keV; energy windows: 20%, 50%, 70% and 100%). We then compared the image quality obtained under the energy window setting conditions. The results of the present study showed that the percentages of acceptable images (as evaluated by three physicians) from group 2 (energy peak, 29keV; energy width, 50%), group 3 (energy peak, 29keV; energy width, 70%) and group 7 (energy peak, 35keV; energy width, 70%) were more than 50%, with group 2 displaying the highest value. Additionally, no statistical significant difference was observed in the iodine-125 seed target/background ratio and iodine-125 seed target/whole-body scintigraphy ratio among the three groups ($P>0.05$).

Subjective image quality assessment is based on the accuracy of diagnosis by a physician according to the image of the disease and degree of confidence. The iodine-125 seed target/background ratio and the iodine-125 seed target/whole-body scintigraphy ratio of the radioactivity counts are based on objective evaluation and do not involve subjective factors, including those at the physical, psychological, and intellectual level. In the present study using combined sub-

jective and objective evaluations, three groups (energy peak=29keV/energy width=50%; energy peak=29keV/energy width=70%; energy peak=35keV/energy width=70%) of image qualities were accredited.

An energy window is usually tailored to the peak of the energy spectrum of a particular radionuclide and ignores other rays that would otherwise contribute noise to the image. Thus, noise caused by Compton scattering can be gated out. A narrow energy window range will cause decreased sensitivity of nuclear medicine images. Conversely, increasing the energy window range will result in increased image noise and reduced image contrast. Thus, a suitable energy window setting is an important issue in nuclear medicine data acquisition. Among group 2 (energy peak=29keV; energy width=50%), group 3 (energy peak=29keV; energy width=70%) and group 7 (energy peak=35keV; energy width=70%), the image acquired under the conditions of an energy peak of 29keV and an energy width of 50% had the highest percentage of satisfaction. Moreover, the energy peak of 29keV for groups 2 and 3 is consistent with the actual energy peak of iodine-125 seeds that was measured in our practical work. Theoretically, the noise associated with a window width of 50% is relatively small compared with that associated with a window width of 70%. Thus, the collected energy is in the range of 21.75~36.25keV. Combined with the spectroscopy and abundance of iodine-125 seeds, this energy range includes 27.4keV (X-ray/ γ -photon), 31.4keV (X-ray), 35.5keV (γ -photon), and 22.1 and 25.2keV (fluorescent X-rays from the titanium capsule).

In conclusion, the parameters to yield high-quality images of iodine-125 radioactive seed were chosen to be an energy peak of 29keV, an energy window width of 50% and a scan speed of 25cm/min.

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The authors declare that they have no conflicts of interest.

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