Study of the Internal Exposure Monitoring and the New Monitoring Methods of Thyroid I-131 for Radiological Staff in Nuclear Medicine

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Research

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The title page

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Study of the internal exposure monitoring and the new monitoring methods of thyroid I-131 for Radiological staff in nuclear medicine

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Abstract

Background： In general, medical staff dealing with nuclear medicine should be entirely safe in their professional environment. Nevertheless, their exposure to radioactive iodine seems to be partially uncontrolled while they perform their duties, namely while administering iodine in the form of tablets or solutions or while taking care of the patients already treated with the isotope.

Purpose: To verify such a hypothesis, develop a simple method for internal exposure monitoring，131I activity measurements in the thyroids of the personnel employed at the three hospitals of Gansu province grade a hospital nuclear medicine. Mastered the internal exposure of nuclear medical personnel.

Methods: Choosing 20 employees of the department of three hospitals of gansu province grade a hospital nuclear medicine, which corresponds to circa 100% of all of the all the staff of the nuclear medicine department who carry out iodine therapy. Automatic packaging and drug delivery staffs were 6, manual packaging and drug delivery staffs were 14. According to the rules of the judgment principles proposed in IAEA safety guidelines, An InSpector 1000 portable spectrometer and its supporting software served as the basic research instrument. In four out of twenty examined staff members. The sitting position was adopted with NaI portable spectrometer. The measurement time was 120s.

Result: Among the manual packaging and drug delivery staffs was 4 (20.0%) detected ^{131}I in the thyroid, with activity range of 27.6-1030.3Bq. Automatic packaging and drug delivery staffs were not detected.

Conclusions: The highest activities in thyroids were detected for the manual packaging and drug delivery staffs, Automatic packaging and drug delivery staffs were

not detected. The dose of some workers is high, so the prevention and control of pollution in nuclear medicine discipline needs to be strengthened urgently.

Keywords: ^{131}I, Thyroid, Nuclear medicine, Medical personnel, Internal doses^{131}I

Introduction

Iodine is one of the elements that are essential for proper functioning of the human organism. Radioiodine has been used clinically for about 70 years, both for diagnosis (^{123}I, ^{125}I and ^{131}I) and therapy (^{125}I and ^{131}I) of various diseases. ^{131}I is the radioisotope most frequently applied in nuclear medicine. In fact, it was used for the first time in 1942 to treat hyperthyroidism (Seanger et al. 1979). Since then it has been widely applied both in diagnosis and treatment of thyroid-related illnesses. ^{131}I is also used in kidney and bladder function tests. The development of clinical nuclear medicine has increased the risk of potential radiation exposure and environmental pollution of the occupational population and the public.

Nuclear medicine and radiation source is primarily radioactive drugs, it has the characteristic of the invisible and ubiquitous, patient, excreta, discarded medical equipment, etc., these factors on the one hand to the nuclear medicine of radiological protection has brought certain difficulties, on the other hand also caused the nuclear medicine personnel ideological paralysis. In recent years, medical cyclotron and PET equipment for the production of positron drugs have been gradually introduced, which brings new problems to the radiological protection of nuclear medicine.

Furthermore, ^{131}I is a radionuclide of importance in nuclear accidents, where it is a rest product from the nuclear fission process in nuclear energy plants. After the Chernobyl accident in 1986, contamination with ^{131}I (and other short-lived isotopes such as ^{132}I and ^{133}I) led to an increased incidence of differentiated thyroid cancers in children but not in adults, with a higher incidence with lower age [1].

There is thus a need for accurate dosimetric calculations of the absorbed dose for both patients examined or treated with radioiodine, personnel handling radioiodine and for personnel and the general population in case of accidental exposure to radioiodine [2-5].

In recent years, with the in-depth research on the effects of cell radiation, more and more attention has been paid to radiation protection.

In occupational exposure protection, one of the current focuses of attention is occupational exposure monitoring of nuclear medical workers and prevention and control of occupational radioactive diseases. The number of nuclear medicine workers in China is about 10,000, whose occupational exposure is characterized by the operation of non-sealed radioactive sources, receiving both external exposure and internal exposure due to the ingestion of radionuclides.

In general, medical staff dealing with nuclear medicine should be entirely safe in their professional environment. Nevertheless, their exposure to radioactive iodine seems to be partially uncontrolled while they perform their duties, namely while administering iodine in the form of tablets or solutions or while taking care of the patients already treated with the isotope [6-9]. To verify such a hypothesis, ^{131}I activity measurements in the thyroids of the personnel employed at the three hospitals of Gansu province grade a hospital nuclear medicine.

Material and method

Equipment selection

Portable survey instrument with energy spectrum recognition function. In this paper we are used the InSpector 1000 portable spectrometer and its supporting software.

Medical staff

The present study included 20 employees of the department of three hospitals of gansu province grade a hospital nuclear medicine, which corresponds to circa 100% of all of the all the staff of the nuclear medicine department who carry out iodine therapy. Among them, automatic packaging and drug delivery staffs were 6, manual packaging and drug delivery staffs were 14, ^{131}I activities in all medical doctors have been measured. The group in the study consisted of 9 men and 11 women. The men were aged 30–56 years old at the time of measurement, whereas the women were aged 21–60 years. The research was approved by the bioethics committee at the gansu provincial center for disease control and prevention.

Survey research

Each participant in the study was asked to complete a survey questionnaire. General questions such as gender and age formed the first ‘demographic’ category. The second category dealt with determining the nature of work with radioactive iodine including details on the type of tasks and ^{131}I handling, duration of exposure to ^{131}I and contacts with patients after treatment or diagnostics. The third category addressed health conditions related to possible thyroid diseases.

Calibration of monitoring instrument

Monitoring instruments shall be calibrated by the Chinese academy of metrology and the Chinese institute of radiation protection and nuclear safety medicine, Chinese center for disease control and prevention. Portable spectrometer iodine-131 calibration method about InSpector 1000 Energy calibration Cesium-137 was selected as the calibration source（Radioactive Activity ranges from 370 - 740 Bq）.

Efficiency calibration

Connect portable spectrometer to computer, the efficiency scale was completed by Genie 2000 spectral analysis software. The accurate efficiency scale is the basis of the quantitative measurement. In this monitoring, the calibration experiment was carried out by using IAEA neck module, thus, the efficiency scale factor is obtained ε. The calibration source is iodine-131.The general procedure of efficiency scale is as follows：

The system parameters are adjusted so that the spectrometer is in stable and good working state；The scale conditions shall be in conformity with the measurement conditions Such as measuring time, distance between detector and measuring target, etc.）,The measurement gets the calibration source spectrum file.

It is generally required that the statistical error of the minimum net peak area count is less than 0.5%（2σ），If necessary, the measurement can be repeated for 2-3 times；

The same spectral analysis method as the monitoring measurement was adopted，Calculate the net area count of 364.5keV characteristic peaks in the calibration source spectrum file That is, the peak area after removing Compton scattering interference.

Calculate the efficiency scale factor for the energy of the production ray at 364.5keVCF_s. See Table 1

$$CF_s = \frac{n_S}{A \cdot e^{-\lambda \Delta t}}$$

CF_s——Instrument efficiency scale factor;

n_s ——IAEA neck module 364.5keV total peak net area count rate;

A ——Activity of iodine-131 calibration source at preparation time or at constant value (t0);

λ——The decay constant of the nuclides（s^{-1}）;

Δt——，Scale source decay time That is, the time interval between the time of source preparation or the time of fixed value and the time of start of measurement（d），$e^{-\lambda \Delta t}$ Is the decay correction factor for this period.

Measurement

Meeting rooms and other areas with low background radiation (<200nGy/h), and avoid radioactive contamination.

Information to register

Record the basic personal information and operation nuclide information of medical institutions and monitored personnel, See annex 2 for details Monitoring information sheer.

Pre-monitoring preparation

Wrap the instrument probe with a clean plastic tape (or plastic film). Ensure timely replacement of each measurement (including measurement of the same person's thigh and thyroid, also need to be replaced), Prevent contamination of instrument probe. If the subject is holding the probe, disposable gloves should be worn.

Measurement point selection

Thyroid gland of all the staff of the nuclear medicine department who carry out iodine therapy.

Measurement process

Background measurement: The person being monitored sits in an adjustable height chair, The portable spectrometer was placed close to the thigh and measured for 120 seconds.

Thyroid gland measurement: His portable digital spectrometer was close to the thyroid gland for measurement .Measure time 120 seconds.

Record

Record the spectral names of the thigh and thyroid measurements on the monitoring information sheet. In principle, the same measured object should only be measured once for the thigh and the thyroid. When the measurement needs to be repeated due to the change of relative geometric position and other reasons during the measurement, the spectrum file name obtained from each measurement should be recorded separately, and it should be marked that the spectrum file is wrong in the measurement process.

Spectral files by computer storage

The computer installed InSpector Maintenance Utility and Genie 2000 spectrum analysis software. The data line connecting the computer to the detector, open the InSpector Maintenance Utility. Click the connect icon to connect. The get and send ICONS are bold after a successful connection, indicating that data can be passed to each other.

Matters needing attention

At the end of the thyroid measurement, The spectral files obtained from the thigh and thyroid measurements of each staff member shall be renamed to ensure that there is no confusion among the spectral files of different staff members, and detailed records shall be made on the monitoring information table。

^{131}I activity measurements

An InSpector 1000 portable spectrometer and its supporting software served as the basic research instrument. In four out of twenty examined staff members, the determined 131I activity was found to be above the detection limit (DL= 5 Bq of ^{131}I in the thyroid). The measurement time was 120s, Calibration coefficient was

0.0094cps/Bq and 0.0152cps/Bq, The MDA was 19Bq 和 23Bq。Energy range: NaI probe: 50 keV-3 MeV, Dose (rate) range: 10nSv/h ~ 100 mSv/h, 10nSv-10Sv I-131 standard sours, Energy (Kev): 364.48 radioactive half-life:8.04 d,

Dose estimation

Data analysis

Thyroid activity measurement results, Formula (1) is adopted for calculation：

$$A_j = \frac{(n_j - n_b)}{CF_S \cdot e^{-\lambda \Delta t}} \quad (1)$$

Ci-Co：

A_j——Measurement activity of radionuclide iodine-131, Bq;

n_j——Thyroid 364.5keV total peak net area count rate was measured, s^{-1};

n_b——huckle 364.5keV total peak net area count rate was measured, s^{-1};

CF_s——Instrument efficiency scale factor, From the efficiency scale process，See annex 1 for details；

λ——The decay constant of the nuclides（s^{-1}）,According$\lambda=\ln2/T_{1/2}$，$T_{1/2}$ is the physical half-life of iodine-131（8.02d）；

Δt——Time interval (days) between the completion of the last operation iodine-131 and the beginning of this thyroid measurement, $e^{-\lambda \Delta t}$ is the decay correction factor for this period。

Accumulated dose of thyroid organs

It is assumed that thyroid uptake of iodine-131 is timed to the completion of the last operation, accumulated dose of thyroid organs, Formula (1) is adopted for calculation.

$$H_T = A_0 \cdot h_T \quad (2)$$

Ci-Co：

H_T——accumulated dose of thyroid organs,（Sv）;

A_0——Thyroid iodine-131 intake,（Bq）;

h_T——Radiation-weighted dose of thyroid per unit intake 1.1×10^{-8},（Sv/Bq）.

Result

This paper presents results of ^{131}I thyroid activity measurements in 20 members of the nuclear medicine department of the Department of Nuclear Medicine (Gansu provincial hospital, Gansu provincial cancer hospital, Lan Zhou university second hospital). An InSpector 1000 portable spectrometer and its supporting software served as the basic research instrument. The measurement time was 120s, Calibration coefficient was 0.0094cps/Bq and 0.0152cps/Bq, The MDA was 19Bq and 23Bq。Energy range: NaI probe: 50 keV ~ 3 MeV, Dose (rate) range: 10nSv/h ~ 100 mSv/h, 10nSv-10SvI-131 standard sourc, Energy (Kev):364.48 radioactive half-life: 8.04d, the highest activities in thyroids were detected for the manual packaging and drug delivery staffs, Automatic packaging and drug delivery staffs were not detected. In four out of twenty examined staff members, the determined 131I activity was found to be above the detection limit (DL= 5 Bq of ^{131}I in the thyroid). It has a lot to do with the workload .Having measured the activities, the activities which were found to range from 27.6 Bq to 1030.3 Bq.

^{131}I activity in thyroids was found to be below the detection limit (DL = 5 Bq of ^{131}I in the thyroid) for 16 subjects in the study. Among the manual packaging and drug delivery staffs was 4 (20.0%) detected ^{131}I in the thyroid, with activity range of 27.6-1030.3Bq. Automatic packaging and drug delivery staffs were not detected. Automatic packaging and drug delivery staffs were 6, checking out 0(0%). The detection rate was significant ($P < 0.01$). For detailed results, see Table 2 Figure 1, Figure 2.

This distribution pattern can be explained by the types of duties performed with respect to exposure to ^{131}I radiology physician and radiology [10]. Nurse were found to be the most exposed contaminated individuals, because they directly participate in preparing and administering radiopharmaceuticals, where their presence at every treatment session is required. In contrast, the highest activities in thyroids were detected for the manual packaging and drug delivery staffs, Automatic packaging and drug delivery staffs were not detected. It has a lot to do with the workload .Having measured the activities, the activities which were found to range from 27.6 Bq to 1030.3 Bq.

Discussion

In occupational exposure protection, one of the current focuses of attention is occupational exposure monitoring of nuclear medical workers and prevention and control of occupational radioactive diseases. The number of nuclear medicine workers in China is about 10,000, whose occupational exposure is characterized by the operation of non-sealed radioactive sources, receiving both external exposure and internal exposure due to the ingestion of radionuclides.

At present, the monitoring of domestic nuclear medicine workers is limited to the monitoring of the individual dose of external irradiation, and the distribution ratio of the per capita annual dose exceeding 5mSv is higher than that of other radiation workers. At the same time, the incidence of posterior polar subcapsular opacification and chromosome unstable aberration in peripheral blood of ionizing radiation irradiated by nuclear medicine workers was significantly higher than that of other occupational irradiated groups [11].

In the study of occupational radiation protection in nuclear medicine in China, internal radiation monitoring methods and internal radiation dose of workers are rarely reported.

The issue of internal radiation exposure to nuclear medical personnel is of great concern internationally, and its research mainly includes (1) the determination of the necessity of internal radiation monitoring among nuclear medical personnel. The international atomic energy agency (IAEA), on the basis of studies by relevant countries, proposed in 1999 the principles for determining the necessity of intra-staff radiation monitoring in nuclear medicine. Chile, Portugal and other countries conducted a survey on the nuclear medical staff who directly operated the nuclides based on the above decision principles, and the results showed that about 70% of the staff who directly operated the nuclides in the nuclear medical disciplines surveyed needed internal radiation monitoring.[12-18] (2) Internal radiation monitoring and dose estimation of nuclear medicine workers. Internal irradiation monitoring is mainly carried out by air sampling, in vitro direct measurement, biological sample analysis and other methods. In the diagnosis and treatment of nuclear medicine, 90mTc, ^{131}I and 18F are frequently used, among which ^{131}I is the most widely used in clinical practice and highly volatile.

Improper operation and protection will easily lead to serious pollution in the workplace, which will lead to internal irradiation of the staff. The internal radiation monitoring of nuclear medicine workers, especially the monitoring of ^{131}I, needs urgent attention.

Radiation sources in nuclear medicine mainly come from three aspects: radioactive drugs, including dispensing kits, generators and therapeutic nuclides; Work waste, including needles, cotton balls, laboratory supplies, etc.; the patient and the patient's feces. For the former two departments to strengthen the management, to have a person responsible for the use of records. The patient is a mobile source of radiation, and the education of the patient is also very important. Patients undergoing examination should wait in the waiting room and not walk freely, so it is necessary to establish the waiting area and special toilets [19-21].

The health of the staff and the safety of the patients are Paramount, and protective equipment and instruments cannot be replaced by any other means. The installation of protective equipment and the rational and scientific layout of departments should be taken into consideration when building or rebuilding a new nuclear medical discipline, which will not be easily changed in the future. Patient and staff corridors should be separated; Follow the layout from low to high radioactivity; If possible, establish a department-wide radiation monitoring network to measure contamination in and out of high-activity areas (marking rooms, wards, etc.).New protective equipment should also be considered when carrying out new diagnosis and treatment projects.

In carrying out daily work and research experiments with large doses, it is very important to design and prepare in advance. Panic and unreasonable operation procedures can prolong the time of exposure to radioactive materials, bringing unnecessary high radiation dose.

Radiation exposure in the work of nuclear medicine is mainly due to unavoidable exposure and radiation contamination in the department. However, due to the lack of systematic radiological protection education and the "invisibility" of radiation, many people are prone to paralysis in thinking. Bad working habits, such as throwing away the syringe after injection and not changing the shoes in and out of the marking room, will lead to radioactive pollution in the department.

Conclusions

There is internal exposure of therapeutic staff in nuclear medicine, the highest activities in thyroids were detected for the manual packaging and drug delivery staffs, automatic packaging and drug delivery staffs were not detected. The dose of some workers is high, so the prevention and control of pollution in nuclear medicine discipline needs to be strengthened urgently.

Currently, at china nuclear medicine units only the staff exposure to external radiation is monitored. Measurements by thermoluminescent dosimeters, however, will not provide any information on the doses due to radio-iodine incorporated into the body. Therefore, the radiological safety standards applied at present fail to meet the requirements of the so-called conservative assessment rule, where upper dose limits should be estimated. With internal dose estimation for the incorporated radio-iodine entirely ignored, the assessed doses tend to be underestimated, and the doses due to the radionuclides absorbed into the body remain undetermined. Radiation workers should pay more attention to individual protection, and improve the operation proficiency to shorten the operation time. Furthermore, in order to protect public from unnecessary irradiation, there should be some changes in staff route and patients administration.

Therefore, periodic and systematic monitoring of the internal contamination should be integrated into radiological protection standards for teams dealing with highly radioactive ^{131}I. While using radiopharmaceuticals for therapeutic or diagnostic purposes in medicine, appropriate radiological safety rules should be observed and proper safety measures taken.

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Ethics approval and consent to participate

The research was approved by the Bioethics Committee at the Gansu provincial center for disease control and prevention. This article does not contain any studies with animals performed by any of the authors.

Consent for publication

All authors agree to publish

Availability of data and materials

Not applicable

Conflict of interest

The authors declare that they have no conflict of interest.

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Authors' contributions:

Gang Liu and Ye Li were a major contributor in writing the manuscript.

All authors read and approved the final manuscript. Gang Liu and Ye Li are Co-first author.

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Figure 1（Background）Energy spectrum diagram（20191225014358）

Figure 2（Thyroidea）Energy spectrum diagram（20191225014059）

Table 1 I-131 Standard source

Nuclide	Activity(Bq)	Energy (KeV)	Branching ratio	$T_{1/2}$ (d)	Date	Activity date	DATEDIFF (d)	Net	Uncertainty	T(s)	Efficiency value	Cps

I-131	3.311E+04	364.48	0.812	8.04	2019/4/26 3:03	2019/3/1 17:00	55.41875	2263	8.88%	120	8.3274E-02	18.85833
I-131	3.311E+04	364.48	0.812	8.04	2019/4/26 3:06	2019/3/1 17:00	55.4208333	1250	16.85%	120	4.6006E-02	10.41667
I-131	3.311E+04	364.48	0.812	8.04	2019/4/26 3:08	2019/3/1 17:00	55.4222222	1513	13.99%	120	5.5692E-02	12.60833
I-131	3.311E+04	364.48	0.812	8.04	2019/4/26 3:10	2019/3/1 17:00	55.4236111	1354	15.67%	120	4.9846E-02	11.28333
I-131	3.311E+04	364.48	0.812	8.04	2019/4/26 3:12	2019/3/1 17:00	55.425	1693	12.64%	120	6.2333E-02	14.10833
I-131	3.311E+04	364.48	0.812	8.04	2019/4/26 3:15	2019/3/1 17:00	55.4270833	1940	10.57%	120	7.1440E-02	176.7667
I-131	3.311E+04	364.48	0.812	8.04	2019/4/26 3:17	2019/3/1 17:00	55.4284722	1147	18.26%	120	4.2243E-02	9.558333
									13.84%		5.87E-02	

Table 2 Measurement of ^{131}I activity in thyroid of nuclear medical staff and internal dose assessment in gansu nuclear medical hospital

Subject code	Gender	Age	Profession	（Background） Energy spectrum filename	（Thyroidea） Energy spectrum filename	Results		
						Thyroid	131I Thyroid activity [B q]	Uncertainty [B q]
1	M	46	physician	20191225011741	20191225011409	not detected	—	—
2	F	36	physician	20191225011026	20191225010720	not detected	—	—
3	F	39	physician	20191225014358	20191225014059	detected I-131	1030.3	141
4	M	42	physician	20191225015006	20191225014713	not detected	—	—
5	F	30	physician	20191225013001	20191225012713	not detected	—	—
6	F	32	Nurse	20191225013716	20191225013352	detected I-131	848.1	119.3
7	M	56	physician	20191225015549	20191225015304	not detected	—	—
8	F	37	physician	20191225005856	20191225005512	Suspected detected I-131	27.6	19.3
9	M	28	physician	20191225031053	20191225030755	not detected	—	—
10	F	38	Nurse	20191225031752	20191225031436	not detected	—	—
11	F	29	technician	20191225032428	20191225032126	not detected	—	—
12	F	54	Nurse	20191225033109	20191225032755	not detected	—	—
13	M	47	physician	20191225033700	20191225033403	not detected	—	—
14	M	50	physician	20191225034309	20191225034002	not detected	—	—
15	M	32	technician	20191225073355	20191225073033	not detected	—	—
16	M	56	physician	20191225072246	20191225071859	detected I-131	368.5	34.3
17	M	30	technician	20191225075705	20191225075324	not detected	—	—
18	F	24	physician	20191225081944	20191225081635	not detected	—	—
19	F	21	physician	20191225082728	20191225082346	not detected	—	—
20	F	60	physician	20191225083502	20191225083145	not detected	—	—

Figure 1（Background）Energy spectrum diagram（20191225014358）

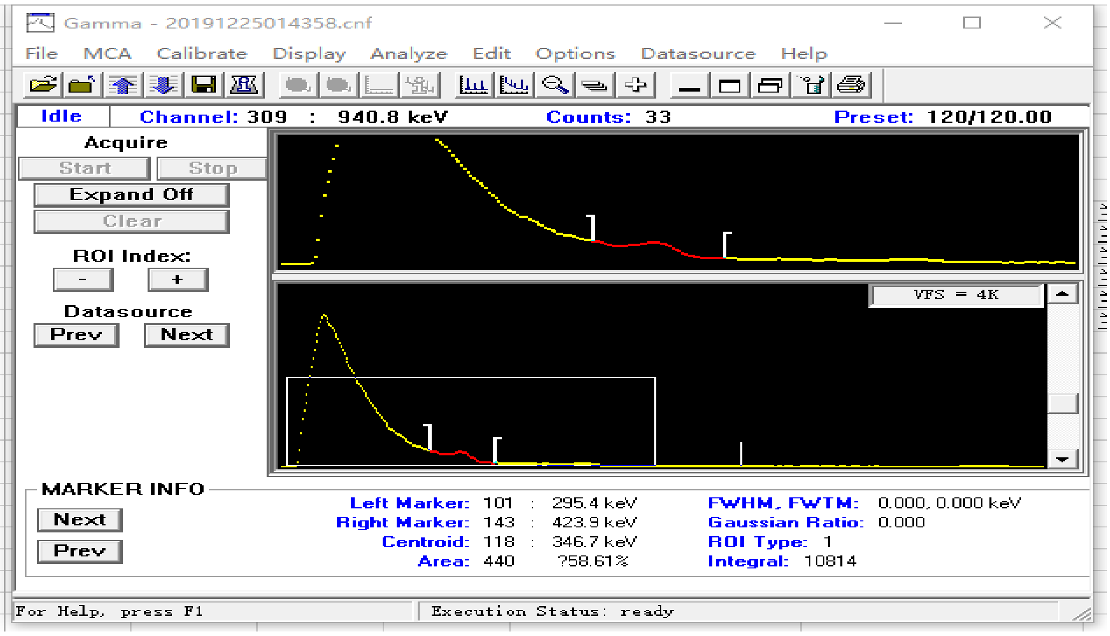
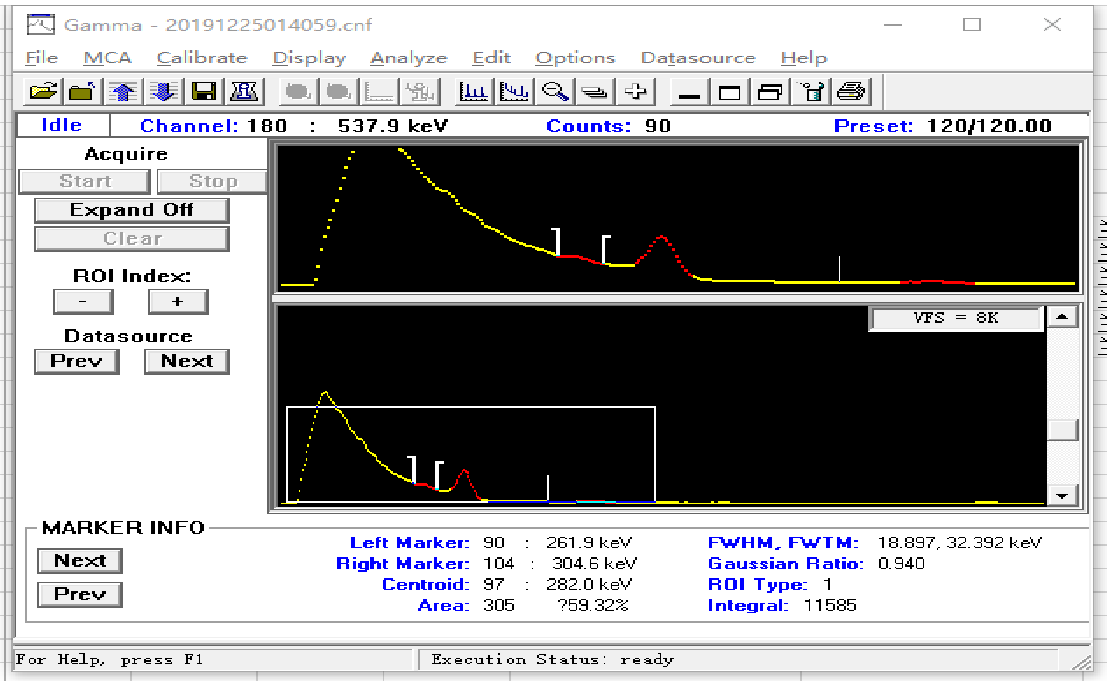


Figure 2（Thyroidea）Energy spectrum diagram（20191225014059）


Gamma - 20191225014059.cnf
File MCA Calibrate Display Analyze Edit Options Datasource Help
Idle
Channel: 180 : 537.9 keV
Counts: 90
Preset: 120/120.00
Acquire
Start
Stop
Expand Off
Clear
ROI Index:
Datasource
Prev
Next
VFS = 8K
MARKER INFO
Next
Prev
Left Marker: 90 : 261.9 keV
Right Marker: 104 : 304.6 keV
Centroid: 97 : 282.0 keV
Area: 305 ?59.32%
FWHM, FWTM: 18.897, 32.392 keV
Gaussian Ratio: 0.940
ROI Type: 1
Integral: 11585
For Help, press F1
Execution Status: ready

Figures

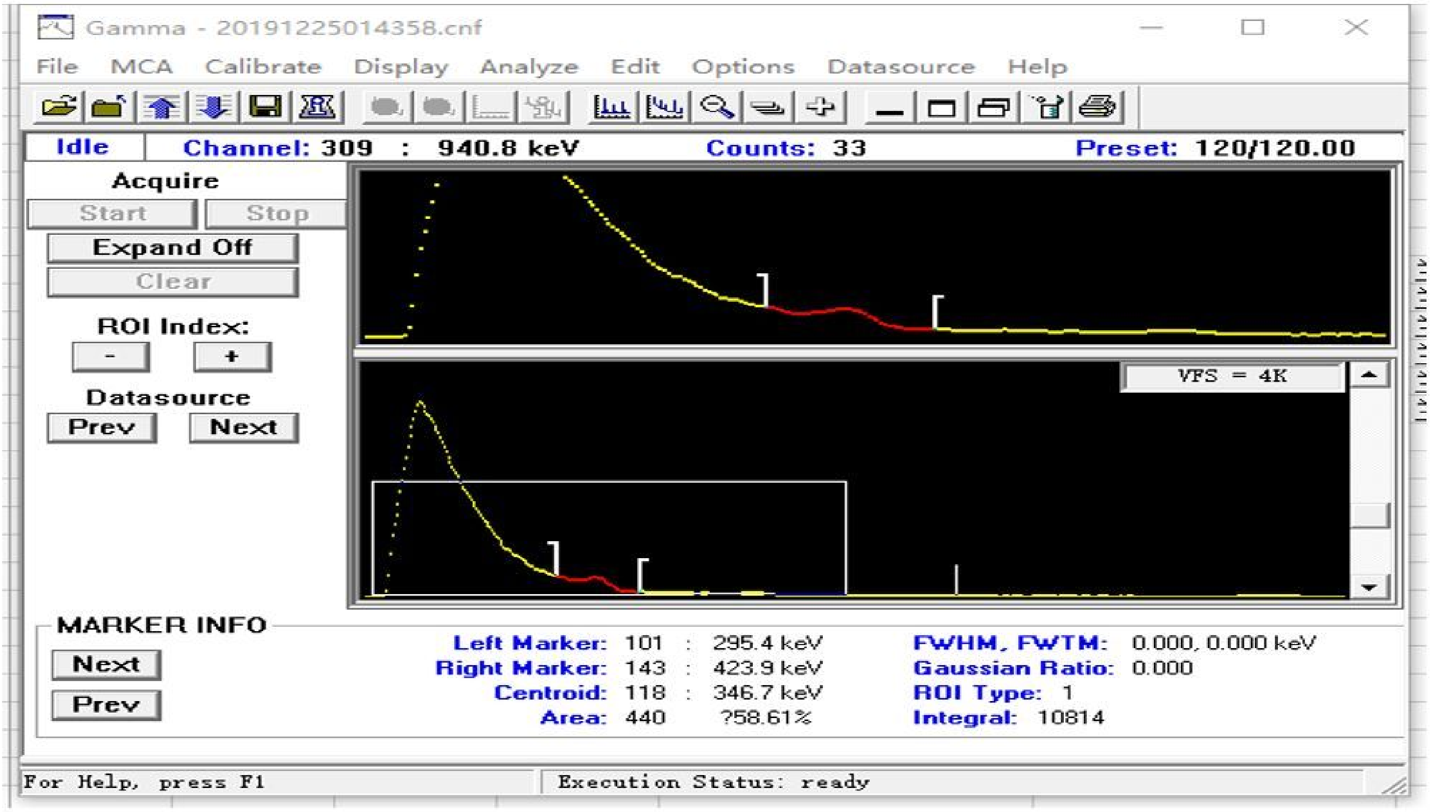


Figure 1

(Background) Energy spectrum diagram20191225014358

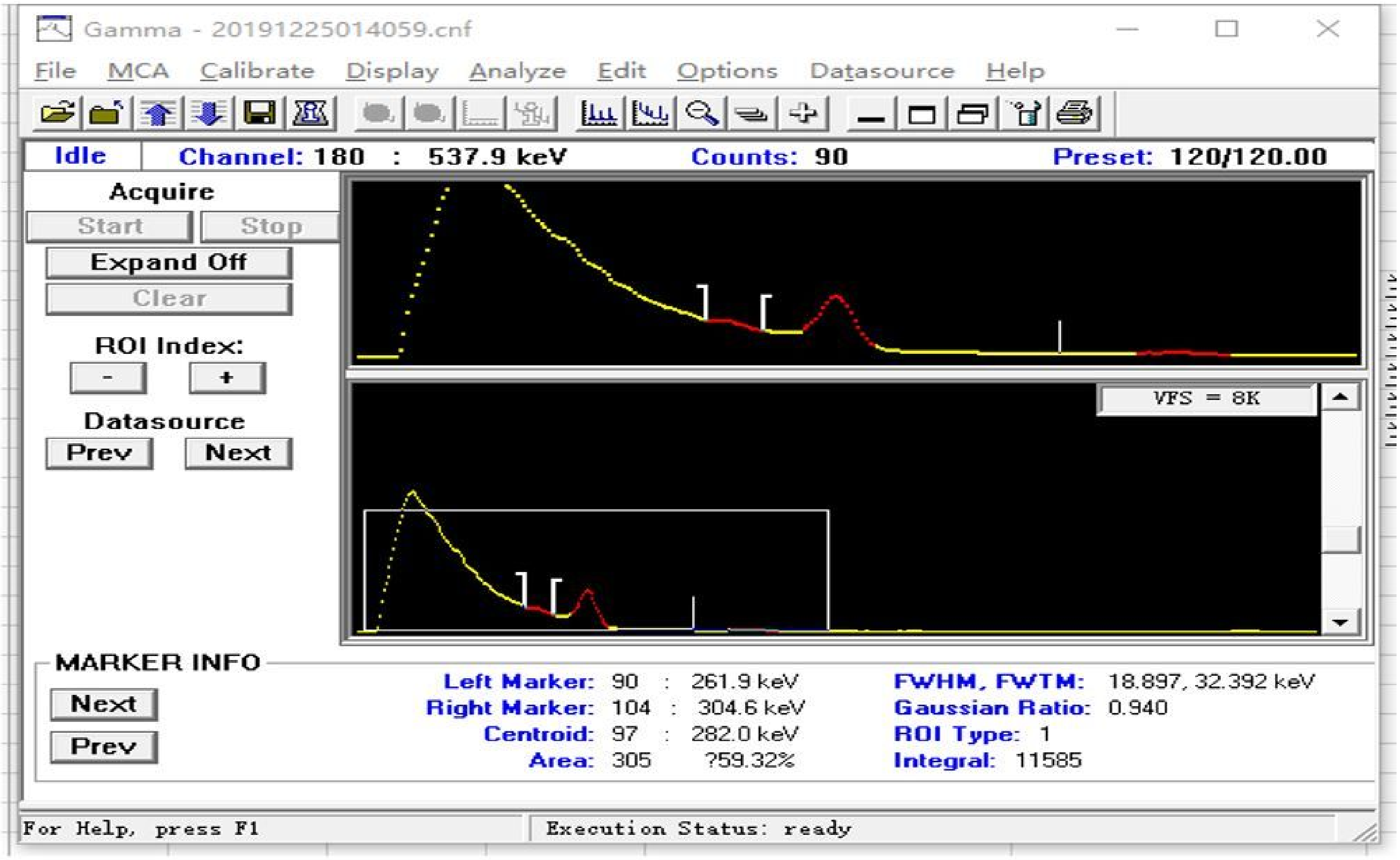


Figure 2

(Thyroidea) Energy spectrum diagram（20191225014059）