Preplanned Studies

National Monitoring and Analysis of Internal Exposure of Nuclear Medicine Workers in ^{131}I Treatment — China, 2021–2023

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Summary

What is already known on this topic?

Healthcare workers in ^{131}I treatment facilities face potential occupational internal exposure through inhalation of volatile radioiodine, in addition to external exposure.

What is added by this report?

This study presents the first comprehensive national monitoring data on internal exposure among Chinese nuclear medicine (NM) workers. Approximately one-fifth of personnel working at radioiodine treatment sites showed detectable levels of ^{131}I in their thyroid tissue.

What are the implications for public health practice?

These findings provide essential baseline data for enhancing radiation protection protocols in NM facilities and optimizing national internal exposure monitoring.

ABSTRACT

Introduction: The effective dose caused by the external exposure of medical radiation workers has dramatically declined in China. By contrast, less attention has been given to internal exposure to radiation. This study aimed to describe the national monitoring of the internal exposure of Chinese nuclear medicine (NM) workers from 2021 to 2023. These findings provide essential baseline data for enhancing radiation protection protocols in NM facilities and optimizing national internal exposure monitoring.

Methods: All the non-military hospitals in China with an NM program were investigated. Portable gamma spectrometers were used to measure the ^{131}I activities of the thyroid of staff members at ^{131}I treatment sites.

Results: A total of 998 hospitals in China had an NM program in 2023. Detectable rate (measurements above minimum detectable activity) decreased from 26.2% in 2021 to 20.1% in 2023. The proportion of measurements exceeding 1.0×10^2 Bq decreased from 12.8% in 2021 to 10.0% in 2023. The detectable rate varied with job categories (P=0.001), with the detectable rate of cleaners being the highest.

Conclusions: In China, ^{131}I was detected in the thyroid of about one-fifth of the subjects working at radioiodine treatment sites. Detectable rate exhibited a slow downward trend in recent years.

The average annual external exposure doses for medical radiation workers in China have shown a significant decline from 1.4 mSv (1996–2000) (*1*) to 0.35 mSv (2016) (*2*). However, beyond external exposure, nuclear medicine (NM) workers face additional risks from potential internal contamination due to their work with unsealed radiopharmaceuticals (*3*). Among these radionuclides, ^{131}I presents the primary internal exposure risk due to its high volatility and extended half-life.

This study aimed to assess internal exposure levels among NM staff across various hospitals to inform the development of evidence-based management and employee protection strategies. Following pilot measurements of ^{131}I internal exposure in NM workers from 2018 to 2020, the study expanded to include 29 provincial-level administrative divisions (PLADs) from 2021 to 2023 (^{131}I monitoring was not conducted in Shanxi in 2023). We present a comprehensive analysis of ^{131}I treatment practices across China and evaluate thyroid ^{131}I activity levels among staff at radioiodine treatment facilities during this period. The findings are intended to provide an empirical foundation for enhancing radiation protection protocols for personnel working at radioiodine treatment facilities throughout China.

This study comprised two main components. First, information about NM hospitals was collected through questionnaires, encompassing all non-military hospitals in China with NM programs. Second, portable gamma spectrometers were calibrated using ^{131}I standard sources at our institution for thyroid activity measurements. The calibrated equipment was used to measure ^{131}I activities in the thyroid of selected staff members at ^{131}I treatment facilities. A standardized measurement and calculation protocol was developed into a handbook and disseminated through training to detection institutions. The detector was consistently positioned in contact with either the neck or thigh (for background measurement), with a measurement duration of 120 s. Minimum detectable activity (MDA) was employed to characterize the gamma spectrometer's capability in quantifying radionuclide presence. The detailed methodology for calculating thyroid ^{131}I activity and MDA has been previously published (*4*). All data were uploaded through the National Radiological Health Information Platform and analyzed using Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA., USA) and SPSS software (version 20.0; IBM, Armonk, USA). Statistical significance was defined as a two-sided $P<0.05$.

In 2023, China had 998 hospitals with NM programs, employing 11,285 workers across all PLADs except Xizang Autonomous Region. Of these institutions, 637 (63.8%) hospitals with 8,818 NM workers conducted ^{131}I treatment procedures, and 358 (35.9%) hospitals with 5,893 workers specifically performed ^{131}I treatment for thyroid cancer. Surface contamination monitors were available in 906 (90.8%) hospitals. Among the 637 hospitals providing ^{131}I treatment, 62.6% were equipped with automated ^{131}I loading devices (Supplementary Table S1, available athttp://weekly.chinacdc.cn/).

National internal exposure monitoring of staff at radioiodine treatment sites commenced in 2021. Table 1 presents the comprehensive monitoring results from 2021 to 2023. The number of monitored hospitals increased from 255 in 2021 to 405 in 2023, with participating staff members rising from 1,884 to 3,137. Both the detectable rate (measurements above MDA) and the proportion of measurements exceeding 1.0×10^2 Bq have showed a consistent decline since 2021.

In 2023, thyroid ^{131}I activity measurements were conducted on 3,137 staff members from radioiodine treatment sites across 29 PLADs (Supplementary Table S2, available at http://weekly.chinacdc.cn/). ^{131}I was detected in the thyroid of 630 participants (20.1%), with the maximum measurement reaching 5.8×10^4 Bq. Further evaluation was performed on measurements exceeding 1.0×10^2 Bq, which represented 10.0% of all participants.

Analysis revealed no significant gender-based differences in detectable rates (P=0.443). However, operators exhibited a significantly higher detectable rate (25.7%) compared to nonoperators (18.2%) ($P<0.001$). Detectable rates varied significantly across job categories (P=0.001). Notably, cleaners, despite not directly operating ^{131}I equipment, demonstrated the highest detectable rate, followed by nurses. Detailed distributions are presented in Table 2.

Among the 908 participants who had operated ^{131}I during the previous year, 899 provided data regarding their most recent ^{131}I operation timing. Analysis of the relationship between measurement timing and detectable rates revealed a clear temporal pattern (Figure 1). The highest detectable rate of 47.4% occurred when measurements were performed on the same day as ^{131}I operations. This rate decreased significantly to 31.6% after just one day and continued to decline progressively with increasing time intervals ($P<0.001$).

DISCUSSION

Our analysis revealed that 998 hospitals in China, employing 11,285 staff members, maintained NM programs in 2023. Approximately two-thirds of these NM facilities provide ^{131}I treatment services, while one-third specifically conduct ^{131}I treatment for thyroid cancer. The latter requires substantially higher radioiodine doses compared to hyperthyroidism treatment protocols.

TABLE 1. Measurements of ^{131}I activities in the thyroid of staff members at radioiodine treatment sites in China, 2021–2023.

Year	PLADs numbers	Hospitals numbers	Participants numbers	Detectable rate (%)	Maximum ^{131}I thyroid activity (Bq)	Proportion of measurements above 1.0×10^2 Bq (%)
2021	22	255	1,884	26.2	4.4×10^4	12.8
2022	20	287	2,210	21.7	2.9×10^4	11.3
2023	29	405	3,137	20.1	5.8×10^4	10.0

Note: Military hospitals are not included in this study.
Abbreviation: PLADs=provincial-level administrative divisions.

Despite a gradual decline in detectable rates from 2021 to 2023, ^{131}I was still detected in the thyroids of approximately one-fifth of workers at radioiodine treatment sites. This detectable rate falls between those reported in previous studies, being lower than the approximately 30% observed in Polish research (*5*) but higher than the 15% reported in Korean investigations (*6*). These variations may be attributed to differences in ^{131}I exposure frequency and radiation protection protocols across countries.

The detectable rate exhibits substantial provincial variation, which may be attributed to differences in radiation protection protocols and sample sizes. Provinces with higher detectable rates require enhanced attention to internal contamination monitoring of nuclear medicine workers. Our stratified analysis revealed that nuclear medicine operators had significantly higher detectable rates compared to nonoperators. Furthermore, we identified a negative correlation between the time interval from operation to detection and the detectable rate.

Notably, cleaners exhibited the highest detectable rate among all nuclear medicine workers, despite not directly operating equipment. This elevated risk stems from their prolonged exposure during the cleaning of radioiodine treatment sites, combined with inadequate personal radiation protection (*7*). The high detectable rate among cleaners likely results primarily from insufficient awareness of self-protection protocols, highlighting the need for enhanced radiation protection training in nuclear medicine facilities. Implementation of basic protective measures, such as wearing charcoal masks and medical rubber gloves, can significantly reduce ^{131}I intake through inhalation and ingestion. The relatively uniform detectable rates observed among other worker categories may be attributed to varied patterns of ^{131}I handling, as all workers except cleaners regularly engage in direct ^{131}I manipulation.

While our findings suggest that increasing the intervals between ^{131}I operations could reduce radiation exposure risk, excessive extension of these intervals may prove counterproductive. Prolonged periods between operations could lead to degradation

TABLE 2. Distribution of the participants above MDA in different groups.

Item	Participants numbers	Above MDA		*P*
		Numbers	Proportion (%)	
Gender				0.443
Male	1,372	267	19.5	
Female	1,765	363	20.6	
^{131}I operation				<0.001
No	2,186	397	18.2	
Yes	908	233	25.7	
Job				0.001
Cleaners	156	44	28.2	
Nurses	806	190	23.6	
Doctors	1,273	241	18.9	
Others	140	25	17.9	
Technicians	762	130	17.1	

Note: Others include physicists, chemists and pharmaceutical engineers. In 2023, thyroid ^{131}I activity measurements were conducted on 3,137 staff members, but the information on ^{131}I operation for 43 subjects is missing. ^{131}I was detected in the thyroids of 630 participants (20.1%).
Abbreviation: MDA=minimum detectable activity.

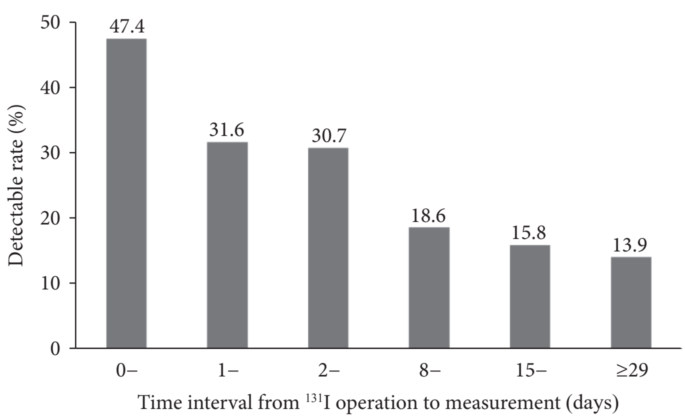

FIGURE 1. Detectable rate of different time intervals from ^{131}I operation to measurement in 2023.
Note: A total of 899 measurements are shown in this figure, because the time intervals from ^{131}I operation to measurement for 8 subjects are missing. Linear-by-linear association chi-squared test suggested that the trend of detectable rate exhibited statistical significance (*P*<0.001).

of technical skills, potentially increasing the risk of radioactive contamination. Therefore, establishing optimal rotation schedules for ^{131}I operations should be a key consideration in daily operational protocols.

This study had a notable limitation regarding the variability in MDA and measurement uncertainty across different monitoring institutions due to the use of diverse portable gamma spectrometers. To enable meaningful comparisons of measurements across PLADs, we standardized the analysis by calculating the proportion of measurements exceeding 1.0×10^2 Bq, as all MDAs were below this threshold. Future monitoring efforts should prioritize the standardization of gamma spectrometry equipment. Additionally, occupational radiation dose assessment should incorporate both external exposure and committed doses from radionuclide intake during the same period (*8*). However, committed doses from internal exposure were not estimated as measurements were conducted only once per year. This limitation arises from the restricted availability of internal exposure monitoring capabilities, with only approximately 70 qualified institutions nationwide. Switzerland's approach of using screening measurements performed by local staff with their own instrumentation offers an economical and practical alternative (*9*). In future work, we aim to develop a scientific and economic routine monitoring program to accurately assess the committed effective doses of NM workers.

The national screening program conducted over the past three years has yielded valuable data on thyroid ^{131}I levels among NM workers and their provincial distribution patterns. Through detailed analysis, we identified key factors contributing to elevated detectable rates. These findings provide an essential scientific foundation for enhancing radiation protection protocols in NM facilities and optimizing national internal exposure monitoring systems.

Conflict of interest: The authors declare no conflicts of interest.

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SUPPLEMENTARY MATERIAL

SUPPLEMENTARY TABLE S1. Overview of ^{131}I treatment and distribution of relevant equipment for nuclear medicine hospitals in China, 2023.

PLADs	NM hospital numbers	NM worker numbers	Tertiary NM hospitals numbers (%)	Performing ^{131}I treatment		Performing ^{131}I treatment for thyroid cancer		Equipment numbers of automatic loading devices (%)	Equipment numbers of surface contamination monitors (%)
				Hospitals numbers (%)	Worker numbers (%)	Hospitals numbers (%)	Worker numbers (%)		
Beijing	41	596	34 (82.9)	25 (61.0)	394 (66.1)	4 (9.8)	56 (9.4)	12.0	100
Tianjin	17	243	17 (100)	8 (47.1)	168 (69.1)	4 (23.5)	122 (50.2)	50.0	100
Hebei	45	423	34 (75.6)	29 (64.4)	335 (79.2)	18 (40.0)	239 (56.5)	48.3	100
Shanxi	27	295	23 (85.2)	21 (77.8)	234 (79.3)	15 (55.6)	182 (61.7)	81.0	100
Inner Mongolia	18	169	16 (88.9)	13 (72.2)	137 (81.1)	8 (44.4)	108 (63.9)	46.2	83.3
Liaoning	35	384	32 (91.4)	13 (37.1)	255 (66.4)	12 (34.3)	226 (58.9)	76.9	97.1
Jilin	17	239	17 (100)	11 (64.7)	196 (82.0)	9 (52.9)	177 (74.1)	81.8	94.1
Heilongjiang	20	249	20 (100)	15 (75.0)	226 (90.8)	11 (55.0)	188 (75.5)	73.3	95.0
Shanghai	49	618	32 (65.3)	24 (49.0)	385 (62.3)	8 (16.3)	225 (36.4)	20.8	95.9
Jiangsu	76	801	60 (78.9)	41 (53.9)	501 (62.5)	22 (28.9)	300 (37.5)	43.9	15.8
Zhejiang	41	542	32 (78.0)	23 (56.1)	415 (76.6)	14 (34.1)	268 (49.4)	87.0	92.7
Anhui	38	343	34 (89.5)	24 (63.2)	273 (79.6)	17 (44.7)	213 (62.1)	66.7	100
Fujian	39	355	34 (87.2)	23 (59.0)	285 (80.3)	13 (33.3)	216 (60.8)	34.8	94.9
Jiangxi	33	275	25 (75.8)	21 (63.6)	213 (77.5)	7 (21.2)	100 (36.4)	76.2	93.9
Shandong	60	657	56 (93.3)	38 (63.3)	528 (80.4)	31 (51.7)	447 (68.0)	89.5	100
Henan	55	690	47 (85.5)	37 (67.3)	585 (84.8)	25 (45.5)	479 (69.4)	78.4	100
Hubei	44	592	39 (88.6)	30 (68.2)	485 (81.9)	22 (50.0)	431 (72.8)	83.3	100
Hunan	47	425	38 (80.9)	31 (66.0)	338 (79.5)	10 (21.3)	131 (30.8)	71.0	100
Guangdong	75	969	67 (89.3)	58 (77.3)	871 (89.9)	27 (36.0)	459 (47.4)	48.3	94.7
Guangxi	56	522	48 (85.7)	45 (80.4)	441 (84.5)	15 (26.8)	221 (42.3)	66.7	98.2
Hainan	8	106	7 (87.5)	8 (100)	106 (100)	6 (75.0)	97 (91.5)	87.5	100
Chongqing	34	313	21 (61.8)	17 (50.0)	249 (79.6)	7 (20.6)	133 (42.5)	82.4	97.1
Sichuan	54	571	45 (83.3)	35 (64.8)	471 (82.5)	20 (37.0)	346 (60.6)	65.7	90.7
Guizhou	10	123	10 (100)	8 (80.0)	114 (92.7)	7 (70.0)	106 (86.2)	100	100
Yunnan	20	293	17 (85.0)	14 (70.0)	242 (82.6)	8 (40.0)	157 (53.6)	71.4	95.0
Shaanxi	18	252	15 (83.3)	8 (44.4)	153 (60.7)	3 (16.7)	79 (31.3)	37.5	100
Gansu	9	95	8 (88.9)	7 (77.8)	84 (88.4)	6 (66.7)	73 (76.8)	28.6	100
Qinghai	3	26	3 (100)	2 (66.7)	21 (80.8)	2 (66.7)	21 (80.8)	50.0	66.7
Ningxia	2	34	2 (100)	2 (100)	34 (100)	2 (100)	34 (100)	100	100
Xinjiang	7	85	6 (85.7)	6 (85.7)	79 (92.9)	5 (71.4)	59 (69.4)	66.7	100

Note: Military hospitals were not included in this investigation. In 2023, China had 998 hospitals with nuclear medicine (NM) programs, employing 11,285 workers across all PLADs except Xizang Autonomous Region. Of these institutions, 637 (63.8%) hospitals with 8,818 (78.1%) NM workers conducted ^{131}I treatment procedures, and 358 (35.9%) hospitals with 5,893 (52.2%) workers specifically performed ^{131}I treatment for thyroid cancer. Surface contamination monitors were available in 906 (90.8%) hospitals. Among the 637 hospitals providing ^{131}I treatment, 62.6% were equipped with automated ^{131}I loading devices.

Abbreviation: PLADs=provincial-level administrative divisions; NM=nuclear medicine.

SUPPLEMENTARY TABLE S2. Distribution of ^{131}I thyroid activity measurements among staff at radioiodine treatment facilities in China, 2023.

PLADs	Participant numbers	Above MDA		Maximum ^{131}I activities (Bq)	^{131}I activities above 1.0×10^2 Bq	
		Numbers	Proportion (%)		Numbers	Proportion (%)
Beijing	106	7	6.6	3.2×10^3	7	6.6
Tianjin	19	14	73.7	2.0×10^3	1	5.3
Hebei	30	14	46.7	8.2×10^2	12	40.0
Inner Mongolia	5	4	80.0	9.0×10^2	3	60.0
Liaoning	86	13	15.1	1.0×10^3	7	8.1
Jilin	102	14	13.7	2.2×10^2	7	6.9
Heilongjiang	200	4	2.0	5.5×10^2	4	2.0
Shanghai	204	6	2.9	5.8×10^4	3	1.5
Jiangsu	200	46	23.0	1.0×10^2	0	0
Zhejiang	96	49	51.0	6.3×10^2	8	8.3
Anhui	213	72	33.8	1.8×10^4	40	18.8
Fujian	231	58	25.1	2.2×10^3	45	19.5
Jiangxi	103	22	21.4	1.5×10^4	21	20.4
Shandong	49	43	87.8	3.1×10^3	21	42.9
Henan	276	61	22.1	4.3×10^3	40	14.5
Hubei	172	27	15.7	1.2×10^3	18	10.5
Hunan	44	1	2.3	1.1×10^2	1	2.3
Guangdong	276	23	8.3	1.8×10^2	6	2.2
Guangxi	252	33	13.1	3.6×10^3	14	5.6
Hainan	57	2	3.5	40	0	0
Chongqing	120	27	22.5	2.7×10^3	16	13.3
Sichuan	59	9	15.3	1.1×10^3	7	11.9
Guizhou	49	12	24.5	5.4×10^2	12	24.5
Yunnan	33	9	27.3	1.0×10^3	6	18.2
Shaanxi	7	7	100	5.2×10^2	5	71.4
Gansu	56	37	66.1	1.2×10^3	3	5.4
Qinghai	22	0	0	−	0	0
Ningxia	18	3	16.7	4.0×10^2	3	16.7
Xinjiang	52	13	25.0	1.8×10^3	4	7.7

Note: No ^{131}I treatment facilities were present in Xizang in 2023, and ^{131}I monitoring was not conducted in Shanxi province in 2023. Military hospitals were excluded from this study. In 2023, thyroid ^{131}I activity measurements were conducted on 3,137 staff members from radioiodine treatment sites. ^{131}I was detected in the thyroid of 630 participants (20.1%), with the maximum measurement reaching 5.8×10^4 Bq. Further evaluation was performed on measurements exceeding 1.0×10^2 Bq, which represented 10.0% of all participants.
"−" indicates that the maximum ^{131}I activity value is not applicable to Qinghai province.
Abbreviation: PLADs=provincial-level administrative divisions; MDA=minimum detectable activity.