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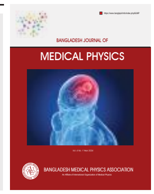

Comprehensive Health Surveillance of Radiation Workers in Nuclear Medicine: Evaluation of Hematological, Hormonal, Biochemical, and Dosimetric Profiles at NINMAS

***Md Shohag Mia, Hasan Mehdi, Sanchoy Chandra Biswasarma, Md. Nur-E-Alam Siddiquee, Sanjida Islam, Muhtasim Kadir, Md. Jashim Uddin, Md. Nahid Hossain**

National Institute of Nuclear Medicine and Allied Sciences (NINMAS), Bangladesh Atomic Energy Commission (BAEC)

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Corresponding Author:
Md Shohag Mia
shohagsh@baec.gov.bd

ABSTRACT

Radiation workers in a clinical setting generally are engaged with ionizing radiation like x-ray, gamma ray, which can be harmful due to its potential biological damage. Locally relevant surveillance data are limited in Bangladesh. So, a systematic health checkup is required to early detect the biological adverse effects. The purpose of the study is to assess hematological, hormonal, biochemical, and dosimetry data among radiation workers working in nuclear medicine facilities at the National Institute of Nuclear Medicine & Allied Sciences (NINMAS). A group of radiation workers involved with the scintigraphy section underwent this cross-sectional study. To carry out this study, Complete Blood Test (CBC), urine R/E, thyroid function tests (TSH, FT4) of the radiation workers were done, and thermoluminescent dosimeter (TLD)-based personal dose reports were measured quarterly. Occupational doses of the radiation workers were correlated with all the biological reports, which were assessed against standard clinical ranges. Radiation dose received by the participants was lower than 0.05 mSv, which is well below the occupational dose limit of 20 mSv per year according to the ICRP 103. Different parameters for Hematology were mostly shown within normal limits, where the variation of lymphocyte values was found with minor change, with one female case of anemia (Hb: 8.3 g/dL). Thyroid hormonal values were within reference ranges, and the TSH value of two female workers showed upper borderline, with one female case of elevated FT4. In a few cases, trace glycosuria and pyuria were found in urinalysis. Effective radiation-protection techniques were consistent with measured doses that were significantly below ICRP limits. The importance of regular surveillance and clinical follow-up is highlighted by the anomalies that have been detected, such as anemia and thyroid dysfunction. The small, uncontrolled sample makes the results illustrative; larger, long-term investigations with more biomarkers are necessary.

1. Introduction

There is a deficit of methodologically integrated evidence of radiation health effects from Bangladesh, despite the fact that foreign studies have uncovered thyroid, hematologic, and urinary effects among radiation workers. Nuclear medicine professionals often merged radiopharmacy activities with patient-facing imaging and therapeutic workflows, and the rapid advancement of PET/SPECT and developing theranostic services is changing the case-mix and procedure volumes. These local practice patterns are significantly different from many previous cohorts. Different facilities also have different access to structured follow-up, periodic laboratory testing, and standardized personal dosimetry, which can impact on measured exposures and the possibility of identifying subclinical impacts. In this regard, locally grounded baseline data that are directly related to individual TLD dosages and practicable to gather under normal circumstances are required.

As ionizing radiation is imperative for nuclear medicine diagnostic and therapeutic treatments, healthcare workers who frequently deal with radiopharmaceuticals are at risk of occupational hazards. Even within legal bounds, long-term low-dose radiation exposure can pose minor or cumulative biological effects, especially on the kidney, endocrine, and hematological systems. To lessen long-term stochastic risks, the International Commission on Radiological Protection (ICRP) recommends an occupational exposure limit of 20 mSv annually averaged over five years, with no year exceeding 50 mSv [1, 14, 15].

Periodic clinical evaluations, laboratory testing like complete blood counts (CBCs), routine urine examinations, thyroid function tests, and radiation dose monitoring using thermoluminescent dosimeters (TLDs) are usually covered in these programs [2,3, 13, 23, 19, 24]. The adverse effects of low-dose radiation exposure on thyroid hormone levels, blood cell counts, and urine indicators have been the topic of numerous studies, with varying degrees of success. While some have shown no noticeable departure from normal ranges, others have reported subclinical inflammation, minor thyroid dysfunction, or lymphocyte suppression [4–6]. Forming baseline data on radiation worker's health is essential for creating national safety rules in Bangladesh, where nuclear medicine is growing quickly.

This study aimed to assess the health of radiation employees working at National Institute of Nuclear Medicine and Allied Sciences (NINMAS). To observe any early signs of occupational radiation exposure, we carried out a thorough cross-sectional investigation of hematological, biochemical, hormonal, and dosimetry data.

2. Materials and Methods

2.1 Study Design and Setting

The National Institute of Nuclear Medicine and Allied Sciences (NINMAS), a tertiary nuclear medicine facility under the Bangladesh Atomic Energy Commission (BAEC), was the area of this cross-sectional investigation. Assessing the biological and dosimetry characteristics of radiation, personnel actively involved in operating nuclear medicine procedures was the goal of this research.

2.2 Study Population

Evidence strength and scope of application are limited by the small convenience sample (n=19) and the absence of a non-exposed control group in this exploratory investigation. The protocol is not a hypothesis-driven trial, but rather an examination of regular occupational surveillance data.

Inclusion of criteria: Worked for more than one year in scintigraphy division, regular users of personal dosimetry (TLD badge), provided accord for the use of surveillance data in anonymized research

Exclusion criteria: Workers with incomplete quarterly dose or laboratory data.

2.3 Radiation Dosimetry Assessment

Thermoluminescence Dosimeters (TLDs) were used to trace occupational exposure to ionizing radiation. Following national radiation safety regulations, each employee wore a whole-body TLD badge during their working period. Every three months, badges were collected and examined. All 19 employees had TLD-reported doses less than 0.05 mSv per quarter during the study period, showing regular exposure to low levels of radiation. The ICRP 103 occupational exposure limit of 20 mSv annually on average over five years and 50 mSv annually in any one year was used to collate the doses. [1].

2.4 Biological Sample Collection and Analysis

Regular quarterly health check-up involved the sterile collection of urine and blood specimens. With calibrated and quality-controlled analyzers, laboratory analyses were performed within the institutional clinical laboratory.

a) Hematological Analysis (Complete Blood Count - CBC): Performed with an automated hematology analyzer. Parameters evaluated included: Hemoglobin (Hb), Red Blood Cell count (RBC), White Blood Cell count (WBC) and differential count (Neutrophils, Lymphocytes, Monocytes, Eosinophils, Basophils), Hematocrit (Hct), Mean Corpuscular Volume (MCV), Platelet count

b) Urinalysis: Routine examination of urine samples included: Physical characteristics (color, appearance, specific gravity, pH), Chemical analysis (protein, glucose), Microscopy (WBCs, RBCs, epithelial cells, casts)

c) Thyroid Hormone Profile: The Siemens ADVIA Centaur® XPT Immunoassay System was used to measure the levels of free thyroxine (FT4) and thyroid-stimulating hormone (TSH) using chemiluminescent immunoassay (CLIA). Reference ranges used: TSH: 0.3 – 5 mIU/L, FT4: 8.5 – 25.5 pmol/L

2.5 Data Management and Statistical Analysis

Descriptive statistics (means, ranges, SDs; counts for categorical findings) were used to summarize the data.

We did not conduct hypothesis testing or give p-values because of the small sample size and lack of a control group, and we regarded any cross-tabulations or scatterplots as purely exploratory. The findings should be taken as illustrative signals to direct further research with sufficient power.

2.6 Ethical Considerations

According to institutional norms, this study was not subject to the formal ethical review because it used anonymized data from an institutional health monitoring program without posing participants at risk or requiring direct action. Every employee provided their informed consent for the use of their data.

3. Results and Discussion

The study cohort comprised 19 radiation workers, including 16 men (84.2%) and 3 women (15.8%), with ages ranging from 29 to 57 years (mean ± SD: 47.3 ± 8.3 years). All participants were routinely involved in nuclear medicine procedures using unsealed radioisotopes. Individual TLD Dose Records are summarized in Table 1.

Table 1. Quarterly and annual TLD dose reports for radiation workers (n=19).

Worker ID	Q1 Dose (mSv)	Q2 Dose (mSv)	Q3 Dose (mSv)	Q4 Dose (mSv)	Annual Dose (mSv)
P-1	<0.05	<0.05	<0.05	<0.05	<5.00
P-2	<0.05	<0.05	<0.05	<0.05	<5.00
P-3	<0.05	<0.05	<0.05	<0.05	<5.00
P-4	<0.05	<0.05	<0.05	<0.05	<5.00
P-5	<0.05	<0.05	<0.05	<0.05	<5.00
P-6	<0.05	<0.05	<0.05	<0.05	<5.00
P-7	**0.102**	<0.05	**0.08**	<0.05	<5.00
P-8	<0.05	<0.05	<0.05	<0.05	<5.00
P-9	<0.05	<0.05	<0.05	<0.05	<5.00
P-10	**0.219**	<0.05	<0.05	<0.05	<5.00
P-11	<0.05	<0.05	<0.05	<0.05	<5.00
P-12	<0.05	<0.05	<0.05	<0.05	<5.00
P-13	<0.05	<0.05	<0.05	<0.05	<5.00
P-14	**0.122**	<0.05	<0.05	<0.05	<5.00
P-15	<0.05	<0.05	<0.05	<0.05	<5.00
P-16	<0.05	<0.05	<0.05	<0.05	<5.00
P-17	<0.05	<0.05	<0.05	<0.05	<5.00
P-18	<0.05	<0.05	<0.05	<0.05	<5.00
P-19	<0.05	<0.05	<0.05	<0.05	<5.00

Personal dosimetry data showed that quarterly whole-body doses measured with thermoluminescent dosimeters (TLDs) were less than the detection limit of 0.05 mSv, with the most of individual doses falling under this threshold; however, in some individuals, higher values were recorded, ranging from 0.08 to 0.219 mSv. When extrapolated, annual effective doses for all workers were <5 mSv, far below the ICRP occupational exposure limit of 20 mSv per year (averaged over 5 years) and the single-year maximum of 50 mSv. These findings indicate that radiation exposures remained low and within internationally accepted safety standards throughout the monitoring period [11, 22].

3.1 Hematological Profile

The mean and standard deviation (SD) for selected CBC parameters are summarized in Table 2.

Table 2. Hematological parameters with mean ± standard deviation and adult reference ranges.

Parameter	Mean ± SD	Reference Range (Adults)
Hemoglobin (g/dL)	13.5 ± 1.8	12.0–16.5 (F); 13.5–17.5 (M)
WBC (×10⁹/L)	8.1 ± 2.5	4.0–11.0
Neutrophils (%)	56.3 ± 9.4	40–75
Lymphocytes (%)	35.1 ± 7.6	20–45
Platelets (×10⁹/L)	263.2 ± 84.5	150–400
MCV (fL)	85.6 ± 7.5	80–100

One female participant (P-3) was found marked anemia with Hb: 8.3 g/dL, low RBC (3.69×10^{12}/L), and Hct: 26.5%; The participant with anemia (P-3) subsequently underwent gynecological evaluation and dietary review, and no link with radiation exposure was found. Elevated WBC was shown in two workers (P-2F: 14.5×10^{9}/L; P-10M: 12×10^{9}/L) without symptoms, suggesting possible subclinical or transient infections. The percentage of lymphocytes varies from 25% to 51%. One male worker (P-9) had mild thrombocytopenia (120×10^{9}/L); however, it was not life-threatening.

3.2 Thyroid Hormone Profile

All participants had thyroid hormone levels within standard clinical reference ranges except one female worker. The mean and standard deviation (SD) for thyroid hormonal parameters are summarized in Table 3.

Table 3. Thyroid hormonal parameters with mean ± standard deviation and adult reference ranges.

Parameter	Mean ± SD	Range	Reference Range
FT4 (pmol/L)	16.1 ± 1.7	12.53 – 18.22	8.5 – 25.5
TSH (mIU/L)	1.57 ± 0.59	0.89 – 2.47	0.3 – 5

Near the upper reference limit, two female workers (TSH: 2.41 and 2.47 mIU/L) displayed comparatively higher values. Corresponding FT4 levels, however, fell within the typical range. One female participant (P-3) was found markedly elevated FT4 with 97 pmol/L, suggesting a cold thyroid nodule. The participant with markedly elevated FT4 (P-3) was referred for endocrinology consultation; no occupational radiation-related cause was identified.

3.3 Results of Urinalysis

Urinalysis findings were infrequent and mostly benign: trace glycosuria in 2/19, pyuria in 2/19, and microscopic hematuria in 1/19 (Table 4). Given small denominators, we report raw counts prominently and provide percentages secondarily.

Table 4. Urinalysis findings (counts; percentages in parentheses).

Finding	Percentage (%)
Trace glycosuria (non-diabetic)	2/19(10.5%)
Pyuria (WBC > 5/HPF)	2/19(10.5%)
Hematuria (RBC > 2/HPF)	1/19(5.3%)
Casts	0/19(0%)

P-9 (M) and P-2 (F) showed trace glycosuria without elevated blood glucose, which may indicate a benign renal glucose leak [17]. P-3 (F) had one example of moderate hematuria (1–2 RBCs/HPF). One female had pyuria (8–10 WBCs/HPF), which could indicate contamination or a minor UTI. Every other finding was within normal limits. It was shown insignificant relationship between TLD dosage and urine, hormonal, or hematological markers. As the sample size (n = 19) was very narrow, illustrative analysis was the sole method used; no inferential statistics were significant. Despite quarterly doses being under 0.05 mSv, biological parameters remained within safe clinical limits. TSH and hemoglobin varied more in female individuals, although not to a crucial degree.

Through the assessment of hematological, thyroidal, urinary, and dosimetry profiles, this cross- sectional study aimed to determine the health status of nuclear medicine workers exposed to low-dose ionizing radiation. Each quarterly dose was consistently below 0.05 mSv, representing cumulative annual exposures well below 5 mSv. All workers received doses below the ICRP annual occupational exposure limit (20 mSv/year). This is under the "low-dose" exposure category, which is frequently considered biologically safe but necessitates monitoring because of possible long-term adverse effects. [1].

3.4 Hematological Findings

Following research performed on healthcare professionals in comparable work environments, the hematological parameters of every employee were mostly within reference ranges. For instance, Shahbazi-Gahrouei et al. (2013) showed that nuclear medicine personnel exposed to low doses of radiation did not exhibit any notable CBC aberrations [2]. While some employees showed slight lymphocyte variability or WBC increase, these results were not statistically significant and might have been caused by temporary viral or inflammatory reactions rather than radiation influences. One participant (P-3) was also found to have marked anemia (Hb 8.3 g/dL, RBC 3.69×10^{12}/L, Hct 26.5%). Participant underwent gynecological evaluation and dietary assessment, which pointed toward non-radiation-related causes. At the reported dose range, radiation-induced anemia is not expected, supporting alternative explanations such as iron deficiency or gynecological factors. [3].

3.5 Thyroid Function

Particularly in younger people and women, the thyroid gland is extremely at risk from radiation. Out of the 19 participants, a female radiation worker (labeled P-3) exhibited a notably high free thyroxine (FT4) level of 97 pmol/L, with suppressed TSH, suggesting clear hyperthyroidism. She was referred for endocrinology consultation. Given the very low occupational radiation dose levels (<0.05 mSv/quarter), a causal relationship with radiation exposure is biologically implausible. Instead, more common etiologies such as autoimmune or nodular thyroid disease are more likely explanations. TSH levels of two female participants were close to the upper limit of normal (2.41 and 2.47 mIU/L), even though all FT4 and TSH readings were within established clinical norms. Although these do not indicate hypothyroidism, they might point to a subclinical trend that is worth keeping an eye on, particularly in light of other research showing that long-term low-dose exposure can pose a subtle impact on thyroid homeostasis [4, 5, 14,18]. Our findings agree with those of Mohammadi et al. (2011), who found no discernible thyroid impairment in radiation workers who received doses less than 5 mSv annually [6]. However, Sharma et al. (2018) showed that 18% of radiation workers had borderline TSH elevation, suggesting the need for routine thyroid exams as part of occupational health surveillance. [7, 20, 27]. Despite the low documented doses, inter-individual susceptibility and cumulative effects cannot be ruled out. In accordance with recommendations for best practices in occupational surveillance programs, female employees with borderline TSH should have their thyroids checked on a regular basis.

3.6 Urinalysis and Renal Considerations

No pathognomonic matrices of radiation-induced nephrotoxicity were shown in the urine. Two people with normal fasting blood glucose levels showed glycosuria, which may indicate a postprandial effect or benign renal glucose spill. A small number of patients encountered mild hematuria or pyuria, which is more likely to be the result of asymptomatic UTIs than radiation adverse effects. These results are in line with those of Abtahi et al. (2018), who found that low-dose radiation workers did not exhibit any discernible renal damage. [8].

These findings highlight the importance of integrating clinical background into surveillance programs: while radiation was not implicated, systematic monitoring ensures timely referral and management of unrelated but clinically significant health conditions.

3.7 Dose Monitoring and Safety Practices

Every quarter, most radiation workers received doses less than 0.05 mSv, indicating low exposure. Even the most anticipated yearly dosage, though, was much lower than the 20 mSv ICRP limit. This demonstrates how well NINMAS's current radiation protection procedures-which include shielding, monitoring, and compliance with ALARA principles [21,26]. It is essential to remember that radiation's stochastic effects, like cancer or genetic changes, can occur even at low doses and have no known threshold. Thus, even if our results are supportive, they highlight the significance of ongoing observation, instruction, and the use of cutting-edge preventative measures such as automatic dose dispensers and remote handling measures [9, 22, 25].

4. Conclusions

Effective radiation-protection techniques were consistent with measured doses that were significantly below ICRP limits. The importance of regular surveillance and clinical follow-up is highlighted by the anomalies that have been detected, such as anemia and thyroid dysfunction. The small, uncontrolled sample makes the results illustrative; larger, long-term investigations with more biomarkers are necessary.

Limitations and Future Directions

These results are merely illustrative. The tiny, uncontrolled sample makes it impossible to test hypotheses, restricts precision, and makes it impossible to rule out weak relationships. In order to identify subclinical impacts, future research should be longitudinal, well powered, job-stratified, and contain cytogenetic/molecular biomarkers.

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