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# Prevalence of X-ray Exposure in Veterinary Personnel in Trinidad and Tobago

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**Abstract** **Background:** X-ray imaging is commonly used as a diagnostic tool in veterinary practice. Chronic exposure to X-rays is an occupational health risk to veterinarians and veterinary assistants. Studies focusing on the Caribbean region are warranted to assess risk and increase safety awareness among veterinary personnel. **Methods:** This study aimed to assess the hematological profile of veterinary personnel exposed to X-rays and compare this profile to an unexposed group in Trinidad and Tobago. Demographic data for the exposed group was collected on the length of exposure to X-rays of persons in veterinary practice. The exposure levels were measured over a month using a personal X-radiation dosimeter. The unexposed group was selected randomly within similar age categories to the exposed group. Data was not collected from Tobago since preliminary research showed that clinics had no X-ray technology available during the study period. **Results:** Seventy-five percent of veterinary practices included in the study conducted 1-5 x-ray examinations per week using manual animal restraint. Manual restraint was found to be a common practice among clinics with personnel using protective aprons (16; 94.1%), leaded gloves (13; 76.5%), thyroid collars (14; 82.4%) and lead-lined glasses (2; 11.8%). X-ray exposure was within acceptable limits (maximum at 72 mrem/year), with increased exposure for veterinary assistants with higher workloads (8-10 hours/day). No significant differences existed between the Complete Blood Count (CBC) parameters of exposed and unexposed groups; p>0.05. No morphological abnormalities were detected on examination of blood smears of veterinary personnel. **Conclusions:** This nine-month study found that X-ray exposure to veterinary personnel in Trinidad was at internationally acceptable levels. There were no significant findings on the hematological analysis of exposed participants related to x-ray exposure. Manual restraint of animals was found to be a common practice, with most clinics using protective devices when operating X-ray equipment. However, complete personnel protection was not achieved in most clinics due to a lack of knowledge on tissue vulnerability. Studies like this are sparse to none for the region of the Caribbean. This is the first report on occupational exposure to X-rays in veterinarians and veterinary assistants in Trinidad and Tobago and provides important baseline data that can be used for future comprehensive studies and assessment of potential occupational health risks in the region.

**Key Words** x-ray exposure, veterinarians, veterinary technicians, hematology, blood cell morphology

## INTRODUCTION

X-ray is a standard diagnostic tool used in veterinary medicine in small and large animal practices, making occupational X-ray exposure a concern for veterinary personnel [1,2]. Previous studies have outlined the effects of X-rays as occupational hazards to veterinarians [1]. X-ray exposure is associated with thyroid-related cancers [3] and adverse effects on red blood cells, white blood cells and platelet variables [4,5].

A study conducted on 47 X-ray technicians in a teaching hospital in Diyala, Iraq, ranging in age from 25-50 years with a control sample of 20 individuals reported that atypical lymphocytes were more common in X-ray technicians when compared to the control group and linked this finding to the increased number of years of exposure to X-rays [4]. Another study reported decreased platelet counts in a group of 40 male subjects of a medical college in Saudi Arabia between the ages of 25-50 years compared to a control group [5].

Decreased levels of white blood cells in 60 X-ray technicians in Sudan were associated with more prolonged X-ray exposure at work compared to a matched control group [6].

Therefore, research suggests long-term occupational X-ray exposure leads to abnormalities in hematological parameters. However, further in-depth studies are necessary to determine the extent of the risks to these groups in Trinidad and Tobago. Evidence-based studies stress the importance of limiting occupational X-ray exposure [4-6]. Therefore, research on the effects of x-ray exposure in veterinary personnel in developing countries such as Trinidad and Tobago is warranted.

This study aimed to measure the levels of X-ray exposure experienced by veterinarians and veterinary assistants at clinics throughout Trinidad and Tobago. Trinidad and Tobago form one Republic that constitutes two islands. However, X-ray diagnostic equipment was unavailable on the island of Tobago at the time of this study, so data was only collected from the island of Trinidad, which is the larger and more populated of the two islands. Occupational exposure levels were recorded using personal dosimeters and compared to internationally acceptable limits. We hypothesized that long-term exposure to X-rays would influence hematological variables in exposed compared to non-exposed individuals. The results from this study would improve professional awareness of occupational safety risks and inform regulatory standards in the arena of X-ray use throughout the veterinary profession in Trinidad and Tobago and the wider Caribbean.

## METHODS

All veterinary clinics included in this study owned and operated X-ray machines. Eight of 14 veterinary clinics were willing and gave written consent to participate. At the time of the study, no veterinary practices in Tobago with X-ray technology were available. Hence, data was only collected from Trinidad. Ethical approval was granted by the Campus Research Ethics Committee of the University of the West Indies, St. Augustine, Trinidad, on 3rd January 2018 (Reference CEC341/11/17). All participants were well informed and gave signed consent before the study.

The inclusion criteria for the exposed group were stationary and mobile veterinary practices, including veterinarians and assistants. There was a minimum age requirement of 18 years and a minimum X-ray exposure requirement of one year. The exclusion criteria included persons with a history of cancer. De-identified demographic and hematological data for the unexposed group was selected to match the ages and genders of the exposed group using data obtained from an ISO 15189 accredited private medical laboratory with branches available near the exposed participants.

Questionnaires were distributed to all exposed participants to solicit demographic, health and occupational exposure risk data, including workload distribution and safety practices. Two Instadose 1™ personal X-ray dosimeters (Mirion Technologies, California, USA) were allotted to each practice for 28-34 days and then checked for exposure levels. The Instadose 1™ has direct ion storage technology and is an accredited USB-compatible dosimeter capable of providing anytime radiation dose measurements. The minimum reportable dose range for this dosimeter is typically 3 mrem to 500 rem (0.03 mSv to 5 Sv). However, upon request, the dosimeter can detect radiation levels as low as 1 mrem (0.01 mSv); this request was not made for this study. The study was conducted over nine months.

Veterinarians and assistants at each practice wore the dosimeters daily at their right collar region. Participants were asked to keep a daily X-ray log to assess exposure times. All dosimeter readings were recorded after the defined period and results on individual x-ray exposure (in mrem units) were obtained (Mirion Technologies). The average annual exposure levels were then estimated per individual based on those values. These estimations were compared with standard acceptable x-ray exposure limits defined by the United States Nuclear Regulatory Commission (NRC) and the Canadian International Commission on Radiological Protection (ICRP) [7,8].

The hematological tests on each exposed participant included Complete Blood Counts (CBC) and peripheral Blood Films (BF) examination. The CBC was used to seek abnormalities in blood cell and platelet parameters and the BF was examined to detect hematological or morphological abnormalities via the laboratory reports and secondary comparison with the Clinical Hematology Atlas-4th ed. by Rodak BF and Carr JH.

A sample size of 18 individuals was estimated to detect a difference in the mean platelet count of 38,575 with a Standard Deviation (SD) of 84,375.9 between exposed and unexposed groups. Statistical analyses were done using the integrated statistical software STATA version 15 Stata Corp, LLC. T-tests were used to detect significant mean (±SE) differences between exposed and unexposed groups of continuous normally distributed variables. The CBC data was classified into low, normal, or high groups according to standard reference values used by the ISO 15189 accredited laboratory to determine a link between x-ray exposure time and hematological effects (morphological changes or deviations from standard reference values for numbers of cells).

The age group of 20-25 years was compared to the other age groups (26-30, 31-35, 36-40, 46-50 and 55-65 years). A Chi-squared test was used to determine if any significant association existed between categories of years, exposure time and categorized values. Logistic regression sought to analyze the comparative effect of variables on differences between the exposed and unexposed groups. Any covariate with a $p<0.1$ was included in the model. Statistical significance was set at $p<0.05$ unless otherwise stated.

## RESULTS

Eight veterinary practices participated in this study. These included small animal (6), equine (1) and mixed small animal and equine (1) practices. Two practices provided mobile X-ray services, while the others had stationary X-ray devices. The exposed group consisted of 17 individuals. Fifteen individuals consented to hematological analysis. The exposed group consisted of 11 veterinarians and 6 veterinary assistants with a male-to-female ratio of 2:3. Hematological data from 80 de-identified individuals was used for the unexposed group. The male-to-female ratio for the unexposed group was 3:5. The age ranges were categorized as shown in Table 1.

From the dosimeter study, two veterinarians (18.2%) and three veterinary assistants or technicians (50%) recorded total effective dosages greater than zero (0 mrem). The total effective dosages for veterinarians and assistants ranged between 0-6 mrem/month, estimated to be 0-72 mrem/year with a maximum dosage of 6 mrem/month.

Concerning the number of X-rays taken-the log showed for participants 35.3%; 0-10 X-rays, 17.6%; 11-20 X-rays, 11.8%; 21-30 X-rays, 11.8%; 41-50 X-rays and 5.9%; >50 X-rays. The veterinary assistants logged the highest X-rays, while veterinarians logged the lowest numbers. Three exposed participants did not compile an X-ray log.

Table 2 summarizes the workload and exposure times for the exposed group. The modal values for workloads (time logged at the practice) were 5-7 days per week and 8-10 hours per day. It was found that five veterinary assistants (83.3%) worked those schedules, while four veterinarians (23.5%) worked 5-7 days per week and five (29.4%) worked 8-10 hours daily. Two veterinary assistants (33.3%) had weekly X-ray exposure frequencies of more than 20, while all veterinarians did not exceed 10 X-rays per week. The modal value for weekly exposure frequency was 1-5 x-rays. The years of exposure for veterinarians and assistants ranged from 21-30 years. The mode of history of exposure was 11-15 years.

Concerning safety practices, nine (52.9%) individuals reported using manual restraints on animals at most times while using chemical restraints at other times and eight (47.1%) always used manual restraints. Ten (90.9%) veterinarians reported using personal protective devices when manually restraining patients for X-rays. The type of protective devices used included protective aprons (16; 94.1%), leaded gloves (13; 76.5%), thyroid collars (14; 82.4%) and lead-lined glasses (2; 11.8%). It was noted that all veterinary assistants used thyroid collars and leaded gloves. Some clinics did not see the need to invest in further protective devices.

Values for red blood cell count (RBC), hemoglobin (Hb), hematocrit (HCT), white blood cell count (WBC), lymphocytes, neutrophils, monocytes and platelet count followed a normal distribution. An independent sample t-test showed that there was no difference between the mean (±SE) values of all variables between exposed and unexposed groups; p>0.05 (Table 3). Basophils and eosinophils showed a non-normal distribution. A two-sample Kolmogorov-Smirnov test showed no difference between the median values for either parameter for exposed and unexposed groups; p>0.05.

For the total population, the difference in mean values for all CBC parameters based on gender was analyzed using a two-sample t-test. The results are displayed in Table 4. There were significant differences in the mean values for RBC, Hb,

Table 1: Categories of the age range for both participating groups (hematological analysis)

| Age range (Years) | Number of Individuals: Exposed | Unexposed |
|---|---|---|
| 20-25 | 2 | 15 |
| 26-30 | 1 | 5 |
| 31-35 | 2 | 10 |
| 36-40 | 7 | 35 |
| 46-50 | 1 | 5 |
| 55-65 | 2 | 10 |

Table 2: Summary of workload and exposure times for exposed group

| Practice | ID Code | Profession | Age (years) | Gender | Number of years Exposed | Workload (days/week) | Workload (hours/day) | X-ray Exposure Time (Number/week) |
|---|---|---|---|---|---|---|---|---|
| A | 1 | Veterinarian | 46-50 | Female | 11-15 | 1-3 | 8-10 | 1-5 |
| | 2 | Veterinarian | 20-25 | Female | 1-5 | 3-5 | 8-10 | 1-5 |
| B | 3 | Veterinarian | 36-40 | Female | 15-20 | 3-5 | 8-10 | 6-10 |
| | 4 | Vet Assistant | 20-25 | Female | 6-10 | 5-7 | 8-10 | 1-5 |
| C | 5 | Veterinarian | 46-50 | Male | 15-20 | 5-7 | 5-8 | 6-10 |
| D | 6 | Veterinarian | 55-65 | Male | 21-30 | 3-5 | 3-5 | 1-5 |
| | 7 | Veterinarian | 36-40 | Male | 11-15 | 1-3 | 1-3 | 1-5 |
| E | 8 | Veterinarian | 36-40 | Male | 1-5 | 5-7 | 8-10 | 6-10 |
| | 9 | Vet Assistant | 36-40 | Female | 1-5 | 5-7 | 8-10 | 1-5 |
| F | 10 | Vet Assistant | 36-40 | Female | 21-30 | 5-7 | 8-10 | > 20 |
| | 11 | Veterinarian | 36-40 | Female | 11-15 | 5-7 | 5-8 | 1-5 |
| | 12 | Vet Assistant | 36-40 | Female | 11-15 | 5-7 | 8-10 | > 20 |
| | 13 | Veterinarian | 55-65 | Male | 21-30 | 3-5 | 5-8 | 1-5 |
| G | 14 | Veterinarian | 30-35 | Female | 6-10 | 3-5 | 5-8 | 6-10 |
| | 15 | Vet Assistant | 20-25 | Male | 6-10 | 3-5 | 5-8 | 6-10 |
| H | 16 | Veterinarian | 30-35 | Male | 11-15 | 5-7 | 8-10 | 6-10 |
| | 17 | Vet Assistant | 25-30 | Female | 1-5 | 5-7 | 8-10 | 1-5 |

Table 3: Mean (±SE) for CBC variables for exposed and unexposed groups

| Overall Results<br>Exposed (n = 15)<br>Unexposed (n = 80) | Mean | Standard error | Standard deviation | 95% confidence interval | | p-value |
|---|---|---|---|---|---|---|
| **RBC Number** | | | | | | |
| Exposed | 4.61 | 0.12 | 0.48 | 4.34 | 4.86 | 0.523 |
| Unexposed | 4.72 | 0.07 | 0.64 | 4.58 | 4.87 | |
| **Hemoglobin** | | | | | | |
| Exposed | 13.26 | 0.42 | 1.64 | 12.35 | 14.17 | 0.829 |
| Unexposed | 13.14 | 0.22 | 1.98 | 12.70 | 13.58 | |
| **Hematocrit** | | | | | | |
| Exposed | 39.73 | 1.17 | 4.53 | 37.23 | 42.24 | 0.916 |
| Unexposed | 39.90 | 0.65 | 5.79 | 38.61 | 41.19 | |
| **WBC Number** | | | | | | |
| Exposed | 6.75 | 0.64 | 2.47 | 5.38 | 8.12 | 0.577 |
| Unexposed | 7.15 | 0.28 | 2.49 | 6.59 | 7.70 | |
| **Lymphocytes** | | | | | | |
| Exposed | 2.30 | 0.21 | 0.80 | 1.86 | 2.74 | 0.145 |
| Unexposed | 2.01 | 0.08 | 0.68 | 1.86 | 2.16 | |
| **Neutrophils** | | | | | | |
| Exposed | 3.80 | 0.42 | 1.61 | 2.91 | 4.69 | 0.323 |
| Unexposed | 4.42 | 0.26 | 2.32 | 3.91 | 4.94 | |
| **Monocytes** | | | | | | |
| Exposed | 0.45 | 0.04 | 0.16 | 0.36 | 0.54 | 0.298 |
| Unexposed | 0.50 | 0.02 | 0.19 | 0.46 | 0.55 | |
| **Platelets** | | | | | | |
| Exposed | 256.67 | 16.90 | 65.44 | 220.42 | 292.91 | 0.730 |
| Unexposed | 250.25 | 7.39 | 66.07 | 235.55 | 264.95 | |

Table 4: Mean (±SE) for CBC variables parameters based on gender for the total population

| Parameter | Number of persons | Mean | Standard error | Standard deviation | 95% confidence interval | |
|---|---|---|---|---|---|---|
| **RBC number** | | | | | | |
| Female | 59 | 4.39 | 0.06 | 0.49 | 4.26 | 4.52 |
| Male | 36 | 5.22 | 0.07 | 0.44 | 5.07 | 5.37 |
| **Hemoglobin** | | | | | | |
| Female | 59 | 12.16 | 0.21 | 1.59 | 11.74 | 12.57 |
| Male | 36 | 14.81 | 0.19 | 1.11 | 14.43 | 15.18 |
| **Hematocrit** | | | | | | |
| Female | 59 | 36.95 | 0.59 | 4.57 | 35.76 | 38.14 |
| Male | 36 | 44.67 | 0.56 | 3.37 | 43.53 | 45.81 |
| **Monocytes** | | | | | | |
| Female | 59 | 0.49 | 0.02 | 0.18 | 0.44 | 0.54 |
| Male | 36 | 0.49 | 0.03 | 0.20 | 0.43 | 0.56 |
| **WBC Number** | | | | | | |
| Female | 59 | 7.09 | 0.31 | 2.37 | 6.48 | 7.71 |
| Male | 36 | 7.07 | 0.45 | 2.69 | 6.16 | 7.98 |
| **Lymphocytes** | | | | | | |
| Female | 59 | 2.12 | 0.09 | 0.73 | 1.93 | 2.31 |
| Male | 36 | 1.96 | 0.11 | 0.65 | 1.74 | 2.18 |
| **Neutrophils** | | | | | | |
| Female | 59 | 4.29 | 0.26 | 2.03 | 3.76 | 4.82 |
| Male | 36 | 4.38 | 0.42 | 2.54 | 3.52 | 5.24 |
| **Platelets** | | | | | | |
| Female | 59 | 272.54 | 8.74 | 67.13 | 255.05 | 290.04 |
| Male | 36 | 216.39 | 7.64 | 45.81 | 200.89 | 231.89 |

HCT and platelet count between males and females of the total population; $p<0.05$. Males in the exposed group and the total population had higher mean RBC, Hb and HCT values, but females had higher mean platelet counts (Table 4 and 5).

The results of the analysis of blood smears are displayed in Table 6. Five (33.3%) exposed individuals had abnormal neutrophils (hypersegmented or vacuoles), some with red cell variations reflective of anemia or reactive lymphocytes (case category 1). Two (13.3%) other individuals had reactive lymphocytes without other abnormal blood parameters, which was attributed to a viral infection. In this study, another individual (6.7%) exhibited signs of a bacterial infection with concurrent stress, case category 2.

One (6.7%) individual had occasional elliptocytic, macrocytic red blood cells (case category 3). In comparison, another individual (6.7%) showed similarities with rouleaux formation, microcytic, hypochromic variations with occasional target cells, low hemoglobin, low hematocrit and

Table 5: Difference between the mean values of CBC parameters based on gender in the exposed group (excluding platelets)

| Parameter | Number of persons | Mean | Standard error | Standard deviation | 95% confidence interval | | t-test p-value |
|---|---|---|---|---|---|---|---|
| **RBC number** | | | | | | | |
| Female | 9 | 4.37 | 0.14 | 0.41 | 4.05 | 4.69 | 0.01 |
| Male | 6 | 4.97 | 0.14 | 0.33 | 4.63 | 5.33 | |
| **Hemoglobin** | | | | | | | |
| Female | 9 | 12.19 | 0.35 | 1.05 | 11.38 | 13.0 | 0 |
| Male | 6 | 14.87 | 0.31 | 0.76 | 14.07 | 15.67 | |
| **Hematocrit** | | | | | | | |
| Female | 9 | 36.67 | 0.90 | 2.69 | 34.60 | 38.74 | 0 |
| Male | 6 | 44.33 | 0.76 | 1.86 | 42.38 | 46.29 | |
| **WBC number** | | | | | | | |
| Female | 9 | 7.02 | 1.06 | 3.18 | 4.57 | 9.47 | 0.624 |
| Male | 6 | 6.35 | 0.31 | 0.75 | 5.56 | 7.14 | |
| **Lymphocytes** | | | | | | | |
| Female | 9 | 2.49 | 0.33 | 1.0 | 1.73 | 3.25 | 0.279 |
| Male | 6 | 2.02 | 0.10 | 0.24 | 1.76 | 2.27 | |
| **Neutrophils** | | | | | | | |
| Female | 9 | 3.9 | 0.69 | 2.06 | 2.32 | 5.48 | 0.781 |
| Male | 6 | 3.65 | 0.28 | 0.68 | 2.94 | 4.36 | |
| **Monocytes** | | | | | | | |
| Female | 9 | 0.44 | 0.07 | 0.20 | 0.29 | 0.60 | 0.95 |
| Male | 6 | 0.45 | 0.03 | 0.08 | 0.36 | 0.54 | |

Statistical significance means p<0.05

Table 6: Cellular morphological abnormalities found in exposed group

| | Morphological Abnormalities | |
|---|---|---|
| Blood components | Veterinarians | Veterinary assistants |
| Red blood cells | 1: Microcytic, hypochromic | 1: Microcytic, hypochromic |
| | 2: Rouleaux formation | |
| | 3: Elliptocytes and occasional target cells | |
| | 4: Occasional elliptocytic macrocytic cells | |
| White Blood Cells | 1: Occasional vacuoles in neutrophils | 1: Occasional vacuoles in neutrophils |
| | 2: Occasional reactive lymphocytes | 2: Occasional reactive lymphocytes |
| | 3: Hypersegmented neutrophils | 3: Hypersegmented neutrophils |
| | 4: Mild toxic granules in neutrophils | 4: Mild toxic granules in neutrophils |
| | | 5: Occasional plasmacytoid lymphocytes |
| Platelets | 1: Occasional, large cells | 1: Occasional, large cells |

a low neutrophil count, which was attributed to a bacterial infection with concurrent iron-deficiency anemia. Large platelets were observed in two (13.3%) individuals with relatively normal cell counts.

## DISCUSSION

Veterinarians and assistants of eight practices throughout Trinidad were found to have acceptable X-ray exposure levels compared to international limits set by the NRC and the ICRP of 5,000 mrem per year [7,8]. However, veterinary assistants had higher exposure associated with higher workloads. There were no significant associations between X-ray exposure and hematology parameters. However, differences in CBC parameters based on gender were detected for the study population.

Recordings of 0 mrem indicated that exposure levels were too low to be detected by the Instadose 1™ personal X-ray dosimeters. Most veterinary assistants recorded dosages >0 mrem compared to veterinarians, indicating a higher likelihood of exposure in veterinary assistants. This finding was consistent with a study involving portable digital veterinary radiology procedures [9]. The authors attributed the findings to assistant proximity to the primary beam and individual positioning as manual restraint was a common practice. All practices in this study practiced manual restraint on animals.

The workload of veterinary assistants was higher than that of veterinarians. This explained the higher number of recorded exposures for assistants. There were no significant differences (p>0.05) between the mean values of CBC parameters (RBC count, Hb, HCT, WBC count, lymphocytes, neutrophils, monocytes and platelets) for the exposed and unexposed groups. This was consistent with findings from a study on X-ray technicians in a teaching hospital in Diyala, Iraq [4]. There was also no significant difference between categories of blood count (normal, low, or high values) for exposed and unexposed groups (Chi-square, 1 (df), p>0.05) in this study. Logistic regression analysis for the hematocrit levels of the exposed and unexposed groups where the age group of 20-25 years was used for comparison to the other age groups (26-30, 31-35, 36-40, 46-50 and 55-65 years) produced no differences; p>0.05. The relationships between the categories of years of exposure time and low, high, or normal CBC values showed no significant findings

(Chi-square, 1 (df), p>0.05). Hence, this study did not establish a relationship between the years of exposure to X-rays and abnormal CBC values.

The findings of white blood cell morphological abnormalities in this study primarily reflected ongoing bacterial or viral infections (Table 5). Case category 1 findings were attributed to a bacterial infection considering neutrophil abnormalities [10,11]. A previous study reported that atypical lymphocytes were found in x-ray technicians compared to the control [4]. Reactive lymphocytes were found in this study (case category 1) but were differentiated from atypical lymphocytes by their cell features [12].

Lymphocytes are considered the most radiosensitive cells, [13] but this study did not find lymphocyte morphological changes reflective of X-ray effects. However, it would have been beneficial to analyze B- and T-lymphocytes separately to increase the sensitivity of detecting radiation effects on the cells [13]. Plasmacytoid lymphocytes in this study indicated a stress response, but an ongoing bacterial infection was also considered for the blood film results of case category 2 [14]. A look at the red blood cells also showed no significant morphological abnormalities due to X-ray exposure, which may support an increased resistance of red blood cells to X-rays measuring up to two hundred gray (200 Gy) [13]. Findings of case category 3 were attributed to iron, folate, or vitamin B12 deficiency [15,16].

The large platelets found in this study were considered either coincidental or post-infection [17]. Platelets and lymphocytes are considered to be highly affected by ionizing radiation exposure [13]. However, a link between platelet morphology and X-ray exposure effects could not be formed in this study. A study on the Gubbio population in Italy found that age, gender and other factors did not affect the finding of hypertensive persons having higher hematocrit values [18]. However, study participants with diabetes, hypertension, renal calculi, or prescription medicine usage may skew CBC results. In this study, most veterinarians and assistants had hematological parameters within normal ranges. Because these findings did not indicate consistent or significant levels of abnormality, the effect of X-ray exposure on changes to blood components could not be concluded.

The eye's lens has been known to be one of the most radiosensitive tissues of the human body, primarily resulting in vision-impairing cataracts. It is classed as a "critical organ" by the ICRP [19]. Only two participants in this study used protective glasses when conducting X-ray procedures. While the use of all protective devices is recommended, the findings of this study indicate a lack of knowledge relating to ocular tissue vulnerability since some clinics did not see a need to invest further in protective devices. The most common types of protective devices used were aprons and thyroid collars. Studies have shown that these devices can effectively protect persons from the primary beam [2]. The use of protective gloves is thus heavily recommended when performing manual restraint of animals for X-ray procedures since the hands of operators will be placed in or near the primary beam.

Limitations to study findings included the small number of exposed participants and some non-compliance to instructions. In addition, the caseload of veterinary clinics in Trinidad may be considered relatively low compared to other veterinary practices in first-world countries. Perhaps with higher caseloads or participant numbers, there may be a link between X-ray exposure and changes to blood components. Holiday periods, including Christmas, Carnival and employee vacation periods, also proved to be threats to the study's accuracy as some practices under investigation were affected by periods of slow business and closure during those times. Ideally, all exposed participants should have worn dosimeters simultaneously from the start to the end of the study period so that holiday periods would have been relatively standard for all practices. The effects of low-dose X-ray exposure are known to be chronic and warrant more long-term studies. Repeated CBC testing is advised to improve the accuracy of detecting abnormalities in cell levels. A more detailed analysis of the morphological changes of lymphocytes exposed to occupational X-rays should also be explored. Since this study was the first one of its kind for Trinidad and Tobago, it lays the groundwork for future studies on the effects of X-ray exposure on veterinary personnel in the region. It will hopefully lead to more substantial safety standards through practice in the region.

## CONCLUSIONS

This nine-month study found that X-ray exposure to veterinary personnel in Trinidad was at internationally acceptable levels. All clinics used manual restraint for animals during X-ray procedures. While most clinics used protective aprons and gloves during procedures, some did not have sufficient measures for complete protection. Knowledge of ocular tissue vulnerability was limited in most clinics. There were no significant findings on the hematological analysis of exposed participants related to x-ray exposure. Still, the study provided the first set of basal hematological data for the sector in Trinidad. Males exposed to X-rays and males in the unexposed group had higher average values for RBC count, Hb and HCT when compared to females but females in the unexposed group had higher average platelet values. This study did not conclude a relationship between X-ray exposure time and abnormal CBC parameters. However, more extended study periods could provide deeper insights into hematologic changes due to the chronic nature of X-ray effects.

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## Author Contributions

Conceptualization: S.A., K.G.; Methodology: S.A., K.G.; Formal analysis and investigation: S.A., K.G.; Writing-original draft preparation: S.A.; Writing-review and editing: S.A., K.G., HA.O.; Funding acquisition: S.A.; Supervision: HA.O., K.G.

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## Competing Interests

There are no competing interests to declare.

## Financial Interests

There are no financial interests to declare.

## Institutional Review Board Statement

Ethical approval was granted by the Campus Research Ethics Committee of the University of the West Indies, St. Augustine, Trinidad, on 3rd January 2018 (Reference CEC341/11/17).

## Informed Consent

Written informed consent was obtained from all participants in this study.

## Data Availability

Data from this study can be provided by the corresponding author upon request.

## REFERENCES

1. Fritschi, Lin, "Cancer in veterinarians." *Occupational and Environmental Medicine,* vol. 57, no. 5, May 2000, pp. 289-297. https://pubmed.ncbi.nlm.nih.gov/10769295/.
2. Tyson, Reid *et al.*, "Estimated operator exposure for hand holding portable X-ray units during imaging of the equine distal extremity." *Veterinary Radiology & Ultrasound,* vol. 52, no. 2, March 2011, pp. 121-124. https://pubmed.ncbi.nlm.nih.gov/21388461/.
3. Neta, Gila *et al.*, "Occupational Exposure to Ionizing Radiation and Thyroid Cancer Risk in U.S. Radiologic Technologists, 1984–2006." *Annals of Epidemiology,* vol. 20, no. 9, September 2010, pp. 696-696. https://www.sciencedirect.com/science/article/abs/pii/S1047279710001821.
4. Mohammed, Mazin R. *et al.*, "Effects of Radiation on the Hematological Parameters in X-Ray Technicians: A Case-Control Study." *Journal of Pioneering Medical Sciences,* vol. 4, no. 2, June 2014, pp. 85-88. https://www.academia.edu/36379306/Effects_of_Radiation_on_the_Hematological_Parameters_in_X_Ray_Technicians_A_Case_Control_Study.
5. Meo, Sultan A., "Hematological findings in male x-ray technicians." *Saudi Medical Journal,* vol. 25, no. 7, July 2004, pp. 852-856. https://pubmed.ncbi.nlm.nih.gov/15235687/.
6. Diaband, Isam E. and Mahdi H.A. Abdalla, "The effect of long-term exposure to x-ray on the peripheral blood cells counts: A predictive tool for the risk of a low degree of the disease severity among x-ray workers." *International Journal of Current Research, vol.* 6, no. 3, March 2014, pp. 5757-5759.
7. United States Nuclear Regulatory Commission, *Subpart C-Occupational Dose Limits: § 20.1201 Occupational dose limits for adults.* NRC regulations (10 CFR), Ending Radical and Wasteful Government DEI Programs and Preferencing 1991, https://www.nrc.gov/ reading-rm/doc-collections/cfr/part020/part020-1201.html.
8. International Commission on Radiological Protection, *Dose Limits Recommended by ICRP* International Commission on Radiological Protection, ICRP Publications 2019, http://icrpaedia.org/Dose_limits.
9. Canato G.R., *et al.*, "Occupational exposure assessment in procedures of portable digital veterinary radiology for small size animals." *Radiation Physics and Chemistry,* vol. 95, February 2014, pp. 284-287. https://www.sciencedirect.com/science/article/abs/pii/S0969806X1300354X.
10. Rodak, Bernadette F. and Jacqueline H. Carr, *Clinical Hematology Atlas.* 4thth Edn., Saunders, Elsevier Inc., ISBN-17: 978-1-4557-0830-7, Pages: 269. https://jasulib.org.kg/wp-content/uploads/2022/10/16.-Clinical-Hematology-Atlas-PDFDrive-.pdf.
11. Scordino, Teresa, *Hypersegmented neutrophil.* American Society of Hematology. 2016, https://imagebank.hematology.org/image/60400/hypersegmented-neutrophil?type=atlas.
12. Cornell University College of Veterinary Medicine, *"Big blue" cells.* Cornell University College of Veterinary Medicine, ECLINPATH: leave the textbook. 2013, https://eclinpath.com/hematology/morphologic-features/white-blood-cells/big-blue-cells/.
13. IAEA, *Effects of Ionizing Radiation on Blood and Blood Components: A Survey.* International Atomic Energy Agency, TECDOC-934, Pages: 42. 1997, https://www.scirp.org/reference/referencespapers?referenceid=609556.
14. Meer, Wim van der et al., "The divergent morphological classification of variant lymphocytes in blood smears." *Journal of Clinical Pathology,* vol. 60, no. 7, July 2007, pp. 838-839. https://pubmed.ncbi.nlm.nih.gov/17596551/.
15. Constantino, Benie Tagala, "The Red Cell Histogram and The Dimorphic Red Cell Population." *Laboratory Medicine,* vol. 42, no. 5, May 2011, pp. 300-308. https://academic.oup.com/labmed/article-abstract/42/5/300/2505011?redirectedFrom=fulltext.
16. Scordino, Teresa, *Elliptocytes.* American Society of Hematology, Washington. 2015, http://imagebank.hematology.org/image/60270/elliptocytes?type=upload.
17. Cornell University College of Veterinary Medicine, *Platelet number.* Cornell University College of Veterinary Medicine, Astra WordPress Theme. 2013, https://eclinpath.com/hemostasis/disorders/platelet-numbers/.
18. Cirillo, Massimo *et al.*, "Hematocrit, blood pressure, and hypertension. The Gubbio Population Study." *Hypertension,* vol. 20, no. 3, September 1992, pp. 319-326. https://pubmed.ncbi.nlm.nih.gov/1516951/.
19. Hamada, Nobuyuki *et al.*, "An update on effects of ionizing radiation exposure on the eye." *British Journal of Radiology,* vol. 93, no. 1115, November 2020. https://pubmed.ncbi.nlm.nih.gov/31670577/.