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RETINAL THICKNESS AND RNFL EVALUATION BY OCT IN RADIOLOGY TECHNICIANS EXPOSED TO X-RAYS WITHOUT EYE PROTECTION IN AMAZONIAN CLINICS

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Abstract

Introduction: While the ocular effects of ionizing radiation have been widely studied, little is known about its impact on the retinas of radiology professionals exposed daily without protective eyewear. This study aimed to assess potential morphological retinal changes using optical coherence tomography (OCT) in radiology technicians working without X-ray protective glasses.

Methods: A total of 11 radiology technicians routinely exposed to X-rays without eye protection were compared with 9 age-matched controls not exposed to ionizing radiation. Subjects with systemic conditions affecting the retina (e.g., diabetes, hypertension) were excluded. OCT scans were performed using Heidelberg Spectralis OCT to assess retinal nerve fiber layer (RNFL) thickness and global retinal thickness.Given the small sample sizes, a descriptive comparison approach was used.

Results: RNFL thickness was thinner in the exposed group compared to controls, particularly in the superior and nasal quadrants. Three individuals in the exposed group showed global retinal thickness below normal limits, compared to one in the control group. The proportion of subjects with retinal thinning was higher in the exposed group, especially in the macula and RNFL. A qualitative assessment revealed temporal macular thinning and superior RNFL thinning around the optic disc.

Conclusion: These findings suggest that chronic X-ray exposure without protective eyewear may be associated with retinal thinning and RNFL loss in radiology technicians. Given the small sample size, further research with larger cohorts is needed to confirm long-term effects and establish preventive measures.

Keywords: Retina, X-Rays exposure, Radiology technicians, radiography, Optical Coherence Tomography. Cite This Article: ALMEIDA, Leidiana Silva de et al. OPTICAL COHERENCE TOMOGRAPHY ANALYSIS IN RADIOLOGY TECHNICIANS EXPOSED TO X-RAYS WITHOUT EYE PROTECTION IN AMAZONIAN CLINICS. International Journal of Retina, [S.l.], v. 8, n. 2, p. 114, oct. 2025. ISSN 2614-8536. Available at: <https://www.ijretina.com/index.php/ijretina/article/view/327>. Date accessed: 01 oct. 2025. doi: https://doi.org/10.35479/ijretina.2025.vol008.iss002.327....

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INTRODUCTION

The effects of ionizing radiation on ocular tissues have been widely documented, particularly regarding lens opacities and cataract formation [1-5]. Radiotherapy-induced eye diseases are influenced by extrinsic factors such as radiation type, dose, fractionation scheme, treatment duration, and potential procedural errors. Additionally, intrinsic risk factors, including diabetes mellitus, hypertension, and chemotherapy, have been linked to increased susceptibility to radiation-induced ocular damage [6]. A long-term prospective study investigating the effects of chronic X-ray exposure on visual function followed 35,705 radiology technicians over 21 years (1983–2004). During this period, 2,382 cases of cataracts a progressive and potentially disabling opacification of the lens—were recorded. Interestingly, cataract occurrence was independent of workers' X-ray exposure levels (5–60 mGy), challenging the International Commission on Radiological Protection (ICRP) guidelines, which suggest a minimum cumulative dose of 2 Gy to induce cataracts. These findings suggest that even low-dose chronic radiation exposure may contribute to ocular damage [7]. While the lens is known to be highly sensitive to ionizing radiation due to its lack of regenerative capacity, less is known about the effects of chronic radiation exposure on deeper ocular structures, such as the retina and retinal nerve fiber layer (RNFL) [8]. Histopathological studies in animal models have shown that ionizing radiation can induce retinal atrophy, vascular changes, and neurodegeneration, but data on occupational exposure in humans are scarce [9,10]. Since radiology professionals are exposed to low doses of X-rays daily, it is critical to assess whether routine exposure without protective eyewear affects retinal morphology [7]. This study aims to fill this gap by using Optical Coherence Tomography (OCT) to evaluate potential morphological changes in the retina and RNFL of radiology technicians who do not use protective glasses while operating radiography equipment. Understanding these potential alterations is essential for assessing occupational risks and improving protective measures in radiology environments.

METHODS

Participants

Three groups were invited to participate in this study. The Non-Exposed Group (Control) consisted of individuals who were not exposed to artificially produced X-rays (n = 9, 4 female). The Exposed with Protection Group included radiology technicians and technologists who were exposed daily to artificially produced X-rays while using protective glasses. However, no participants were found for this group, likely due to a lack of awareness about the effects of ionizing radiation on ocular structures or the unavailability of protective equipment in their workplaces. The Exposed without Protection Group consisted of radiology technicians and technologists who were exposed daily to artificially produced X-rays without using protective glasses (n = 11, 5 female). These professionals usually have 6 hours of work in a hospital or clinic, but it is not uncommon for them work in more than one place to increase their income. Amplitude of years in the profession ranged from 7 to 28 years. Participants in the control and exposed groups were matched by age (mean 42.5 ± 16.5 years) and sex distribution to reduce potential confounding. Participants were recruited from four hospitals and two clinics located in the city of Belém, capital of the State of Pará, Brazilian Amazon, and informed consent was obtained after they were informed about the study's objectives and the tomographic evaluation methodology (optical coherence tomography). Exclusion criteria included individuals with conditions that could interfere with the study's objectives, such as diabetes mellitus, hypertension, or exposure to heavy metals or organic solvents. Additionally, all participants underwent a comprehensive battery of neuroophthalmological tests, including a Visual Acuity Test with Snellen Optotypes, Goldmann Applanation Tonometry, Anterior Segment Biomicroscopy, Autorefraction, and Automated Perimetry. These tests ensured the absence of any detectable neuro-ophthalmological abnormalities.

Tomographic Investigation

Structural examination of the retina was conducted using the Heidelberg Spectralis OCT system (Spectralis). Both eyes of all participants were examined to measure the RNFL and optic nerve disc parameters. For Spectralis, the signal quality is assessed by Q score, which is an indicator of image quality. A Q score of 15 is the manufacturer's recommended threshold for acceptable image quality, and scores above 20 are considered good or excellent for measurements such as RNFL thickness. Lower signal strength can lead to artefactual thinning, so a Q score of 20 or greater is recommended to ensure reliable measurements. Only scans with Q score signal strength ≥ 20 and without segmentation errors were included in the final analysis. The tomographic sections were performed with a thickness of 2 mm, with both axial and lateral resolution set to 5 μm. The measurements included global retinal thickness, assessed as the mean thickness across the central macula using the ETDRS grid, and RNFL thickness, measured around the optic disc at a diameter of 3.45 mm. When an individual's measurement is taken, the Spectralis software performs a statistical test to compare it to the normative database. The pvalue is used to represent the probability of obtaining that measurement from the healthy population, assuming the person is healthy. Assuming $\alpha = 0.05$, a smaller p-value suggests that the measured thickness is unlikely to be within the healthy, normal range, thereby indicating potential pathology.

Data Analysis

Given the small sample size (n = 9 for the control group and n = 11 for the exposed group), a descriptive comparison approach was used instead of parametric or non-parametric statistical tests to compare groups. The analysis focused on comparing global retinal thickness and RNFL thickness between the two groups. These parameters were assessed and presented using the proportion of subjects with retinal thinning, defined as macular thickness below 150 μm and RNFL thickness below 100 μm. In addition, Spectralis thresholds of < 150 μm for macular thickness and < 100 μm for RNFL thickness were used to compare individual patient measurements against the equipment normative database of healthy individuals. This database establishes expected ranges, and measurements below a certain percentile of these healthy values are flagged as potentially abnormal. The specific thresholds of 150 μm and 100 μm represent values below the first or fifth percentile of ageand-gender-matched healthy controls, respectively, in the Spectralis software's internal normative data. A qualitative assessment of thinning patterns, such as temporal thinning in the macula and superior RNFL thinning around the optic disc, was also conducted..

Ethical Considerations

This study was approved by the Research Ethics Committee of the Universidade da Amazônia (protocol 17789313.5.0000.5173) and was conducted in accordance with the Declaration of Helsinki.

RESULTS

Global Retinal Thickness in the Macula

Tomographic evaluation of global retinal thickness in the macula was performed for both the control group (9 subjects) and the group exposed to Xrays without eye protection (11 subjects), as shown in Figures 1 and 2. In the control group, 3 out of 9 subjects (33%) exhibited regions in both eyes with retinal thickness below the clinical threshold of 150 μm ($p < 0.01$), indicating significant thinning (Figure 1). Similarly, in the exposed group, 3 out of 11 subjects (27%) had regions in at least one eye with retinal thickness below 150 μm ($p < 0.01$), also indicating significant thinning (Figure 2). The retinal thinning in both groups was often localized to the temporal region, as observed in the retinal thickness maps. While the prevalence of retinal thinning was slightly higher in the control group (33% vs. 27%), the exposed group's thinning was more extensive in some subjects, particularly in the temporal region, suggesting a potential effect of X-ray exposure on macular health.

Retinal Nerve Fiber Layer (RNFL) Thickness Around the Optic Disc.

The thickness of the retinal nerve fiber layer (RNFL) was assessed by optical coherence tomography (OCT) at a 3.45 mm diameter around the optic disc in the left eye of subjects from both groups, as shown in Figures 3 and 4. The results revealed a higher prevalence of RNFL thinning in the exposed group compared to the control group. Specifically, in the control group, 1 out of 9 subjects (11%) had RNFL thickness below the clinical threshold of 100 μm, with the thinning localized to the nasal region in Figure 3 and the superior region (ST to SN) in Figure 4 ($p < 0.05$). In contrast, in the exposed group, 3 out of 11 subjects (27%) had RNFL thickness below 100 μm, with the thinning consistently observed in the superior region (SN to NU) across both Figures 3 and 4 ($p < 0.05$). The higher prevalence of RNFL thinning in the exposed group (27% vs. 11% in the control group) and the consistent pattern of superior RNFL thinning suggest that X-ray exposure without eye protection may preferentially damage this region of the optic disc, potentially increasing the risk of optic neuropathy.

Combined Abnormalities in Global Retinal and RNFL Thickness

Figures 5 and 6 highlight individual subjects with abnormalities in both global retinal thickness and RNFL thickness. In the control group, one subject exhibited significant abnormalities in both eyes (Figure 5). This subject had regions of global retinal thickness below 150 μm in the temporal region of both eyes ($p < 0.01$) and RNFL thickness below 100 μm in the superior region (ST to SN in the left eye, SN to NU in the right eye) of both eyes ($p < 0.05$). The bilateral nature of these findings suggests a possible underlying condition, such as early glaucoma or retinal degeneration, despite the subject being in the control group. In the exposed group, one subject exhibited similar abnormalities, but only in the left eye (Figure 6). This subject had regions of global retinal thickness below 150 μm in the temporal region of the left eye ($p < 0.01$) and RNFL thickness below 100 μm in the superior region (SN to NU) of the left eye ($p < 0.05$). The unilateral nature of the findings in this exposed group subject, combined with the consistent pattern of superior RNFL thinning seen in other exposed group subjects (Figures 3 and 4), suggests that X-ray exposure may be associated with localized retina damage, possibly due to the angle of exposure or individual anatomical differences

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Clinical Implications and Comparison

The findings indicate that both the control and exposed groups exhibit retinal and RNFL thinning, but the exposed group shows a higher prevalence of RNFL thinning (27% vs. 11%) and a consistent pattern of superior RNFL damage, likely due to Xray exposure without eye protection. The retinal thinning in the exposed group, while similar in prevalence to the control group (27% vs. 33%), appears more extensive in some subjects, as seen in the retinal thickness maps (e.g., Figure 6). The RNFL measurements around the optic disc (Figures 3, 4, and 6) show a clearer difference between the groups compared to the macular retinal thickness measurements (Figures 1 and 2), suggesting that RNFL thickness may be a more sensitive marker of radiation-induced damage. The superior RNFL thinning in the exposed group could lead to inferior visual field defects, while the temporal retinal thinning may affect central vision if it progresses. Both subjects with combined abnormalities (Figures 5 and 6) should be monitored for functional vision changes, with the control group subject potentially requiring further evaluation for an underlying condition and the exposed group subject needing monitoring for radiation-induced damage.

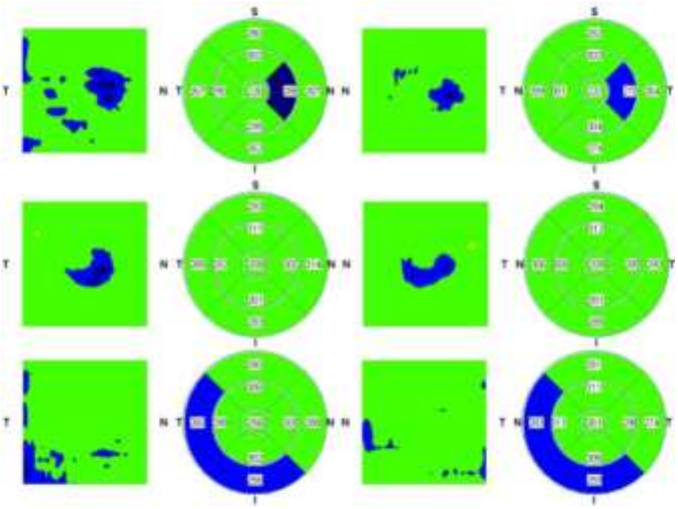

Figure 1. **Tomographic evaluation of the global retinal thickness in the control group. Of the 9 subjects, 3 had regions in both eyes with thickness below 150 µm ($p < 0.01$).**

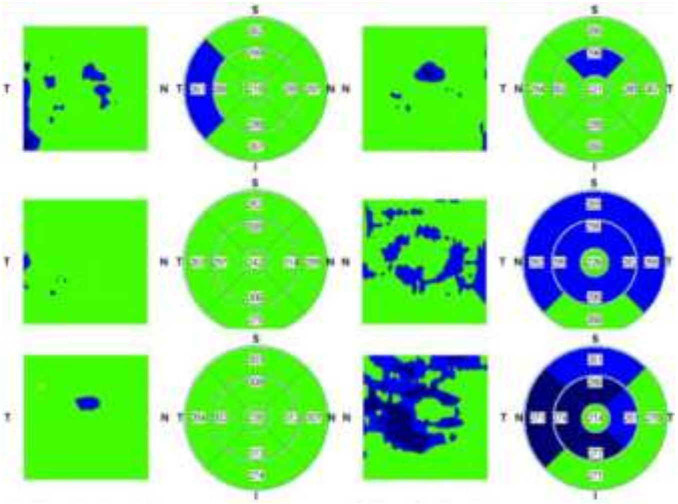

Figure 2. **Tomographic evaluation of the global retinal thickness in the group exposed to X-rays without eye protection. Of the 11 subjects, 3 had regions in at least one eye with thickness below 150 µm ($p < 0.01$).**

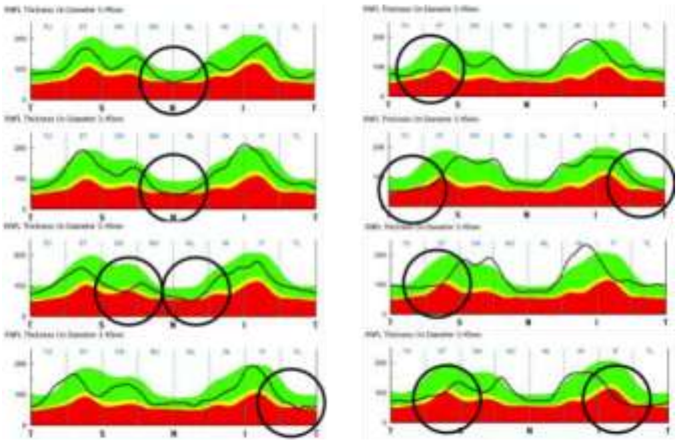

Figure 3. **Tomographic evaluation of the RNFL thickness at a 3.45 mm diameter around the optic disc in the left eye of control group participants (left column) and exposed group participants (right column). One subject in the control group and three in the exposed group had RNFL thickness below 100 µm (circled regions, $p < 0.05$).**

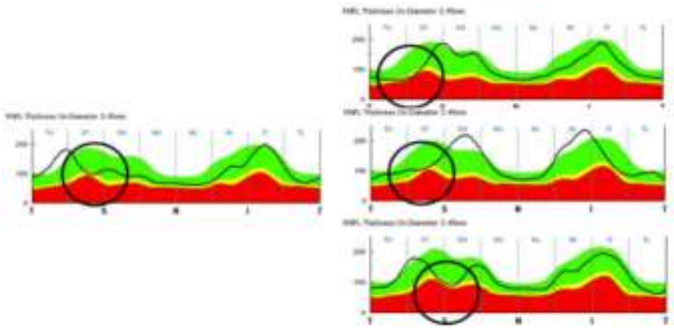

Figure 4. **Tomographic evaluation of the RNFL thickness at a 3.45 mm diameter around the optic disc in the left eye of control group participants (left column) and exposed group participants (right column). One subject in the control group and three in the exposed group had RNFL thickness below 100 µm (circled regions, $p < 0.05$).**

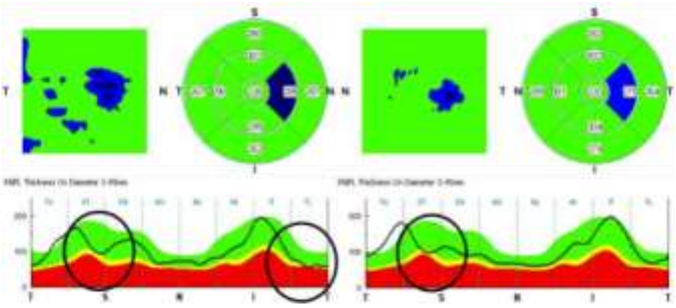

Figure 5. **One subject in the control group exhibited abnormalities in both global retinal thickness (p < 0.01) and RNFL thickness at a 3.45 mm diameter around the optic disc (p < 0.05) in both eyes.**

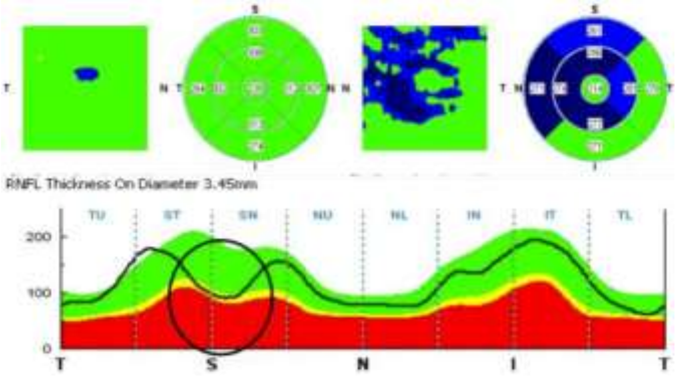

Figure 6. **One subject in the group exposed to Xrays without eye protection exhibited abnormalities in both global retinal thickness (p < 0.01) and RNFL thickness at a 3.45 mm diameter around the optic disc (p < 0.05), but only in the left eye.**

DISCUSSION

This study demonstrates that exposure to X-rays without eye protection is associated with significant structural changes in the retina, particularly in the retinal nerve fiber layer (RNFL). The tomographic evaluation revealed that 3 out of 11 subjects (27%) in the exposed group had global retinal thickness below 150 µm in at least one eye (Figure 2), compared to 3 out of 9 subjects (33%) in the control group with thinning in both eyes (Figure 1). More notably, the RNFL thickness at a 3.45 mm diameter around the optic disc was more frequently compromised in the exposed group, with 3 out of 11 subjects (27%) showing RNFL thickness below 100 µm in the left eye, compared to only 1 out of 9 subjects (11%) in the control group (Figures 3 and 4). The RNFL thinning in the exposed group was consistently localized to the superior region (SN to NU), suggesting that

this area may be particularly vulnerable to radiation-induced damage. The higher prevalence of RNFL thinning in the exposed group, along with the consistent pattern of superior RNFL involvement, indicates that X-ray exposure without eye protection may be associated with impairments in the inner retinal layers, particularly the ganglion cell axons that form the RNFL. This is further supported by the findings in Figures 5 and 6, where one subject in each group exhibited combined abnormalities in both global retinal thickness and RNFL thickness. In the exposed group subject, the abnormalities were unilateral (left eye only), with temporal retinal thinning and superior RNFL thinning (Figure 6), mirroring the patterns seen in the broader exposed group. In contrast, the control group subject had bilateral abnormalities (Figure 5), suggesting a possible underlying condition, such as early glaucoma or retinal degeneration, rather than an effect of radiation [10].

Potential Mechanisms of Radiation-Induced Damage

The observed RNFL thinning in the exposed group may be attributed to the vulnerability of the inner retinal layers, particularly the ganglion cells and their axons, to ionizing radiation. The inner retinal segment, which includes ganglion cells, bipolar neurons, amacrine cells, and Müller glial cells, has a high metabolic rate and is sensitive to oxidative stress, a well-documented effect of ionizing radiation. X-rays can induce DNA damage, reactive oxygen species (ROS) production, and apoptosis in retinal cells, with ganglion cells being particularly susceptible due to their long axons and high energy demands [11].

The superior RNFL's consistent involvement in the exposed group (Figures 3, 4, and 6) might be related to anatomical factors, such as the density of nerve fibers in this region or the angle of X-ray exposure, which could result in greater radiation absorption in the superior optic disc area [8]. The original hypothesis that the inner retinal layers are affected first because "ionizing radiation reaches this area first" is unlikely, as Xrays penetrate the entire retina uniformly due to its thin structure (approximately 200–300 μm) [8]. Instead, the inner retinal layers' vulnerability may be due to their cellular properties rather than their anatomical position. Additionally, radiationinduced vascular changes, such as damage to the retinal pigment epithelium (RPE) or choroidal vasculature, could contribute to secondary effects on the inner retina, including RNFL thinning. For example, Sahoo et al. (2021) noted that radiation retinopathy often involves vascular damage, which can lead to secondary retinal thinning over time [10]. Future studies should investigate these mechanisms using histological analysis or biomarkers of oxidative stress to confirm the cellular basis of the observed changes

Comparison with Prior Studies

The effects of ionizing radiation on the retina have been explored in other contexts, with varying results. Tamplin et al. (2024) studied patients with uveal melanoma who underwent radioisotope brachytherapy and found thinning of the inner plexiform layer and ganglion cell layer, consistent with the RNFL thinning observed in the current study [12]. However, they also reported thickening of the RNFL in some areas, which contrasts with our findings of RNFL thinning. This discrepancy may be due to differences in the type and dose of radiation (brachytherapy delivers a localized, high dose to the tumor, whereas X-ray exposure in our study is likely lower and more diffuse) or the timing of the measurements (brachytherapy effects may evolve over time, leading to compensatory RNFL thickening in some regions) [12]. Additionally, the high radiation doses used in brachytherapy can cause vascular and inflammatory changes that differ from the effects of routine X-ray exposure (10). In contrast, Loganovsky et al. (2020) assessed retinal morphometric parameters in individuals 25 years after the Chernobyl accident and reported a considerable increase in retinal thickness [11]. This finding differs markedly from the thinning observed in our study, likely due to the different exposure contexts. The Chernobyl survivors experienced acute, high-dose radiation exposure, which may have triggered chronic inflammatory or fibrotic responses leading to retinal thickening over decades [11]. In contrast, our study likely involves lower-dose, routine X-ray exposure (e.g., occupational or medical imaging), which may cause more immediate cellular damage and thinning without a long-term compensatory response [4]. These discrepancies highlight the importance of considering the radiation dose, exposure duration, and time since exposure when interpreting the effects of ionizing radiation on the retina [10].

Clinical Implications

The findings suggest that routine X-ray exposure without eye protection can lead to structural changes in the retina, particularly RNFL thinning, which may have functional consequences. The superior RNFL thinning observed in the exposed group (Figures 3, 4, and 6) corresponds to the inferior visual field, meaning that affected individuals may develop inferior visual field defects over time, a hallmark of optic neuropathies such as glaucoma or radiationinduced optic neuropathy [10]. Similarly, the temporal retinal thinning observed in both groups (Figures 1, 2, and 6) could affect central vision if it progresses, as the temporal macula contributes to the central visual field [13]. While this study did not assess functional outcomes, the structural changes observed warrant further investigation into their impact on visual acuity, visual fields, and overall visual function. The higher prevalence of RNFL thinning in the exposed group (27% vs. 11%) and the consistent pattern of superior RNFL involvement underscore the importance of eye protection during X-ray exposure, particularly in occupational settings (e.g., radiologists, technicians) or during medical imaging procedures [7]. Studies of radiologic technologists have shown increased risks of ocular conditions, such as cataracts, with prolonged radiation exposure, supporting the need for protective measures [2]. The unilateral findings in the exposed group subject (Figure 6) suggest that individual factors, such as the angle of exposure or baseline retinal thickness, may influence the extent of damage, highlighting the need for personalized risk assessments [14].

Limitations and Future Directions

This study has several limitations that should be addressed in future research. First, the lack of functional data (e.g., visual field testing, visual acuity) limits our understanding of the clinical impact of the observed retinal and RNFL thinning. Future studies should include functional assessments to determine whether the structural changes translate into visual impairment [10]. Second, the study did not quantify the dose or frequency of X-ray exposure in the exposed group, making it difficult to establish a doseresponse relationship. Detailed exposure data, including cumulative radiation dose and exposure duration, would help clarify the risk threshold for retinal damage, as demonstrated in studies of radiologic technologists [7]. Third, the small sample size (9 control subjects, 11 exposed subjects) and the focus on the left eye for RNFL measurements (Figures 3, 4, and 6) limit the generalizability of the findings. Larger studies with bilateral assessments are needed to confirm the patterns observed. Additionally, the presence of retinal and RNFL thinning in the control group (Figures 1, 3, 4, and 5) suggests that some degree of thinning may be due to natural variation or undiagnosed conditions (e.g., early glaucoma, retinal degeneration) [10]. Future studies should include more detailed screening to exclude such conditions in control subjects, as recommended in studies of age-related eye diseases [14]. Finally, longitudinal studies are needed to assess the progression of the observed thinning and its longterm impact on vision, particularly in the exposed group, where radiation-induced damage may worsen over time [11].

CONCLUSION

In conclusion, this study provides evidence that routine X-ray exposure without eye protection is associated with structural changes in the retina, particularly RNFL thinning in the superior region, which may increase the risk of optic neuropathy and visual field defects [10]. The inner retinal layers, especially the ganglion cells and their axons, appear to be particularly vulnerable to radiation-induced damage, likely due to their sensitivity to oxidative stress and DNA damage [11]. While the findings align with some prior studies showing inner retinal changes after radiation exposure [12], discrepancies with other studies highlight the importance of exposure context in determining retinal outcomes [11]. These results underscore the need for protective measures during X-ray exposure [2] and call for further research to elucidate the functional consequences, underlying mechanisms, and long term effects of such exposure on retinal health.

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