ORIGINAL ARTICLE

Combined Effects Of Temperature Changes And Radiation Absorption On Living Tissue

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ABSTRACT

***Background**: The need for the development of criteria for the referral of patients for radiographic examinations, especially in the face of the results of separate studies on temperature and radiation effects, formed the background to this study. The aim of this study is to determine the possible consequences of low dose radiation to living tissue in the presence of elevated temperatures, with a view to developing referral criteria for patients scheduled for radiodiagnostic examinations.*

***Method**: A two part procedure in the form of x-irradiation of water phantom at temperatures ranging from 25 45 degrees Celsius, to assess absorbed dose with temperature variation, as well as histological study of living tissue extracted from the skin and lungs of experimental animals, exposed to x-radiation at kilovoltage range between 50 90 and temperature values between 25 and 45 degrees Celsius.*

***Results**: Results showed increased radiation absorption with rising temperature in the studied samples suggesting that radiation absorption and therefore effects, may be functions of the temperature of the absorbing medium, being more pronounced at higher temperatures, even at constant exposure.*

***Conclusion**: A combination of elevated temperatures and x-radiation, even at diagnostic exposures doses, may not be safe for patients, especially in paediatric radiography patients presenting with body temperatures in the neighborhood of 40 degrees Celsius. The application of this as a radiation protection measure in the use of ionizing radiation is recommended, especially where highly dividing tissue is involved.*

KEYWORDS: *Radiation damage; Temperature; Kilovoltage; Skin; Lungs; X-radiation.*

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INTRODUCTION

Medical Radiography is the largest source of artificial radiation to man. Therefore, control of imminent hazards through dose control is vital and must be continuous and absolute. There is however no danger to either patient or staff in a properly managed X-ray department[1]. Radiation protection is designed to achieve a limited exposure of the patient to a minimum quantity of radiation consistent with satisfactory results, and to protect all other persons from exposure to the useful beam, scattered and leaking radiation[2].

One area of radiation protection often emphasized in radiographic technique, is the adoption of a careful technique whose essence is to prevent repeats and unwarranted exposure to the patient. To achieve a careful technique, certain criteria may need to be considered in the choice of patients subjected to radiodiagnosis. One of such criteria may be hyperthermia patients presenting with elevated body and /or tissue temperatures. This becomes more important when viewed in the light of a report by Hofer[3], that "hyperthermia potentiates radiation damage to living tissues".

This study seeks to determine the possible consequences of presenting febrile patients for X-ray diagnosis. The question of whether local hyperthermia in combination with low energy ionizing X-irradiation, would accelerate or deter the repair of radiation damage or modify the incidence of radiation induced effects in the treated tissue, is addressed.

Irradiation of localized tumours with a view to destroying them had been the basis of radiotherapy, over the years. But considering that the simplest ultimate effect of radiation absorption is heating, though the quantity (of such heat) produced in the range of electromagnetic radiation is very minute, the

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events that take place in such irradiated tissues may be more than what readily meets the eye.

One of the cellular effects of heat, which has contributed to the rationale for the clinical/therapeutic use of hyperthermia, is that heat plus radiation is more effective in cell killing than either agent alone [4]. This, in other words agrees with Hofer[3] that radiation exposure of tissues at elevated temperatures magnifies the cytotoxic effects of radiation not just to malignant tissues but also to normal tissue.

MATERIALS AND METHOD

The materials used for this work included the following: a three phase, high frequency X-ray generator - model R501 with all accessories, water phantom, beakers for holding the water phantom, 30 Wistar Albino rats, Cages (enclosures for the rats, maintained at different temperatures), a thermometer calibrated in ^{o}C, Lithium Fluoride TLD chips, immobilization binders for holding the rats in place for exposure, and a TLD reader.

The methodology adopted was in two parts, the first being the exposure of equal volumes of the water phantom in different beakers to X-radiation after heating them to temperatures varying from 25 ^{o}C to 45 ^{o}C, in steps of 5 ^{o}C. With a constant mAs (100mA and 0.1seconds, i.e. 10mAs), and a Source to Object distance (SOD) of 90cm, exposures were made at 50 kV, 60kV, 70kV, 80kV and 90kV, respectively. In all, 25 TLD chips were placed, one each, under a beaker holding water at a particular temperature for each kilovoltage (kV) respectively.

After the exposures, the radiation absorbed by the TLD chips were read with a Vinten Solaro TLD reader, Model 680, having a nitrogen flush system as a coolant, and operating at 300 ^{o}C, read and anneal temperature, for twelve (12) seconds. The quantity of radiation absorbed by each chip was a measure of the quantity of radiation transmitted by the water phantom under which it was placed. From these, the quantity of radiation absorbed by each specific water container (at its particular temperature) were computed as follows:-

Absorbed Intensity =Incident Intensity - Transmitted Intensity (by water phantom) (TLD reading). (1)

The second part of the study was designed to aid observation of possible effects of the absorbed radiation intensities on animal tissue at varying temperatures and kilovoltages. 30 Wister Albino rats of average weight 280 grams, were separated into six (6) groups of five (5) rats per group, with one group serving as the control. The other five groups were placed in a cage, each maintained at a particular temperature. Body temperatures of the experimental animals were confirmed with a thermometer between the limbs and the body. Those that met the required temperatures were then exposed to x-radiation with the same exposure factors as were used for exposing the water samples. The radiation beam was coned or collimated to include the entire thoracic and upper part of the abdomen of the experimental animals, with the body temperatures at which exposures were made being respectively, 25^{o}C, 30^{o}C, 35^{o}C, 40^{o}C and 45^{o}C. The rats, which were immobilized with a binder before exposure (to minimize motion and the possibility of the animal moving away from the radiation field), were marked with indicators of the temperatures at which they were irradiated. They were put back in their respective cages (at room temperature) after irradiation. Some of the rats were kept for physical observation while two tissue samples - skin and lung tissue (selected because of the frequency of their exposure to radiation by virtue of the predominance of chest x-ray examinations in the study area) were extracted for histological preparations from the others. The extraction was done after two days to give some time for the effects to be manifest since immediate effects are not so marked [5]. Staining was done with the Haematoxylin and Eosin technique and micrographs made at a magnification of x40.

RESULTS

The incident intensities in milliamperes (mA), for the different kilovoltage (kV) values (50, 60, 70, 80 & 90) were 79.02, 82.41, 86.32, 89.18, and 93.26 respectively. These were obtained by directing the primary beam, at each

kilovoltage, to the dosimeter chips (LiF-TLD 700) and computing the averages from each pair of readings per exposure. The results obtained are presented in the Tables I and II, and Plates 1- 14.

The results show that radiation absorption and therefore effects may be functions of the temperature at which an exposure is made. Plates 1-14 show the histological evidence of this on the skin and lung tissues at the extreme temperatures of 25°C and 45°C used in this work. Comparison between the plates shows that there is progressive accumulation of mononuclear inflammatory cell infiltrations in the alveolar interstitium and congestion of the alveolar spaces (pneumonitis and pulmonary congestion) of the lung tissue. On the skin tissue, there is evidence of progressive thinning of the epidermal layer. These effects were more severe at the higher temperature (45 °C) than at the lower temperature (25 °C).

The experimental animals which were kept alive after exposure to x-rays, revealed a delayed physical observation of hair loss at about the 10th day post irradiation. This increased with time, and was accompanied by general body weakness up to about the 14th day. It was also observed that the rats irradiated at 40°C and 45°C developed some additional skin reddening with nodular swellings, which were quite marked around the limbs at about the 14th day. These died after about three weeks.

Table I. Transmitted Intensities with different kV and Temperature

	Temperature (in degree Celsius)				
	25	30	35	40	4 5
Kilovoltage (kV)	TLD Readings (mA)				
50	75.35	74.42	73.25	70.24	68.78
60	76.22	75.10	74.02	72.21	70.40
70	77.25	76.42	75.25	74.66	73.70
80	80.64	79.99	78.25	76.99	74.60
90	82.70	81.99	80.60	78.87	76.50

Table II. Absorbed intensities by respective volumes of water for the different kV and Temperature.

	Temperature (in degree Celsius)				
	25	30	35	40	45
Kilovoltage (kV)	TLD Readings (mA)				
50	3.67	4.60	5.77	8.78	10.24
60	6.19	7.31	8.39	10.20	12.01
70	7.07	9.90	11.07	11.66	12.62
80	8054	10.19	11.93	12.19	14.58
90	10.56	11.27	12.66	14.39	16.76

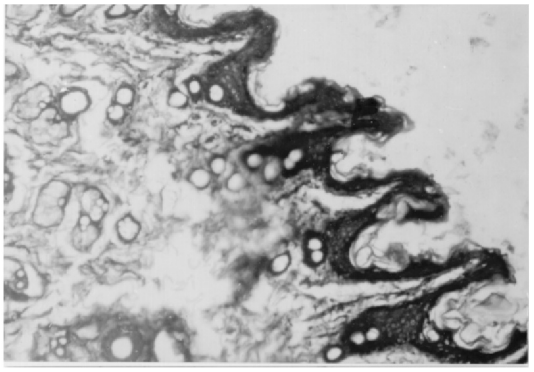

Plate 1 - Micrograph of Skin Tissue (Control)

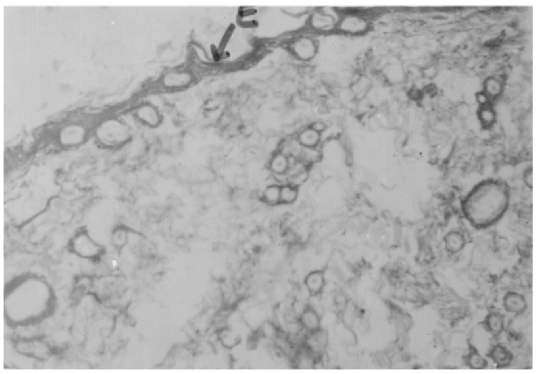

Plate 2 - Micrograph of Skin Tissue at 90kV and 25°C

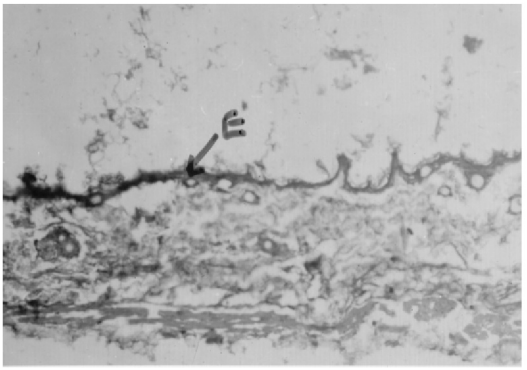

Plate 3 - Micrograph of Skin Tissue at 90kV and 45°C

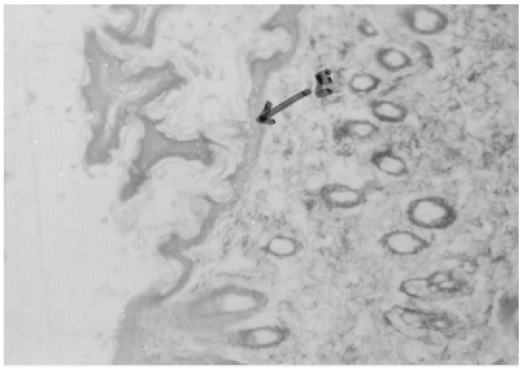

Plate 4 - Micrograph of Skin Tissue at 80kV and 25°C

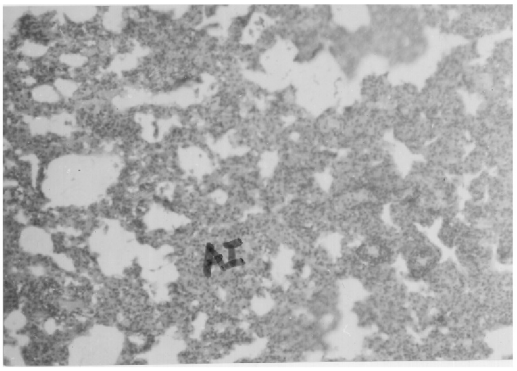

Plate 8 - Micrograph of Lung Tissue (Control)

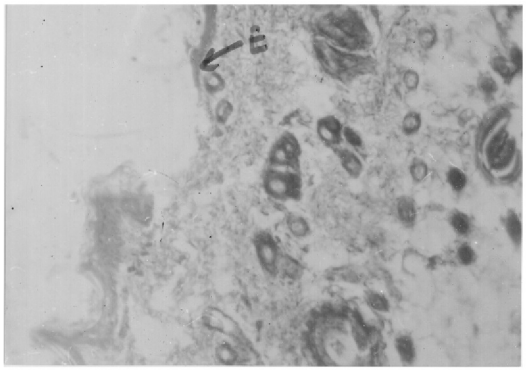

Plate 5 - Micrograph of Skin Tissue at 80kV and 45°C

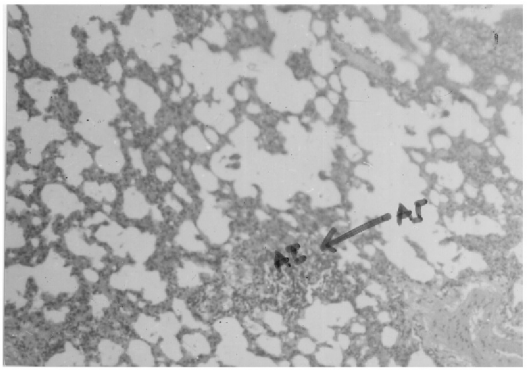

Plate 9 - Micrograph of Lung Tissue at 90kV and 25°C

Plate 6 - Micrograph of Skin Tissue at 70kV and 25°C

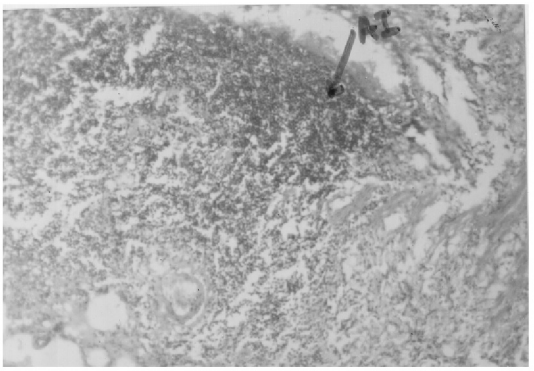

Plate 10 - Micrograph of Lung Tissue at 90kV and 45°C

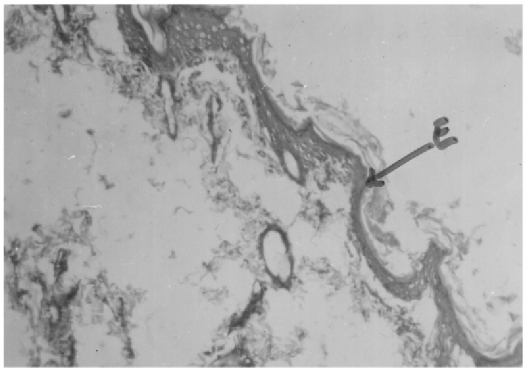

Plate 7 - Micrograph of Skin Tissue at 70kV and 45°C

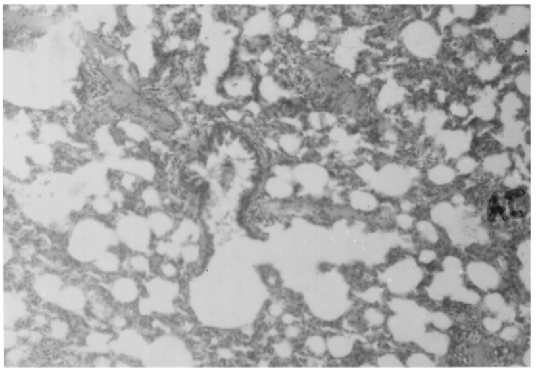

Plate 11 - Micrograph of Lung Tissue at 80kV and 25°C

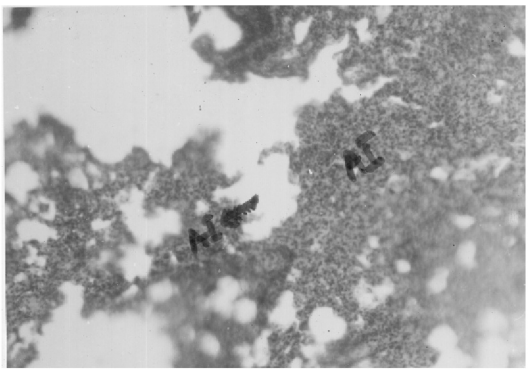

Plate 12 - Micrograph of Lung Tissue at 80kV and 45°C

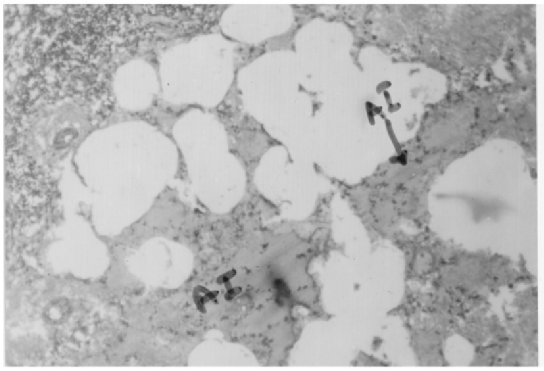

Plate 13 - Micrograph of Lung Tissue at 70kV and 25°C

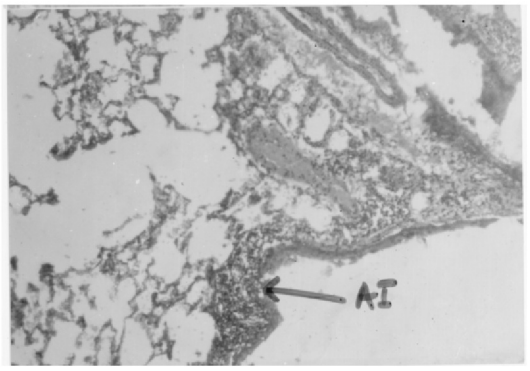

Plate 14 - Micrograph of Lung Tissue at 70kV and 45°C

DISCUSSION

Every radiation exposure potentially involves a small degree of risk [6]. The risk, which occurs as harmful effects of radiation interaction with tissues, may be immediate [5] or delayed [7]. We find from our results that the degree of radiation effects occurring in tissue is dependent on the absorbed quantity, which is itself, dependent on the temperature of the irradiated body. The result of temperature increase in tissue produces a larger surface area attributable to expansion occurring in the medium. Interaction of heat energy with the atoms of the medium leads to the weakening of the attractive forces between the nucleus and the electrons thereby reducing the binding energy. Irradiation needs only impart minimal energy to the atom to produce radiation damage[8].

The ratio of average weight of the experimental animals used to man is about 1: 250, suggesting that higher exposures will be required to produce the same effects in average man, neglecting the contribution due to increased scatter radiation. This is in agreement with Meredith and Massey [8] that the effective energy decreases with increase in depth and field size. The results may however be most relevant in paediatric radiography, especially involving children (neonates) weighing < 5 kilograms where radiation effects would not only be significant but could also produce lasting damage especially since children have a higher lifetime exposure potential than adults [9]. On the other hand however, elevated temperatures may be of advantage in radiotherapy in combination with ionizing radiation.

The replicative nature of most cells in the body and the inherent ability for repair enables a degree of cell healing to occur [10]. Repair, however, is inhibited in hyperthermic conditions [11]. Our results agree with Kampinga [4] and Hofer [3] that elevated temperatures potentiate radiation damage in tissues. This point is further stressed by comparing the results of this report with that of Mbenkum and Egbe [5] which showed that normal Wistar Albino rats exposed to x-radiation in the neighborhood of the exposures used for this work, gradually returned from general body weakness and drowsiness in the first eight days (post irradiation), to their normal activity by the 15th day (post irradiation). This is against the backdrop of the death of the same specie of experimental animals irradiated at elevated temperatures (40 degrees and 45 degrees respectively) after three weeks.

CONCLUSION

A combination of elevated body temperature with x-irradiation, even at diagnostic levels of

exposure may prove more deleterious to the patient than the effects of either phenomenon alone. While this combination may be useful in radiation therapy of tumours, it may be useful to suggest that patients undergoing diagnostic examination with radiation, particularly paediatric cases (with weights < 5 kg), who present with elevated temperatures of say 40 degrees Celsius and above, should have such examinations postponed until their body temperatures fall below this value as the epidermis (the most radiosensitive portion of the skin) may as a result face reduced cell division [12] since cells are more greatly endangered at temperatures in the neighbourhood of 42°C and above [13]. This will reduce the degree of possible radiation effects to the patient especially if differential susceptibility within populations i.e. that some people or cells are more susceptible to radiation than others even at low exposures [9, 14], is borne in mind.

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