

Determination of scatter radiation to the breast during lumbosacral x-ray examination using thermoluminescence dosimeter

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ABSTRACT

Objective: Exposure to ionizing radiation during radiographic examination is associated with some biological effects. The study was aimed to determine the amount of scatter radiation to the breast during lumbosacral x-ray examination.

Materials and Methods: The study was a prospective, cross-sectional study carried out among 60 women referred for Lumbosacral spine radiography from September 2019 to December 2019. Ethical approval was granted by the hospital ethical committee. A single-phase mobile X-ray unit was used to dispense the radiation while a thermoluminescent dosimeter (TLD) chip was used to measure the radiation dose. The TLD chip was attached to the peri-areolar region of the left breast and held in place by a transparent adhesive tape. The TLD was carefully enclosed in a black polythene sachet before and after the investigation to shield it from background radiation. After the investigation the TLDs were sent to the Centre for Energy Research and Training (CERT) for readout.

Results: The mean age and BMI of participants were 55.32 ± 12.35 years and $29.70 \pm 7.09 \text{ kg/m}^2$ respectively. The cumulative mean (\pm SD) ESD to the breast was $3.87 \pm 0.87 \text{ mGy}$. The highest scatter radiation dose was observed in the age group 60-69 years. Pearson's correlation showed a weak correlation between age and ESD.

Conclusion: The study showed that there were scatter radiations to the breast during lumbosacral X-Ray investigations which was lowest among the age group 50-59 years. No significant difference was seen between AP and lateral positions. The cancer risk was approximately 1 in 2,155 indicating that there might be a need to shield the breast while performing lumbosacral X-ray.

Keywords: Scatter Radiation, Breast, Lumbosacral X-Ray Thermoluminescence Dosimeter

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INTRODUCTION

There are naturally occurring and man-made sources of radiation, with the latter being used largely for medical diagnosis and therapy (1). The exposure of man to radiation for medical practices arises from diagnostic and therapeutic procedures which constitute the largest component of radiation doses to the population from artificial sources (1). Since the discovery of x-ray in 1895, there has been a marked growth in the installation of x-ray machines and in the frequency of diagnostic x-ray examinations (2). Although radiation doses from fluoroscopy and computed tomography are much higher than that of x-ray (3), the main concern about patient dose relates to stochastic effects which have no threshold to induce cancer and hereditary changes (4).

Evidence abounds for radiation-induced cancer risks from exposure to x-ray in the course of diagnosis (5).

Persons exposed early in life have high relative risks for cancers. Although the dose from the x-ray procedure is well below 10mSv which poses no challenge in deterministic effects, stochastic effects which can occur even with a low dose continue to present a challenge (6). Exposure to the minute amount of radiation has lifetime attributable risk to cancer which varies according to patient age and gender, with risk doubling in individuals 20years or younger and 2.22 times higher in women (7). These Dose increases have consequently raised concerns in the literature (1).

Therefore, the use of x-ray requires strict adherence to the principles of radiation protection to ensure that the risk to patients does not outweigh the benefit gained from the procedure (8). The international commission on radiological protection (ICRP (9)) is involved in radiation protection and has recommended that all medical exposures be subjected to radiation safety principles of justification, optimization and limitation (9). Optimization of patient protection requires that the magnitude of radiation doses be as low a reasonably achievable (ALARA) (9,10). One anatomical region often examined with high radiographic radiation doses is the lumbosacral spine because of its high anatomical density. Higher exposure settings and dense anatomical regions increase the tendency for scattered radiation (11).

The scatter radiation reaches the breast as entrance skin dose which could increase the risks of stochastic effects (11-13). Stochastic effects of radiation can be induced by any amount of radiation dose since it has no threshold. The breast, a high radiosensitive organ, often receives scattered radiation during x-ray examination of distant organs like the lumbosacral spine and head (12,13). Radiation exposure of the breast is the predominant factor in risk considerations since it contributes more than 98% to the effective dose of the thoracic region (12-14). At present, it is generally assumed that, with regard to cancer induction by ionizing radiation, the glandular tissue is the most vulnerable part of the breast. Glandular tissues trap scattered radiation to the breast (14).

Developing low-resource countries have faulty radiation protection culture, with most radiology facilities using older and secondhand equipment (15). Patient doses can be controlled through appropriate investigation of its quantity in order to predict risk, and thereafter recommending appropriate measures to reduce this risk.

Many researchers have estimated entrance surface dose and the absorbed dose to the breast using mammography locally, but none has estimated scatter radiation arising from lumbosacral examination, hence the need to determine the scatter radiation to the female breast during lumbosacral x-ray examination using thermoluminescence dosimeter. This will help to predict risks and guide the formulation of radiation protection policies as well as open more windows for research.

MATERIAL and METHODS

The study was a prospective, cross-sectional study carried out from September – December 2019, in the Radiology Department of Federal Medical Centre (FMC) Asaba, Delta State of Nigeria among 60 women who were referred to the radiology department for radiographic examination of the Lumbosacral Spine.

Ethical considerations

Ethical approval was granted by the hospital ethical committee of Federal Medical Centre Asaba Delta State. Signed informed consent was also obtained from every participant. Ambulant, adult female patients referred for lumbosacral x-ray examination without any history of preexisting breast lesion who granted consent participated in the study.

Taro Yamani formula as quoted by Uzoagulu (2011) (16), was used to calculate and obtain the sample size. A sample population of seventy (70) (17) being the number of female patients referred for lumbosacral radiography from September to December of the previous year was used to determine the sample population resulting in a sample size of sixty (60).

The sample size (n) was obtained using the equation below.

$$n = \frac{N}{1 + N(e)2}$$

Where n = sample size

N= Sample population (known)

e = error limit/alpha value (5%; 0.05)

$$n = \frac{70}{1.175}$$

$$n = 59.57 \approx 60$$

Equipment: A single-phase mobile X-ray unit having a kilovoltage range of 40-150kVp (Table 1), was used for the study. The x-ray unit is adapted to radiographic couch and a stationary grid.

A thermoluminescent dosimeter (TLD) chip (TLD-100) with an active ingredient of Lithium-Fluoride, doped with Magnesium and Titanium (LiF: Mg, Ti) was used to measure the patients' entrance surface dose (ESD). All the TLD chips were annealed at the Centre for Energy Research and Training (CERT) in Kaduna, Nigeria, which is a Secondary Standard Dosimetry Laboratory (SSDL). The TLD chips were carefully enclosed in a black radiolucent polythene sachet before and after x-ray irradiation to shield them from background radiation.

Methods: Patients for lumbosacral x-rays were identified from the reception area using their radiological request forms. Before the commencement of the examination, the nature of the investigation was explicitly explained to the participants and an informed consent form was filled by each participant. Prior to the radiographic examination the patient's age (years), weight (kilogram) using a weighing balance and height (meters) were obtained. The weight and height were then used to calculate the BMI of participants.

The lumbosacral X-ray examination was done using a standard radiographic procedure based on patient weight and thickness. Each patient was in a supine position at a film-focus-distance (FFD) of 90 – 100 with a grid system in place. Two views involving anteroposterior (AP) and lateral were

obtained. The TLD chip was placed at the peri-areolar region (been the most central aspect) of the left breasts during the examination. Immediately after the exposures the TLD's were carefully removed and labeled with the patient's identity. The TLD's were then placed in a cellophane bag having the patient's identity written in the abbreviation for patient's confidentiality.

They were then placed inside a black bag in other to prevent the exposure of the TLD's to spurious background radiation and later sent to the radiation dosimetric laboratory of the Regional Centre for Energy Research and Training for reading.

The effective dose (E) arising from scatter radiation was calculated using the mathematical relation:

$$\text{Effective dose (E)} = \sum [\text{Tissue weighting factor (W}_T\text{)} \times \text{Equivalent dose (H}_T\text{)}] \quad (1)$$

The tissue weighting factor (W_T) was determined using the International Commission on Radiological Protection (ICRP) report 103 and the equivalent dose (H_T) was determined from the product of the absorbed dose and radiation quality factor for X-ray.

$$\text{Similarly, Equivalent dose (H}_T\text{)} = \text{Quality factor (Q)} \times \text{Absorbed dose (D}_T\text{)} \quad (2)$$

In this case the radiation quality factor (Q) for X-ray \equiv 1.

Method of data analysis: The data was analyzed with the aid of Statistical Package for Social Sciences (SPSS) version 20.0. The ESD values for the two views (antero-posterior and lateral) were collated and summed to obtain the cumulative ESD to the breast. Descriptive and inferential statistics were used in the data analysis. The relationship between parameters was accessed using Pearson's correlation method. Results were presented in tables. Statistical significance was to be set at $p \leq 0.05$.

RESULTS

The majority of the participants are within the age group 50-59years which accounts for 28.33%, followed by the age group 60-69years (26.67%), whereas 80 years and above were the least (1.67%) as shown in **Figure 1**. The mean (\pm SD) age and BMI of participants were 55.32 ± 12.35 years and 29.70 ± 7.09 kg/m² respectively (**Table 3**). However, concerning the BMI, age group 40-49years and 50-59years were obsessed, with a BMI of 31.78 ± 5.12 kg/m² and 31.65 ± 8.87 kg/m² respectively (**Table 3**).

The cumulative mean (\pm SD) scatter radiation reaching the breast was 3.87 ± 0.87 mGy but the lowest amount of scatter radiation was demonstrated among the age group 50-59years (3.62 ± 0.97 mGy) as also illustrated in table 2. According to **Table 3**, the mean ESD AP (mSv) was 2.20 ± 0.70 and the ESD Lat (mSv) was 1.70 ± 0.40 mSv. The mean exposure factor in respect to the kVp Lat was 78.00 ± 4.00 with a rand of 70 to 86 kVp while the mean mA AP 236.00 ± 29.00 with a range of 180 to 320.

A Pearson correlation analysis to ascertain statistical significance and strength of the relationship between Scattered radiation reaching the breast with age revealed that, there was no significant between scatter radiation and age ($p=0.767$), while there was a weak relationship with a Pearson correlation coefficient of 0.039 ($r=0.039$).

Similar findings were seen between scatter radiation with BMI (where the $p=0.975$ and $r=0.004$), showing no statistical significance and weak relationship (**Table 4**). The scatter plots show uneven distribution along the midline between age and breast effective doses as well as BMI and breast effective dose as shown in **Figure 2** and **3**.

A comparison of means for scattered radiation reaching breasts from antero-posterior and lateral dimensions was done using paired sample t-test. Results indicate that there was no significant difference in mean (**Table 5**). This is an indication that the direction of scattered radiation didn't influence the ESD.

As shown in table 6, the mean dose to the breast in the index study when compared with other related studies revealed that the result obtained in the present study was higher than that obtained in Slovenia, and United Arab Emirates (**Table 6**).

A One-Sample t-test shows that there was no statistically significant difference in the mean dose to the breast among the 4 studies that were compared ($P=0.224$).

The lifetime risk of cancer incidence in this study was 4.5×10^{-4} and 5.2×10^{-4} (for HPA and ICRP 103 report respectively). When compared to the Health Protection Agency (HPA) and the ICRP 103 report, the risk was 1 in 2,155.56 for HPA and 1 in 2,153.85 for ICRP 103 report as demonstrated in **Table 7**.

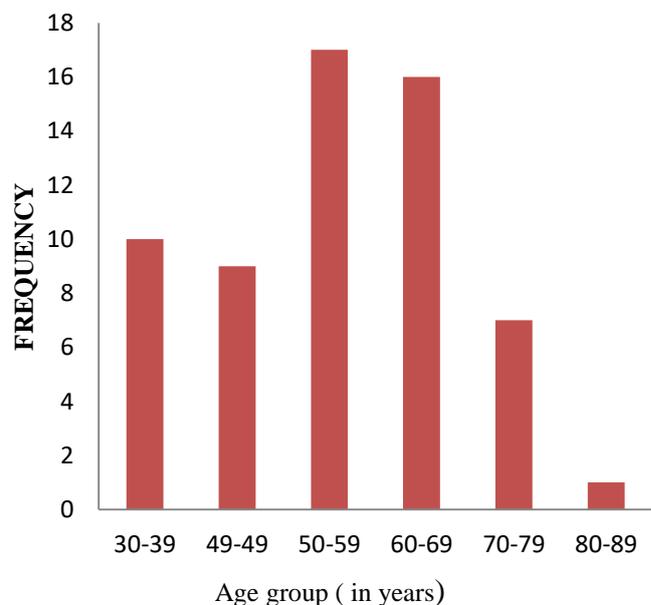


Figure 1: Age group distribution of participants

Table 1. Device specification

Mobile Radiography Device specifications	
Manufacturer	STEPHANIX
Type	Mobile Unit
Serial Number	8K1545
Machine Model	MOVIX 16 E ⁺
Power Capacity	32kW
kVp Range	40-150kVp
mAs Range	0.1-500mAs
Maximum Current	3.5-1.6A
Total Filtration	3.3mmAl
Focal Spot	1.0/0.3
Total Filtration	3.3mmAl
Line Voltage	110-240V
Phase	1, 50/60Hz
Target	Tungsten
Manufactured Date	September 2018

Table 2: showing the distribution of age BMI and ESD following age group classification.

Age Group	Frequency (N)	Age (Years)	BMI	Esdose (Mgy)
30-39	10 (16.67%)	35.90±3.04	28.66±4.95	3.76±0.74
49-49	9 (15%)	44.89±3.10	31.78±5.12	3.93±0.68
50-59	17 (28.33%)	55.76±2.56	31.65±8.87	3.62±0.97
60-69	16 (26.67%)	63.94±3.19	30.42±6.38	4.20±0.95
70-79	7 (11.67%)	72.14±2.67	23.24±5.67	3.70±0.80
80-89	1(1.67%)	80.00±0.00	22.10±0.00	4.67±0.00
TOTAL	60 (100%)	55.32±12.35	29.70±7.09	3.87±0.87

Table 3: Showing the minimum, maximum, Mean and Standard error of variables

Variable	n	Min	Max	Mean ± SD	SE Mean
Age (years)	60	31	80	55.30 ± 12.40	1.60
Weight (kg)	60	42	146	79.30 ± 20.00	2.60
Height (m)	60	1.45	1.77	1.61 ± 0.10	0.01
BMI (kg/m ²)	60	13.5	58.5	30.00 ± 7.10	0.92
ESD AP (mSv)	60	1.02	3.61	2.20 ± 0.70	0.09
ESD Lat (mSv)	60	1.02	2.80	1.70 ± 0.40	0.05
ESD Total (mSv)	60	2.22	5.73	3.87± 0.87	0.11
kVp AP	60	68	88	77.00 ± 4.00	0.52
kVp Lat	60	70	86	78.00 ± 4.00	0.53
mA AP	60	180	320	236.00 ± 29.00	3.80
mA LAT	60	175	320	214.00 ± 31.00	4.00
mAs AP	60	40	80	48.00 ± 9.00	1.20
mAs Lat	60	35	80	58.00 ± 10.00	1.32

Table 4: Showing Pearson Correlation of Scattered radiation with age and BMI

	Correlation	AGE	BMI	ESD
AGE	Pearson Correlation	1	.005	.039
	Sig. (2-tailed)		.967	.767
	N	60	60	60
BMI	Pearson Correlation	.005	1	.004
	Sig. (2-tailed)	.967		.975
	N	60	60	60
ESD	Pearson Correlation	.039	.004	1
	Sig. (2-tailed)	.767	.975	
	N	60	60	60

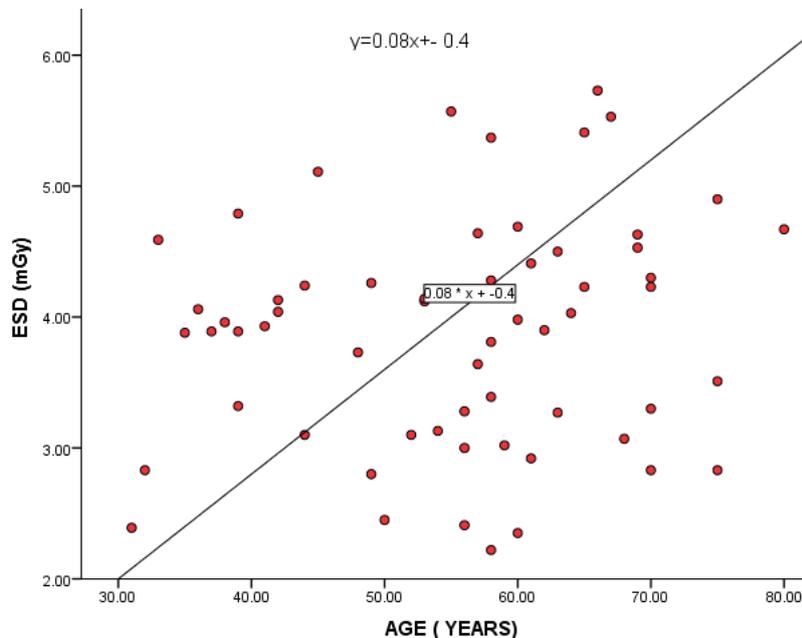


Figure 2: Scatter plot showing the distribution of scatter radiation reaching the breast in relation with age.

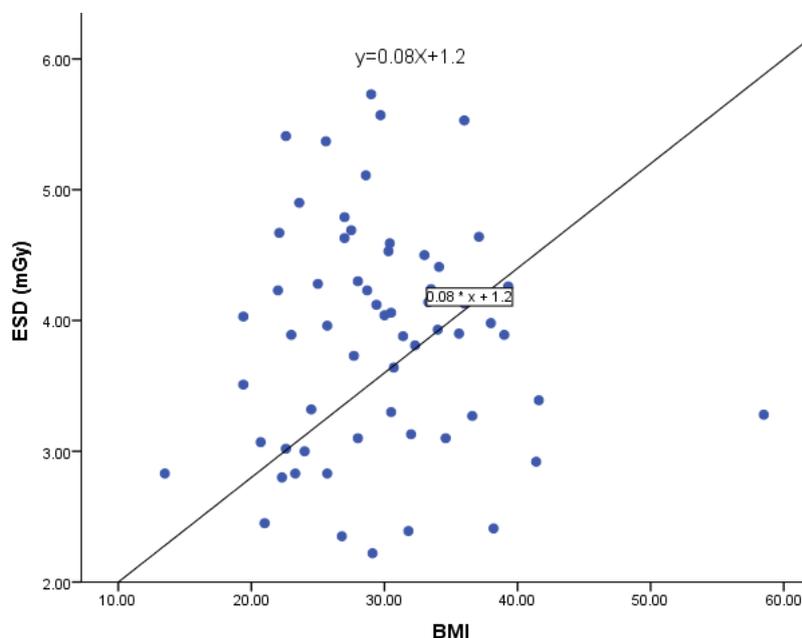


Figure 3: Scatter plot showing the distribution of scatter radiation reaching the breast in relation with BMI

Table 5. An independent sample t test to compare mean difference in scatters to breasts in AP and lateral dimensions

	Position	N	Mean ± SD ESD (mSv)	t (Statistics)	p	Remarks (Distribution)
Independent Sample T-test	AP	60	2.20 ± 0.70	0.738	0.462	No significant difference exists
	Lateral	60	1.70 ± 0.40			

Table 6. Comparison of this study mean breast dose with other studies

Authors	Year	Detector/Patient type	Location	Mean ESD ± SD (mGy)
Present work	2020	TLD/Real patients	Nigeria	3.87± 0.87
Mekis et al	2013	TLD/Phantom	Slovenia	0.36± 0.13
Elshami et al	2020	*Solid state /Phantom	UAE	0.0008± 0.0003
Jecl et al	2015	**Solid state/Phantom	Slovenia	0.35±0.37

*The solid state detector used was a Piranha (RTI electronic AB, Sweden), ** solid state detector used was Unfors (Raysafe AB, Sweden)

Table 7. Lifetime risk of cancer incidence for the breast based on HPA and ICRP report

Report	lifetime risk of cancer incidence (%per Sv)
This study	4.5×10^{-4}
HPA (UK)	0.97
This study	5.2×10^{-4}
ICRP 103	1.12

DISCUSSION

Ionizing radiation exposure to the breast following radiographic investigation may vary significantly with reference to the type of examination, exposure factors, and patient habitus. The index study estimated scatter radiation doses to the breast from lumbar-spine X-ray examination (AP/lateral) using TLD chips was conducted using 60 participants. The mean (\pm SD) age of participants was 55.32 ± 12.35 years and the majority of the participants are within 50-59 years. One of the commonest investigations for patients presenting with low back pain (LBP) is the lumbosacral spine radiography (18). It can then be deduced that LBP is relatively commoner among patients within age group 50-59 years. This is closely in accordance with the finding in the study to assess various lumbosacral spine abnormalities which revealed that the peak incidence of low back pain (LBP) was in the fourth and fifth decade of life (19). The mean (\pm SD) scatter radiation reaching the breast was 3.87 ± 0.87 mGy but the lowest amount of scatter radiation was demonstrated among the age group 50-59 years (3.62 ± 0.97 mGy). This finding is higher than the values obtained by Mekis et al (20) where the ESD without a lead shield was 0.45 ± 0.25 mGy and 0.26 ± 0.14 mGy on the right and left breasts respectively. Factors like the type of the detector, FFD and field size may have contributed to the difference in variation. The index study is a real patient evaluation while the study by Mekis et al (20) was a phantom study. This may have caused the significant difference seen which is characterized by the scatter properties of both media (real patient and phantom). According to the International Commission on Radiological Protection (ICRP, 2017) (9), there is up to 30-40% in dose variation and uncertainty with the use of phantoms.

In another study to evaluate the efficacy and feasibility of breast shielding during abdominal fluoroscopic examinations with sixty-six women revealed that the mean radiation to the skin of the unshielded breast was 119 mR which is equivalent to 1.19 mGy (21). The value in their study (21) is also higher than that of the index study. The variation may be attributed to the kind of examination, the field of view and the exposure factors used. The mean dose to the breast in the index study when compared with other related studies also revealed that the result obtained in the present study was higher than that obtained in Slovenia and United Arab Emirates (20-23). A One-Sample t-test shows that there was no statistically significant difference in the mean dose to the breast among the 4 studies that were compared ($P = 0.224$).

The mean ESD (\pm SD) for the antero-posterior (AP) and lateral (Lat) views were 2.20 ± 0.70 mGy and 1.70 ± 0.40 mGy respectively. A comparison of means for scattered radiation reaching breasts from antero-posterior and lateral dimensions was done using paired sample t-test. Results indicate that there was no significant difference in mean.

This is an indication that the direction of scattered radiation didn't influence the ESD. The variation in ESD for lumbosacral X-ray for AP and lateral views was 18%, this was lower compared to a study by Elshami et al, 2020 (22), where the variation in ESD from cervical X-ray for AP and lateral positions was 34%. The reason for the difference may be due to the type of examination where their study (22) is cervical spine radiograph while the index study was a lumbosacral spine. It may also be attributed to the type of detector, FFD and field sizes that were used for the study.

There was no significant statistical relationship but there was a weak correlation between scatter radiation and age as well as scatter radiation and BMI, which was also evident by the uneven distribution in the scatter plot. The lifetime cancer risk in this study was compared to the Health Protection Agency (HPA) and the ICRP 103 report. The risk from this study was 1 in 2,155.56 for HPA and 1 in 2,153.85 for ICRP 103 reports. The study was subject to some limitation such as sizes of the breast, and only one breast was evaluated instead of the two, the exact mid-point of the breast could not be ascertained, and the field size for individual examination was not recorded. Notwithstanding the limitations, the study shows that there were scatter radiations to the breast during lumbosacral X Ray investigation.

CONCLUSION

The study shows that there were scatter radiations to the breast during the lumbosacral X-Ray investigation. The lowest amount of scatter radiation was demonstrated among the age group 50-59 years. The study also revealed that there was no difference in ESD when the patient lies in AP and lateral positions. The cancer risk was approximately 1 in 2,155 indicating that there might be a need to shield the breast while performing lumbosacral X-ray.

Recommendations: Based on the findings and conclusion from this study, the study recommends that patient bio-data and machine parameters should be properly documented for every procedure. This will ensure a dose audit and any point in time. The use of protective devices for lumbosacral X-ray is necessary as this will reduce the amount of radiation that reaches the breast with the need to optimize the lumbosacral protocol to reduce patient doses.

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Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all participant individuals and their spouses included in the study.

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Ethical issues: All authors declare originality of research.

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