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Re-evaluation of the radiation safety at the teletherapy unit of the Korle Bu Radiotherapy Center, Accra, Ghana.

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Abstract

Background: The radiotherapy unit of the Korle-Bu Teaching Hospital, Accra, Ghana uses a GWGP-80 cobalt-60 teletherapy machine. On the beam-off position, leakage radiation around the radiation head must not exceed 200μSv/h at five centimetres from the surface of the radiation head or 10μSv/h at one meter from the radiation source.

Purpose of study: To evaluate the radiation safety at the radiotherapy center by comparing the measured scatter dose rates with standard recommendations.

Method: Instantaneous dose rates were randomly measured in the treatment room, treatment control console room and the lobby between the treatment room and treatment control console room in both vertical and horizontal planes. Measurements of dose rates in the treatment room were taken at the beam-off position while those in the control console room and the lobby were taken at the beam-on position. The distances from a reference point to the points of measurement were also taken. The data were analysed using Microsoft Excel 2007 spread sheet.

Results: The instantaneous dose rate in the treatment room ranged from 0.1μSv/hr -95.0μSv/hr and 0.1μSv/hr-100μSv/hr in the horizontal and vertical planes respectively. In the control console room, the range was 0.2μSv/hr in the horizontal plane and 0.1μSv/hr in the vertical plane. The range at the lobby between the treatment room and the control console room was 1.0μSv/hr in the horizontal plane and 1.5μSv/hr in the vertical plane.

Conclusion: The scatter of gamma radiations in the treatment room (at the beam-off position), the treatment control console room and the lobby between the treatment room and the control console room (at the beam-on position) were found to be below the recommended dose rate limit.

Keywords

collimator, gamma radiation, cobalt, isotope

Introduction

Radiotherapy plays a major role in cancer management. It is estimated that 50% of all cancer patients receive radiotherapy as a primary treatment, or in combination with other treatment modalities either for cure or palliation [1, 2]. Maximizing radiation dose to tumour cells whilst ensuring minimal dose to normal tissues and ensuring the safety of the health personnel is one of the central focuses of radiotherapy. X-rays, gamma rays, and charged particles are types of radiation used for cancer treatment. Both x-rays and gamma rays are electromagnetic radiation or photons. The only difference between the two is their origin. X-ray radiation for cancer treatment may be produced by a linear accelerator or by a high-energy x-ray unit. High-energy electrons are fired into a target metal, such as tungsten or tantalum. Gamma rays occur during the nuclear transitions or radioactive decay of some radioactive material, such as cobalt-60. The action of either x-rays or gamma rays is to remove electrons from atoms and break the bonds that hold compounds together. When the deoxyribonucleic acid (DNA) bonds are broken, cell deaths can result. Additionally, damage can occur to other cellular compounds that are equally important for the survival and reproduction of the cell line. The killing of the cells in the tumor eventually leads to its destruction [3-5].

The Radiotherapy Center at the Korle-Bu Teaching Hospital, Accra, Ghana uses gamma radiation. The gamma radiation is produced by a single source GWGP-80 cobalt-60 isotope with a half-life of 5.26 years. The maximum activity of the source is 259 TBq (terabecquere) (7000 curie {Ci}) and the maximum output at one meter (m) is 1.50Gy/min [6]. The cobalt-60 source is stored in two heavy metal blocks for shielding the gamma beam while the machine is in the off-position [7].

At the storage position, the cobalt-60 source still undergoes decay and possibly some gamma radiation leakage. From a safety point of view, when the radiation source is in the beam-off position the dose rate, due to leakage radiation around the radiation head, must not exceed 200μSv/h at a distance of five centimetres (cms) from the surface of the radiation head or 10μSv/h at a distance of one metre from the radiation source [8, 9].

The radiation from the source is also scattered by materials in its path of travel including the collimator, tray, block, patient, etc [10].The scattered photons have energiesclose to that of the incident beam [2, 11, 12]. This scattering involves the divergence of the exit beam in all directions [13] and this explains the importance of estimating the scatter dose at various locations in the treatment room [2, 12].

The harmful effects of x-rays that were detected in early radiation workers due to overexposure to radiation [14-17] have resulted in a lot of irrational fears among people, especially radiation therapists [18, 19]. This notion is reflected in the attitude of the radiation therapists at the Korle-Bu Radiotherapy Center as their perception is that the cobalt-60 source produces significant leakage and scatter doses when the source is in the off-position. There is no empirical evidence to support this assertion, however. This situation therefore creates apprehension among radiation therapists during patients' treatment set-ups which could lead to human error with its adverse radiobiological effects on the patients [19].

Purpose of the study

During the commissioning of the cobalt-60 teletherapy machine at the National Radiotherapy Center, Korle Bu, Accra in 1999 safety aspects of the equipment were assessed and were found to have met acceptable standards. A decade of continuous usage of the machine and a source replacement in 2007. Since the machine is old with loose head casing joints, has necessitated a re-evaluation of the radiation safety by comparing the measured scatter dose rates with acceptable dose limits so as to guarantee the safety of the radiation therapists and the patients [2, 20].

Instrumentation and method

The instantaneous dose rate measurements taken with a mini-rad 1000 survey metre at specified positions in the horizontal and vertical planes are presented in Tables 1 to 7. Data obtained are presented in several figures below. Locations around the machine, the control console and the lobby between the treatment room and the control console were randomly selected for instantaneous dose rate measurement (see Figures A to D). The distances from chosen reference points to the specified positions were also ascertained with a tape measure. In the treatment room, the reference point was the center of the collimator. The center of the door to the maze and the door to the control console room were the reference points for the measurements at the lobby and control console room respectively. These locations are positions where the radiation therapists are usually found while in the working area.

Instrument specifications of the mini-rad survey meter:

- Type: MFGO31A
- Serial Number: 999
- Calibration Certificate Number: 10816
- Can measure background radiation up to 500μSv/hr
- Sensitivity: 0.045-2.5

Results

As shown in Figure E the measurement in the horizontal plane ranged from 95.0μSv/

Table 1: Measured dose rates at some non randomly selected areas in the treatment room.

LOCATION	DOSE RATE (μSv/hr)		DISTANCE (m) FROM THE CENTRE OF COLLIMATOR
	Horizontal Plane	Vertical plane	
A	10.0	10.0	0.31
B	3.0	3.5	0.33
C	2.0	2.1	0.38
D	0.2	0.1	2.00
E	2.5	2.0	0.31
F	4.0	4.0	0.24
G	9.0	8.0	0.34
H	5.0	5.0	0.60

Table 2: Measured dose rate at some randomly selected areas in the treatment room.

LOCATION	DOSE RATE (μSv/hr)		DISTANCE (m) FROM THE CENTRE OF COLLIMATOR
	Horizontal Plane	Vertical plane	
Q	0.2	0.2	2.85
R	3.0	3.0	0.12
S	0.1	0.1	2.55
T	0.2	0.1	2.45
U	95.0	100.0	0.21
V	0.2	0.1	1.66
W	0.7	0.6	1.93
X	0.2	0.2	2.15
Y	0.3	0.5	1.85
Z	0.1	0.2	1.88

Table 3: Measured dose rates in the control console room.

LOCATION	DOSE RATE (μSv/hr)		DISTANCE (m) FROM THE CENTRE OF COLLIMATOR
	Horizontal Plane	Vertical plane	
A	0.1	0.1	1.15
B	0.1	0.2	1.47
C	0.3	0.2	2.57
D	0.2	0.2	2.8
E	0.1	0.2	1.98
F	0.1	0.1	2.55
G	0.3	0.2	0.2
H	0.1	0.1	1.66
I	0.1	0.1	0.59
J	0.1	0.1	0.5

Table 4: Measured dose rate in the controlled area.

LOCATION	DOSE RATE (μSv/hr)		DISTANCE (m) FROM THE CENTRE OF COLLIMATOR
	Horizontal Plane	Vertical plane	
ii	2.0	2.5	0.51
iii	1.5	1.0	0.66
iv	0.7	1.5	1.20
v	1.5	1.0	2.00
vi	1.0	1.0	2.98
vii	1.5	1.5	1.80
viii	2.0	2.5	0.87
ix	1.5	1.5	1.39
x	1.0	0.8	2.19
xi	1.0	1.0	2.29

Table 5: Inter comparison of measured dose rates in the treatment room and acceptable dose rates.

LOCATION	DOSE RATE (μSv/hr)		ACCEPTABLE DOSE RATE (μSv/hr)
	Horizontal Plane	Vertical plane	
A	10.0	10.0	7.5
B	3.0	3.5	7.5
C	2.0	2.5	7.5
D	0.2	0.1	7.5
E	2.5	2.0	7.5
F	4.0	4.0	7.5
G	9.0	8.0	7.5
H	5.0	5.0	7.5
Q	0.2	0.2	7.5
R	3.0	3.0	7.5
S	0.1	0.1	7.5
T	0.2	0.1	7.5
U	95.0	100.0	7.5
V	0.2	0.1	7.5
W	0.7	0.6	7.5
X	0.2	0.2	7.5
Y	0.3	0.5	7.5
Z	0.1	0.2	7.5

Table 6: Inter comparison of measured dose rates at the control console room and acceptable dose rates.

LOCATION	DOSE RATE (μSv/hr)		ACCEPTABLE DOSE RATE (μSv/hr)
	Horizontal Plane	Vertical plane	
A	0.1	0.1	7.5
B	0.1	0.2	7.5
C	0,3	0.2	7.5
D	0.2	0.2	7.5
E	0.1	0.2	7.5
F	0.1	0.1	7.5
G	0.3	0.2	7.5
H	0.1	0.1	7.5
I	0.1	0.1	7.5
J	0.1	0.1	7.5

Table 7: Inter comparison of measured dose rate in the controlled area and the acceptable dose rates.

LOCATION	DOSE RATE (μSv/hr)		ACCEPTABLE DOSE RATE (μSv/hr)
	Horizontal Plane	Vertical plane	
ii	2.0	2.5	7.5
iii	1.5	1.0	7.5
iv	0.7	1.5	7.5
v	1.5	1.0	7.5
vi	1.0	1.0	7.5
vii	1.5	1.5	7.5
viii	2.0	2.5	7.5
ix	1.5	1.5	7.5
x	1.0	0.8	7.5
xi	1.0	1.0	7.5

hr to 0.1μSv/hr while those in the vertical plane ranged from 100μSv/hr to 0.1μSv/hr. Apart from location *U* (0.21m, QI) which recorded an unusually high dose rate in both planes, the range of dose rates in the horizontal and vertical planes for other locations was 9.9μSv/hr. It was noticed that locations within a radius of 38 cms from the center of the collimator recorded dose rates ranging from 2.5μSv/hr to 10.0μSv/hr. However, locations A (0.31m, QII) and G (0.34m, QI) were found to record readings above the acceptable dose rate limit of 7.5μSv/hr with location A (0.31m, QII) recording 10.0μSv/hr in both planes and location G (0.31m, QI) recording 9.0μSv/hr in the horizontal plane and 8.0μSv/hr in the vertical plane.

Figure F compares the IDR measured in the lobby and that of acceptable dose rate limit. The range of dose rates in the horizontal plane was 0.2μSv/hr while that in the vertical plane was 0.1μSv/hr. This means that the shielding in the lobby was adequate as the range of the IDR measured was less than 0.5mSv/hr [21].

Discussion

The property of a scattered beam is phenomenal and its resultant geometry after scattering is different from the primary beam. The photons of the scattered beam move in different directions [8] thus the instantaneous dose rate (IDR) measurements were taken in the horizontal and vertical planes. An individual who stands at locations A (0.31m,QI) and G (0.34m,QI) while the beam is off will be receiving high doses of scatter radiation close to 10.0μSv/hr which is above acceptable dose rate limits. This could be avoided by standing alongside of the couch at these locations [22, 23] which could reduce the dose rate received to a lower value of about 0.2μSv/hr to 0.7μSv/hr as proved by the IDR measured at locations w (1.93m,QII) and x (2.15m,QI). Furthermore, with a growing number of patients treated daily on average of 50 [21] as opposed to about twenty patients estimated before the commissioning of the unit [6] gives clear evidence of a higher workload on the machine. This factor has contributed to the loose joint of the cobalt-60 head casing. Additional factors, such as the number of patients treated per day, the prescribed dose rate and the time used for treatment also affect the workload [8, 24]. In view of the current state of the cobalt-60 machine, after several years of continuous usage, measures to replace the old ma-

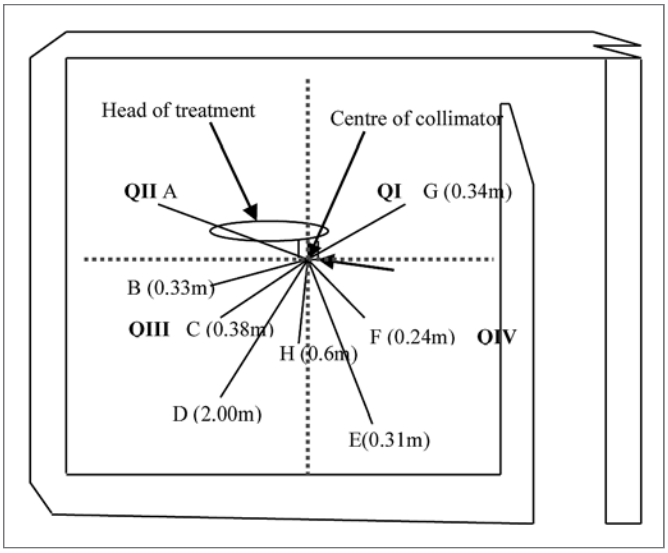

Figure A: *Treatment room*

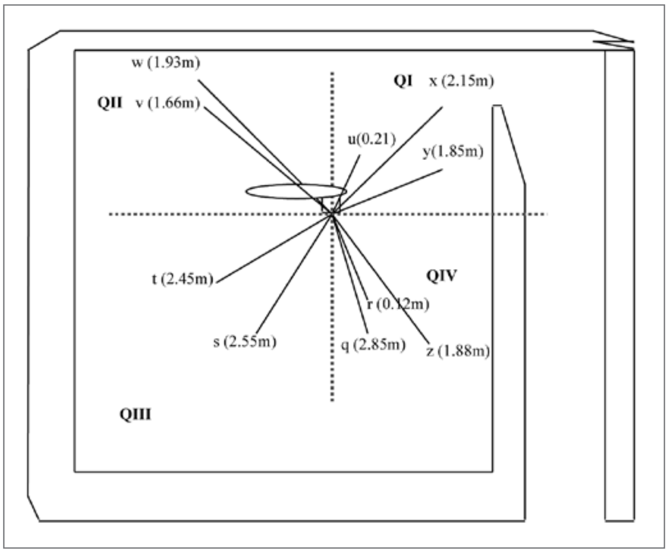

Figure B: *Treatment room*

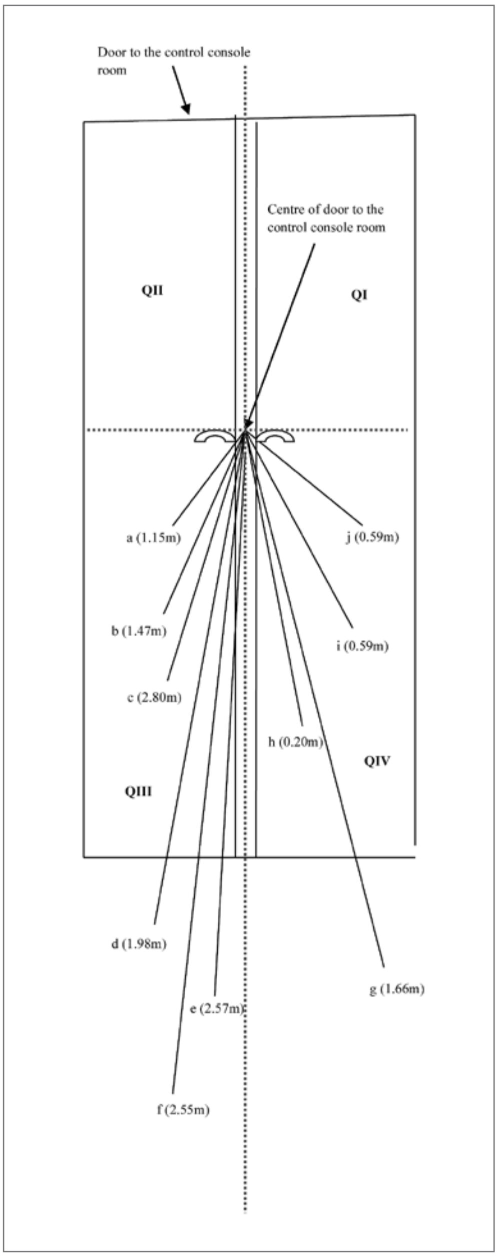

Figure C: *Control console room*

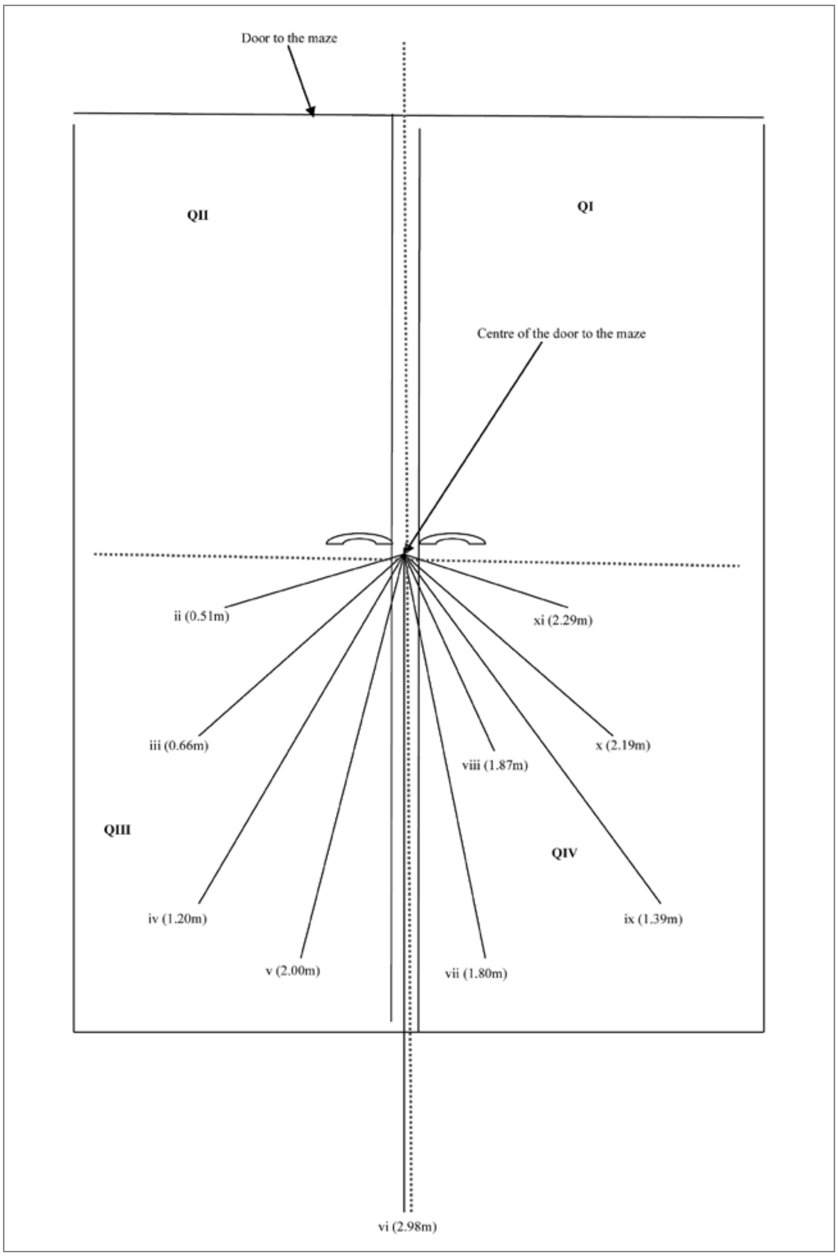

Figure D: *Lobby*

chine or replace the casting head are essential. Location *U* (0.21m, QI) on Figure E recorded a high dose rate of 100µSv/hr in the vertical plane and 95.0µSv/hr in the horizontal plane. This reading is significantly higher than the recommended dose rate limit of 7.5µSv/hr. This location is very close to where the optical distance indicator (ODI) is found on the machine head. This part may not be properly shielded and would need remedial action to be taken to correct the situation to make it safe for the radiation therapists, especially when they have to get closer the source to fit the beam splitter for half-beam set-up *U* (0.21m, QI).

Assuming a radiation therapist spends one hour in the treatment room every day for treatment set-up and considering that s/he spends this time at location A on Figure F (0.31m, QI), then,s/he might be receiving a total dose of 2.6mSv/annum. At location *G* (0.34m, QI), such a person might receive a dose ranging from 2.1mSv/annum and then at location *U* (0.21m, QI), a dose ranging from 24.7mSv/annum to 26.0mSv/annum.

These doses are likely to be received by the head (lens of eye, brain), neck (thyroid) or chest (lungs) depending on the height of the staff. Comparing these estimated doses with the tolerance dose of the above named organs, these estimated doses are below the tolerance of these organs and as such any radiation effect to staff would be probabilistic [1]. These readings are below the recommended dose rate limit of 7.5µSv/hr. This is consistent with the study by Emi-Reynolds and Kyere [6] who confirmed the shielding of the treatment as adequate.

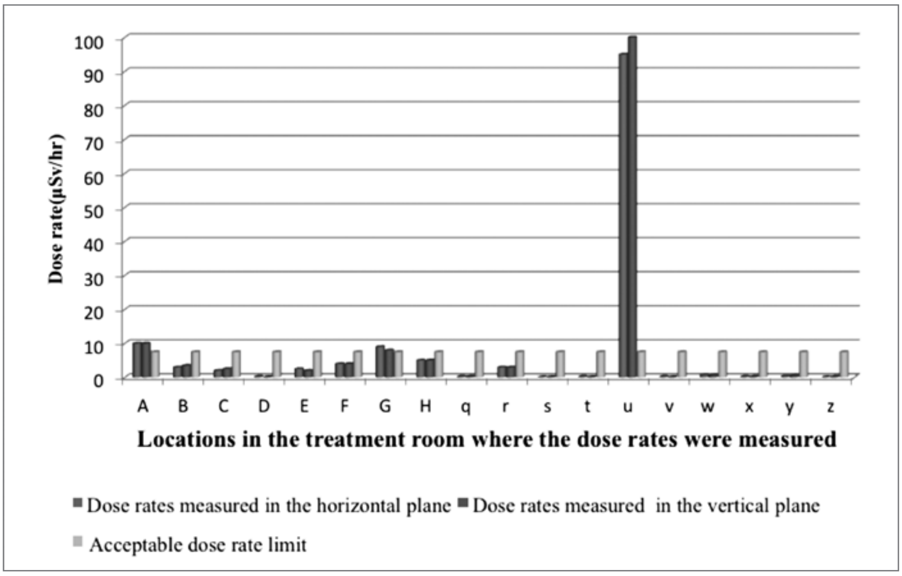

Figure E: *Comparing the measured dose rates in the treatment with the acceptable dose limit.*

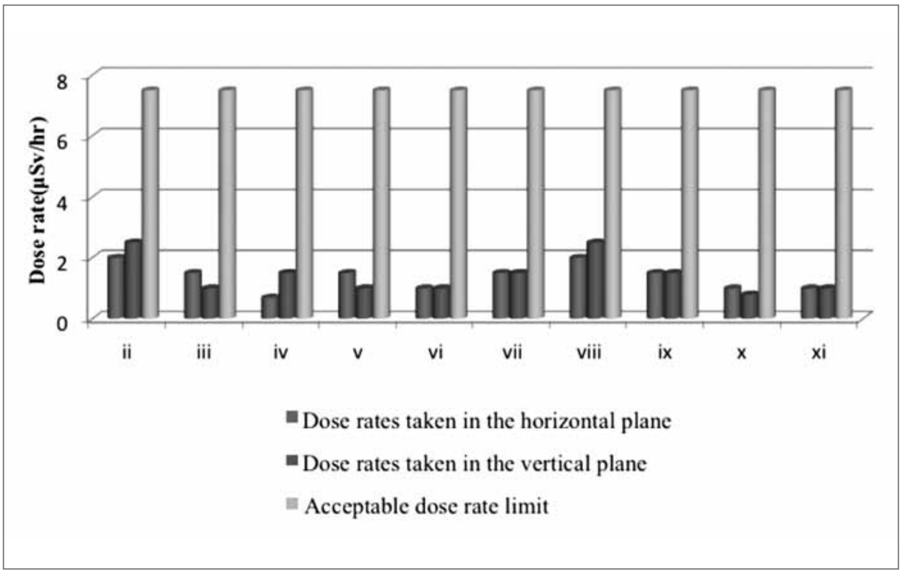

Figure F: *Locations in the lobby where the dose rates were measured.*

Conclusion

The line of weakness for protection of staff and patients in the study was found along the point where the optical distance indicator is fitted and where the head casing is joined. The critical locations were found to be around A, B and U on Figure E. It is suggested that the machine head casing should be reassessed and repaired or changed to ensure adequate shielding.

Generally, it was found that the safety of the cobalt-60 teletherapy machine is assured. The biological shielding provided protection for staff when the beam is in the off-position [25]. The scatter of gamma radiations in the treatment room (at the beam-off position), the treatment control console room and the lobby between the treatment room and the control console room (at the beam-on position) were found to be below the recommended dose rate limit.

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