

## Total body irradiation when the source of radiation is horizontal on the patient (phantom)

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### Abstract

**Background:** Medically administered total-body irradiation, (also known as whole- body radiation), involves the use of external radiation sources that produce penetrating rays of energy to deliver a relatively uniform amount of radiation to the entire body. TBI can be done any for to suppress the patient's immune system and prevent rejection of donor-bone marrow after a bone marrow transplant using donor marrow (from some one other than the patient).

**Objective:** using new technique for body irradiation to serve total body irradiation (TBI) (the radiation will be covered the whole body) and detect time and dose of required exposure by using a phantom (it is a material like a human tissue), When The source of radiation was used in horizontal position on the phantom.

**Materials & Methods:** The source of radiation, obtained from  $^{60}\text{Co}$  available in Hospital of Radiotherapy and Nuclear Medicine in Baghdad. Thimble Chamber: It is an instrument employed in measurement of the ionizing radiation. Phantom: Data on dose distribution are almost entirely derived from measurements in phantoms (tissue equivalent materials)

**Results:** This technique is easily applied with less expenditure and the radiation will be covered the whole body, but here because of large distance between the patient and source of radiation, the dose rate is small so we need more time to give the prescribed dose. The max. Field size of radiation that we get is (150cm x 150 cm) and because the average length of Iraqi adult is 170 cm, therefore the patient should bend his knee in order to be totally within the field size.

**Conclusion:** Recommend for future study on (Gamma – Ray in horizontal position) which might be more effective than vertical position in case, they use (acceleration device) that device will increase dose rate which result to reduce time of exposure to radiation.

### الخلاصة

**المقدمة:** طبياً تشعيع الجسم الكلية تتضمن استخدام مصدر خارجي للإشعاع الذي ينتج طاقة إشعاع مخترقة لتوليد كمية منتظمة نسبياً من الإشعاع لكامل الجسم .

تشعيع الجسم الكلية ممكن ان يتم نتيجة لواحد من إحدى الأسباب الآتية :

1. قمع (وقف عمل ) الجهاز المناعي للمريض بحيث لا يرفض نخاع العظم للمتبرع بعد عملية زرع نخاع العظم باستخدام نخاع المتبرع

2. تشعيع موضعي للجسم لقتل الخلايا الغير طبيعية التي نجت من معالجات اخرى مثل الجراحة أو العلاج الكيماوي .

3. تشعيع الجسم الكلية تستخدم كشرط من شروط زرع نخاع العظم لمعالجة العديد من الحالات الخبيثة

**الهدف:** تصميم تقنية جديدة لتشعيع الجسم لخدمة تشعيع الجسم الكلية (تشعيع الجسم بشكل تام) و تحديد وقت و جرعة التعرض المطلوبة باستخدام الفانتوم ( مادة تشبه النسيج البشري ) , (وعندما مصدر الإشعاع تكوم بشكل أفقي على المريض) (الفانتوم)

**المواد وطرق البحث:**

• مصدر للإشعاع و حصلنا عليها من  $^{60}\text{Co}$  المتوفرة في مستشفى الإشعاع و الطب النووي في بغداد

- كاشف Thimble Chamber : و هو جهاز يقيس التأين الإشعاعي
  - المعلومات أو البيانات على توزيع الجرعة غالباً يستمد من قياسات داخل الفانتوم ( مادة مكافئة للنسيج )
- النتائج:** هذه التقنية سهلة التطبيق مع كلفة اقل و يغطي الإشعاع جسم المريض و لكن بسبب بعد المسافة بين المريض و مصدر الإشعاع , لذا تكون معدل الجرعة صغيرة لهذا نحتاج إلى وقت أكثر لإعطاء الجرعة الموصوفة و أقصى مجال مساحة تشعيع للجسم حصلنا عليها (150cm x 150 cm) لذا المريض يجب أن يحني ركبته لكي يكون ضمن مجال التشعيع ( لان معدل طول المواطن العراقي 170cm)
- الاستنتاج:** نوصي مستقبلاً بدراسة على أشعة كاما في الوضع الأفقي باستخدام جهاز التعجيل التي ربما هي أكثر تأثيراً من الوضع العمودي في حالة إذا استخدم ذلك الجهاز سوف يزيد معدل الجرعة و نتيجة لذلك تقلل زمن تعرض المريض للإشعاع.

## Introduction

Medically administered total-body irradiation, also known as whole-body radiation, involves the use of external radiation sources that produce penetrating rays of energy to deliver a relatively uniform amount of radiation to the entire body<sup>(1)</sup>.

Radiation can penetrate all areas of the body. This allows the treatment to reach cells even within scar tissue or deep recesses of the body that other agents such as chemotherapy drugs, which are injected into blood or orally , can not reach<sup>(3)</sup>.

Total body irradiation (TBI) combined with chemotherapy and bone marrow transplantation (BMT) can successfully treat disseminated malignancies. TBI is used prior to bone marrow transplantation to avoid the acute side effects of high-dose chemotherapy–and radiotherapy<sup>(1,4,5)</sup>.

Bone Marrow Transplantation (BMT) has been increasingly used to replace the Bone Marrow (BM) of patients with inborn errors of metabolism, malignancies, and chronic viral infections with hematopoietic progenitor cells from a healthy donor. BMT is also used to induce immunological tolerance to other transplanted organs<sup>(6,7)</sup>. In nearly all these clinical settings the recipient must be reconditioned by TBI before receiving BM graft. The dose to the core of the lungs must be reduced by partial shielding<sup>(8)</sup>.

The current study was conducted aiming to study the following; using new technique for body irradiation to serve total body irradiation (TBI) and detect time and dose of required exposure, when  $\gamma$ -ray was used in horizontal position on the phantom.

## Materials and methods

1- Cobalt-60 unit: It is device which emits  $\gamma$  - rays at 1.17 Mev and 1.33 Mev. And has a high specific activity. The half – life is relatively short (5.26 yr), so that treatment times to be increased by about 1% per month to correct for the decay. It is of course impossible to switch off the gamma emission from the cobalt-60, so that some means of interrupting the beam must be provided. The source is mounted within a massive head, which is made from lead and depleted uranium. This head will weight about one ton for a 5000 ci source of cobalt-60 sec<sup>(9)</sup>.

Co-60 device components<sup>(10)</sup>: This device we used present in hospital of radiotherapy and nuclear medicine of Baghdad, fig 1.

2- Phantom (materials like tissue): It is seldom possible to measure dose distribution directly in-patients treated with radiation. Data on dose distribution are almost entirely derived from measurements in phantoms tissue equivalent materials, usually large enough in volume to provide full scatter conditions for the

given beam <sup>(11)</sup>. The phantom we used is of Mixed D, Table (1) <sup>(11,12)</sup>.

3- **Thimble Chamber:** It is an instrument employed in measurement of the ionizing radiation <sup>(13)</sup>.

Here we use thimble chamber when the chamber is exposed to radiation, electrons are generated in the thimble wall and produce ionization of the air in the thimble cavity <sup>(9)</sup>.

The negative ions are attracted to the positive central electrode and the positive ions are attracted to the negative inner wall. Ions are collected; the charge on the electrodes is reduced. The reduction charge is proportional to the exposure. The chambers are designated by the maximum exposure that can be measured <sup>(11)</sup>, figure 2.

• **Methods of total body irradiation when the beam source is horizontal on the phantom.**

Here the patient or (a phantom) is situated inside a large Co-60 irradiation field at a few meters distance (mainly 3.6m) from the source in such a position that the field (1.5 X 1.5 m<sup>2</sup>) totally envelops the patient. The most often-used beam direction is horizontal and patient is positioned on his or her side to make anterior – posterior irradiation and vice – versa.

In this method the source surface distance (SSD), the field size and the dose rate are constant so we study the effect of depth and thickness of a phantom on dose distribution first at the center then at corner.

From figures (3) & (4) these plot show that the dose rate (rad/min.) and percentage depths dose (%DD) as a function of field size (cm<sup>2</sup>) when distance equal 360 cm

- 1 Radiation head
- 2 Stand
- 3 Terminal plug and fuses
- 4 Bearing stip
- 5 Treatment couch
- 6 Shell
- 7 Beam limiting device (collimator)
- 8 Radiation head support arm

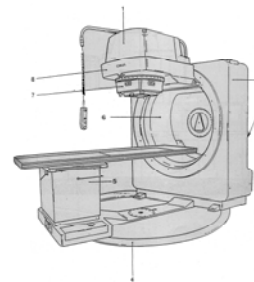


Figure 1. Co-60 device components <sup>(10)</sup>

Table 1.

Contents	Mas density g/cm <sup>3</sup>	Number of electrons g × 10 <sup>23</sup>	Photoelectric
Paraffin: 60.8	0.99	3.41	7.05
Polyethylene: 30.4			
Mgo: 6.4			
Tio <sub>2</sub> : 2.4			

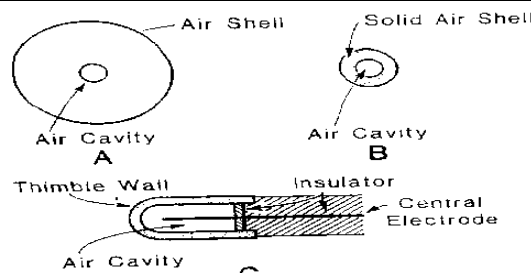


Figure 2. Thimble chamber <sup>(11)</sup>

## Results

A Phantom is situated inside a large Co-60 irradiation field at a few meters distance (mainly 3.6m) from the source from such distance we study :-

First: as shown table ( 1), when we increasing the field size of radiation ( Area of Radiation  $\text{Cm}^2$ ) on surface from  $16 \text{ Cm}^2$  gradually we increase the area to  $150 \times 150 = 22500 \text{ Cm}^2$ , we notice that the dose rate( absorbed Dose of Radiation  $\text{Rad/min.}$ ) increases with increasing of surface area when the distance is fixed between the patient and the source of Radiation (Gamma ray) in horizontal position.

Table 2. the effect of area of radiation(field size  $\text{cm}^2$  on dose rate distribution ( $\text{Rad/min.}$ ) on a surface of a patient

Area of radiation $\text{cm}^2$	16	25	49	100	400	900	1024	1296	1600	1936	2304	2704	3136	4096	5184	$22500 = 150 \times 150$
Dose rate (DR) on a surface( $\text{Rad/min.}$ )	4.64	4.68	4.87	5.13	5.67	5.98	6.03	6.16	6.25	6.3	6.35	6.43	6.49	6.59	6.74	7.14

Second :- as shown in table (2) we employed different depths inside the patient: from 5cm gradually to 20 cm , and from each depth, we increased the surface area of radiation (gradually increasing) from  $16 \text{ Cm}^2$  to  $22500 \text{ Cm}^2$ , when the distance remain stable between the patient and the source of radiation equals to 360cm distance .Also we noticed that the absorbance dosage of radiation (  $\text{Rad/min}$  ) decrease with increasing in depth nad the dosage increase within increasing of the surface are of radiation.

(Table 3) : the effect of depth inside a patient (cm) and area of radiation ( $\text{cm}^2$ ) on dose rate distribution ( $\text{Rad/min.}$ )inside a patient

depth of tissue(cm)	Area of radiation $\text{cm}^2$	16	25	49	100	400	900	1024	1296	1600	1936	2304	2704	3136	4096	5184	22500
	Dose rate (DR) ( $\text{Rad/min}$ )																
5		3.59	3.66	3.93	4.24	4.83	5.14	5.19	5.32	5.42	5.47	5.59	5.67	5.73	5.87	6.02	6.62
10		2.53	2.61	2.87	3.17	3.78	4.11	4.15	4.28	4.37	4.43	4.49	4.59	4.69	4.78	4.99	5.60
15		1.76	1.85	2.05	2.32	2.89	3.22	3.25	3.27	3.46	3.51	3.56	3.67	3.72	3.87	4.02	4.65
20		1.23	1.3	1.46	1.68	2.19	2.49	2.52	2.63	2.71	2.77	2.81	2.91	2.96	3.04	3.23	3.77

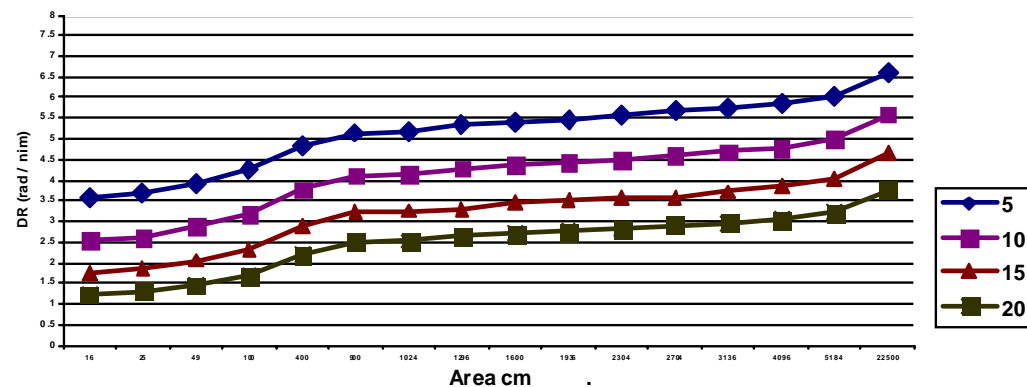


Fig 3  
Dose Rate distribution (rad/min.) at distance = 360 cm With different depths inside the patient

We notice in this datagram between absorb dosage (Rad/min) and area of radiation  $\text{Cm}^2$  for different depths inside the Patient, The upper curve represents the depth 5 Cm, the lower curve 10cm and the other less one 15 cm and the lowest curve represents depth 20 cm inside the patient also we notice from this figure absorb dosage decreases with the increasing depth inside the patient and increases with increasing of area of radiation.

Third

Table 4): representing ((% DD (depth dose) with increasing of depth cm . inside the patient

-:

depth of tissue(cm)	Area of radiation cm <sup>2</sup>	16	25	49	100	400	900	1024	1296	1600	1936	2304	2704	3136	4096	5184	22500
	%Depth dose(%DD)																
5		77.52	78.88	80.87	82.66	85.28	86.12	86.19	86.50	86.75	86.90	88.11	88.32	88.43	89.16	89.37	92.83
10		54.62	56.26	59.12	61.98	66.81	68.79	86.88	69.52	70	70.33	70.77	71.43	72.31	72.55	74.18	78.57
15		38.14	39.69	42.16	45.27	51.13	53.88	54	54.8	55.38	55.78	56.30	57.22	57.45	53.82	59.74	65026
20		26.66	27.86	30.02	32.9	38.67	41.67	41.91	42.75	43.47	44.07	44.43	45.39	45.63	46.23	48.04	52.84

We have formula %DD =:-

$$\% \text{ DD (depth dose) } = \frac{\text{Absorbed dose (Dose rate) at any depth}}{\text{Absorbed dose (dose rate) at a reference points (surface)}} \times \%100 \quad (11)$$

- We notice that if %DD when fix the depth inside the patient within increase in area of radiation in case the stable of depth and changing in surface area , % DD increase when decrease of surface area  
 -%DD when fixing of surface area and changing in depth inside the patient , in this case the stable of surface area and change in depth, %DD decrease the % DD decrease with increase of depth inside the patient .

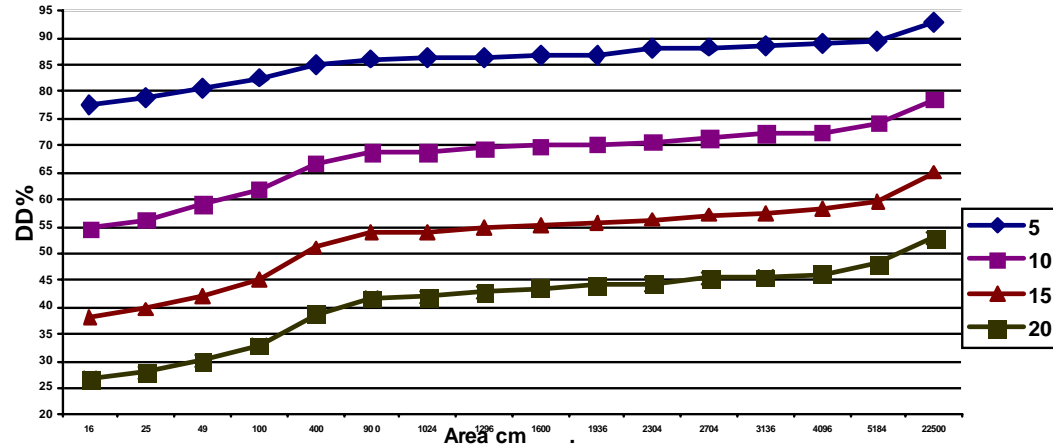


Fig 4. DD% at distance between source and patient = 360 cm with defrent depths inside a patient

Figure (4) represents the relation of %DD with area of radiation, the upper carve represents the depth 5cm , and the less is 10 cm and the less carve 15 cm and the lowest carve is 20 cm depth inside the patient . We notice that %DD increase within increasing in area of radiation when the depth is stable and %DD decrease when depth inside the patient increases when the area of radiation is fixed

## Discussion

✧ The dose rate (Rad/min.) and percentage depth dose(%DD) increase with increase of field size( $\text{cm}^2$ ) for each depth, as shown in table 3 and table 4, ( fig 3 and fig. 4).

So in order to get high dose rate we will increase the field size ( $\text{cm}^2$ ) when the distant between the patient and source is constant = 360 cm.

When the distance is 360 cm, the dose rate (Rad/min.) is greatly decreased and so we need more time for exposure the patient to radiation and because the inverse square law does not apply with large distances used in TBI due to wall and floor scatter contributions.

So in hospital of radiotherapy and nuclear medicine, the beam source is horizontal, the maximum field size that we obtained equal to 150 cm ×

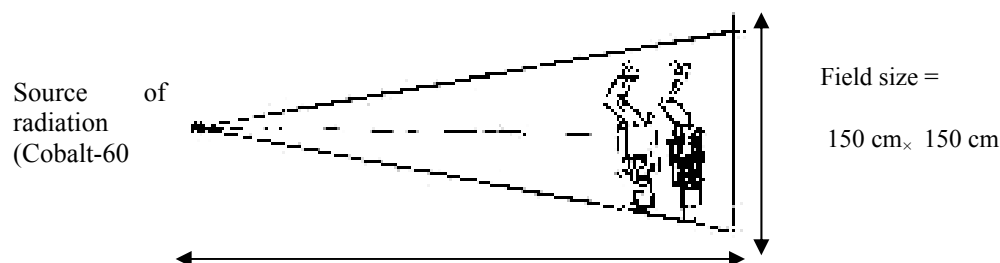
The distance between source and patient=360 cm

150 cm, because the average length of Iraqi adult is 170 cm, therefore the patient should bend his knee in order to be totally within the field size.

This technique is easily applied with less expenditure, but here because of large source surface distance, the dose rate is small so we need more time to give the prescribed dose and this will disturb the patient.

## Conclusion & Recommendations

Recommend for future study on (Gamma – Ray in horizontal position) which might be more effective than vertical position in case, they use (acceleration device) that device will increase dose rate which result to reduce time of exposure to radiation.



If the beam source horizontal, the field size that we get is (150cm x 150 cm) therefore the patient should bend his knee

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