Measurements of Electron Beam Dose Distributions in Perspex Block for Different Field Size

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Abstract. The linear accelerator is used in radiotherapy to treat tumors whether it was benign or malignant. The megavoltage electron beam is used to treat superficial tumors that do not exceed 5cm depth. In this work the dose distribution before irradiating the patient to check whether the prescribed dose is matched with the irradiated dose to help the physicist to fix the errors or deviations if it is detected. The quality assurance (QA) measured of electron beam with energy 12 MeV at common different depths and field sizes using StarTrack 2D detector and to ensure that it does not exceed the recommended limits. The equipped QA device is a StarTrack 2D detector under the linear accelerator infinity from Elekta at 100 cm from source-to-surface distance SSD. The tested energy 12 MeV at depths 0.5 cm and 1.5 cm for field sizes 6cm×6cm, 10cm×10 cm and 14cm×14cm as limits measured according to the International Electrotechnical Commissioning (IEC) protocols. Results show that the revealed an error in the output dose at 6cm×6cm and 10cm×10 cm field sizes for 1.5 cm depth but for 14cm×14cm field size at 0.5 cm depth, the dose found to be above the tolerance. Also it’s found that the output dose is highly reached to 1.5 cm depth than the 0.5 cm. Furthermore, all the rotation axis of the collimator are within the limits with a few noises in the signal at the inline and the crossline axis. We conclude that there was an error in the output does need to be recalibrated before irradiating the patients to electron beam therapy at 12 MeV to assure that the treatment is qualified and efficient.

Keywords: Field size, Output Dose, StarTrack, 12 MeV.

1. Introduction
In cancer treatment, radiation therapy is the primary non-surgical procedure. More than 50 % of patients undergo any care during malignancy management [1, 2]. Megavoltage electron beams have a limited range property and therefore do not provide large dose of radiation to distal depths. Therefore, electron beam therapy is ideal for low-lying (< 5 cm deep) tumors such as skin cancers, irradiation in the chest wall, and elevated exposure to the node. In general, electrons give dosage stability with a minimum dose of a distal organ in these goal volumes [3]. The linac linear accelerator is a significant instrument used to treat tumor, malignant or benign, for radiotherapy purposes [4]. Such parameters influence the dosage distribution of the central axis. These include beam quality or energy, width, size and structure, surface distance sources (SSD) and beam collimation [5, 6]. These include beam quality and energy. A software designed to track and sustain the quality level set out for this software is
defined in the word quality assurance (QA). The quality improvement policy is basically a collection of protocols and practices for ensuring the standard of patient treatment for radiation oncology. Generally, the basic requirements or quality levels are decided together by the profession. These requirements are required to be fulfilled by a QA curriculum uniquely developed by an institution [7]. It is often referred to as "the aspect of quality control that is based on ensuring that quality specifications are met or a structured protocol to ensure the reliability of a product or service [8, 9].

Lazim and Rejah et al [10] have evaluated the QA of the Linac in analyzing the used dose profile in the treatment of cancer tumors. The Star Track device was used for the routine quality assurance of the Linac, using a photon beam for the reference maximum dose or so called Dmax and source to the surface distance of 100 cm. they found out that the flatness and symmetry of beams for the reference field size did not exceed from ±2%, as they were within the allowed range.

The contrast and drawbacks of the usage of one Quality Management Mechanism, StarTrack, and Quality Control were analyzed by Boroto and April et al [11]. They stated that measurements were made with a water tank and that measurements were taken with StarTrack. There appear to be just a few common findings in the beam domain, meaning that further data collection can be confirmed. They conclude that the operation of the StarTrack and Omni-Pro Progress showed a strong contrast with performance and tolerances of the water tank.

This work aimed to test the high energy electron beam whether it could treat the patient by delivers the specified dose to the target and compared the dose difference between the planned and measure dose detected by StarTrack 2D array detector whether it is within the accepted limits of ± 2 cGy. And then to check that if the percentage dose delivered through the gantry rotation is within the accepted tolerance ± 2 % in inline, crossline, diagonal A, and Diagonal B axis.

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2. Materials and Method
This study was conducted from November 2019 to June 2020 in Baghdad center for Radiotherapy and Nuclear Medicine, Baghdad Medical City, Baghdad, Iraq. The linear accelerator (linac) used in this study is the Infinity manufactured by Elekta Company (Elekta Incorporation, Atlanta, GA). The energy of the electron beam used in this study is 12 MeV. The field size of the beam can be varied depending on the size of the treated target. The energies irradiated with field sizes: 6cm×6cm, 10cm×10 cm and 14cm×14cm. The device used for the quality assurance (QA) check is the StarTrack 2D array detector. It was designed and built-in cooperation with Torino University and INFN (Italy). StarTrack contains 453 vented pixel ionization chambers, simultaneous readout of all chambers' automatic pressure and temperature corrections. It had a 5 mm detector spacing along the main axis, 7 mm detector spacing along diagonals which is proved and established Pixel Ionization Chamber (PIC) technology. The Outer Dimensions 56 cm (Length) x 6 cm (High) x 32 cm (Width) [12]. A Perspex was used for depth measurement of 0.5 cm and 1.5 cm. The Perspex is a commercial name for the polymethylmethacrylate (PMMA), which is a water equivalent material or so-called solid water manufactured in a form of different thickness used for dosimetric and quality assurance. An electron applicator is also called cones. The beam should be positioned next to the surface of the patient (~5 cm away). The electron mode and electron beam energy are intertwined. Typically, superficial rehabilitation is performed with appliers or cones fixed to the machine's diaphragm. The QA test is according to International Electrotechnical Commissioning (IEC).

3. Results
The International Atomic Energy Agency [13] and the American Association of Physicists in Medicine (AAPM TG-142) [14] had published the guidelines of accepted limitation and tolerances for the dose of photon and electron. But these protocols don’t discuss the details for the effect of depth. So, we include two depths 0.5 cm and 1.5 cm for the common clinical electron beam energy used 12 MeV at common field sizes 6cm×6cm, 10cm×10 cm and 14cm×14cm. The reference dose that should be reached to the StarTrack 2D array detector is equal to 100 cGy. The StarTrack 2D detector was
calibrated such that it gives the dose output for electron energy of 12 MeV. The dose measurements were acquired with an error limit of ± 2 %. The accepted difference in this study of dose must be no more than ± 2 cGy according to IEC. Table 1 illustrate the electron dose difference for the high electron beam energy 12 MeV at three different field sizes 6cm×6cm, 10cm×10 cm and 14cm×14cm. It appears that at 6cm×6cm, 10cm×10cm field sizes at 1.5 cm depth that the dose exceeds the tolerance value. While for the 14cm×14cm field size at depth of 0.5 cm, the dose was found to be above the tolerance.

**Table 1.** The output dos difference at different field sizes and depth for both energies 12 MeV.

| Depth          | 0.5 cm | 1.5 cm |
|----------------|--------|--------|
|                | Output dose (cGy) | Diff. | Output dose (cGy) | Diff. |
| 6cm×6cm        | 98.54  | 1.46   | 104              |       |
| 10cm×10cm      | 98.08  | 1.92   | 103.24           | -4.24 |
| 14cm×14cm      | 96.12  | 3.88   | 100.89           | -0.89 |

The relationship of field size with the depth at a given dose as shown in Figure 1. It appears that the electron dose is decreasing with increasing the field size, especially at 14cm×14cm, also, the dose at 1.5 depth was higher than those at 0.5.

![Figure 1](image_url)  

**Figure 1.** The relationship between the output dose and the variation of field size for electron energy 12 MeV at depth 0.5 cm and 1.5 cm.

The percentage of output dose profile against the distance or the position in StarTrack 2D detector for the studied field sizes are measured to test the difference between the calculated date tolerances at the time of commissioning and the actual measurements. To verify that the gantry rotation axis lies within the isocenter sphere. The position of an isocenter indicator is measured relative to a fixed point marking the isocenter position, as the gantry is rotated. This is aligned on the collimator rotation axis and with the tip at the isocenter distance. To confirm that, in the plane of the gantry rotation, the StarTrack 2D array detector applied using the measurements of the four axes: inline, crossline, diagonal A, and diagonal B. The deviation of the percentage maximum dose at along radiation axis is measured as the gantry is rotated. The variation of each axis should be within the limits ± 2 % according to IEC. Table 2 shows the percentage deviation of maximum dose details of energy 12 MeV for inline, crossline, diagonal A, and diagonal B axis at 0.5 and 1.5 cm depth at field sizes 6cm×6cm, 10cm×10 cm and 14cm×14cm. The calculated difference between the reference and measured the
maximum percentage dose for each axis shows that all difference is within the limits (less than ±2 %). The StarTrack provides its efficiency to check the dose deviation for multiple field sizes and depths, these results are illustrated in Figures (2, 3, 4, 5, 6, 7, 8, and 9) for the inline, crossline, diagonal A and diagonal B axis at a depth of 0.5 cm and 1.5 cm with energy 12 MeV.

**Table 2.** The percentage between the reference and measured of dose deviation difference for electron beam with energy 12 MeV at depths 0.5 cm and 1.5 cm.

| Field size 6cm×6cm | StarTrack Axis | 0.5 | Difference | 1.5 | Difference |
|-------------------|----------------|-----|------------|-----|------------|
|                   | Reference      | measured | Reference | measured |           |
| Inline            | 2.07           | 2 | 0.07       | 1.02 | 1 | 0.02       |
| Crossline         | 2.88           | 4 | -1.12      | 1.44 | 2 | -0.56      |
| Diagonal A        | 2.88           | 4 | -1.12      | 1.35 | 1 | 0.35       |
| Diagonal B        | 3.11           | 3 | 0.11       | 1.7  | 2 | -0.3       |

| Field size 10cm×10cm | StarTrack Axis | Depth 0.5 cm | Difference | 1.5 cm | Difference |
|----------------------|----------------|-------------|------------|--------|------------|
|                      | Reference      | measured    | Reference  | measured |           |
| Inline               | 3.08           | 3 | 0.08       | 2.36 | 2 | 0.36       |
| Crossline            | 3.19           | 4 | -0.81      | 2.13 | 3 | -0.87      |
| Diagonal A           | 4.21           | 5 | -0.79      | 2.7  | 3 | -0.3       |
| Diagonal B           | 5.17           | 5 | 0.17       | 3.5  | 4 | -0.5       |

| Field size 14cm×14cm | StarTrack Axis | 0.5 | Difference | 1.5 | Difference |
|----------------------|----------------|-----|------------|-----|------------|
|                      | Reference      | measured | Reference | measured |           |
| Inline               | 4.6            | 5 | -0.4       | 2.46 | 5 | -0.4       |
| Crossline            | 4.08           | 4 | 0.08       | 4.08 | 4 | 0.08       |
| Diagonal A           | 4.57           | 5 | -0.43      | 3.75 | 5 | -0.43      |
| Diagonal B           | 6.42           | 7 | -0.58      | 6.42 | 7 | -0.58      |
Figure 2. Comparison the percentage of dose between three different field sizes: 6cm×6cm, 10cm×10 cm and 14cm×14cm for inline for 12 MeV at 0.5 cm depth.

Figure 3. Comparison the percentage of dose between three different field sizes: 6cm×6cm, 10cm×10 cm and 14cm×14cm for inline for 12 MeV at 1.5 cm depth.

Figure 4. Comparison the percentage of dose between three different field sizes: 6cm×6cm, 10cm×10 cm and 14cm×14cm for crossline for 12 MeV at 0.5 cm depth.
Figure 5. Comparison the percentage of dose between three different field sizes: 6cm×6cm, 10cm×10cm and 14cm×14cm for crossline for 12 MeV at 1.5 cm depth.

Figure 6. Comparison the percentage of dose between three different field sizes: 6cm×6cm, 10cm×10cm and 14cm×14cm for diagonal A for 12 MeV at 0.5 cm depth.

Figure 7. Comparison the percentage of dose between three different field sizes: 6cm×6cm, 10cm×10cm and 14cm×14cm for diagonal A for 12 MeV at 1.5 cm depth.
Figure 8. Comparison the percentage of dose between three different field sizes: 6cm×6cm, 10cm×10cm and 14cm×14cm for diagonal B for 12 MeV at 0.5 cm depth.

Figure 9. Comparison the percentage of dose between three different field sizes: 6cm×6cm, 10cm×10cm and 14cm×14cm for diagonal B for 12 MeV at 1.5 cm depth.

4. Discussion
Quality assurance is an important procedure that need to be done to devices to ensure a precise dose delivery for patients who underwent radiotherapy. The distribution of the output dose for megavoltage electron beam should have a priority in the QA checkup. This study shows a difference in the output dose and it exceeds the tolerance when using some parameters. This is due to the energy degradation as the distance increases between the source and the surface of the detector (SSD). So, this is an important finding means that the linear accelerator and its accessories need to be calibrated before being used for the treatment of patients using an electron beam with these energies, field sizes, and depths. Paganetti [15] stated that there was excellent cooperation between absolute dosage calculation and detector calculation of 0.15 cGy and data uncertainty. Moji et al [16] reported on average that the profiler 2 scanning device detector is used for electron beams suggesting overestimation of the dose consumed at the time of fifth week. This revealed the profiler 2 thus.

The linear accelerator dose production constancy for the linear accelerator can be tracked over time using a scanning device. All performance dose readings are similar to that of our studied electricity, except for 12 MeV with a field size of 10 cm to 10 cm and a region of over 10 cm.
The chamber or detector impact is the most possible explanation. For rooms the clinical spectrum of field size reduces, and the level of falloff is smaller. This is in line with IAEA 398 findings of Sharma et al. [13].

Furthermore, with the decreased field scale, the central axis would have a lower degree of lateral electronic equilibrium and the dosage and performance component would be highly responsive to position and intensity of the region [17]. These results agreed with Abdabro et al [18] when they also found that the dose decreased as field size increased and the dose and they declare that the maximum point dose was measured close to the surface. They use different field sizes (3cm × 3cm, 4cm × 4cm, 5cm × 5cm, 6cm × 6cm, 8cm × 8cm, 10cm × 10cm, 15cm × 15cm, 20cm × 20cm, and 25cm × 25cm) for wide range of energies from 6 to 21 MeV. As it is obvious that the applicators used to shape the field sizes of the beam, maybe the reason behind this is that the very small field may cause an under dosage of the lateral tissue.

Our results appear from the inline and cross-line Figures that for both depths the readings of dose shifted to the positive side of the axis rather than the negative side at all field sizes and energies and depths. For the diagonal A and B, all the dose profile readings are in the center. All of the axis (inline, crossline, diagonal A, and B) show a little noise in the upper uniform area. The differences were less than 2 mm in the areas of high doses (± 2%). These changes can result from the shift of the Perspex blocks, or from a statistical error and electronic instability in the diode detector or changes in detector sensitivity. With the enhanced air disparity between the device and the base, the electron beam profile is reduced owing to the improved air dispersal of electrons. So, the output dose needs to be re-adjusted. Meyer et al [19] result agreed with our results. They studied the deviation or so-called shifted in beam penetration dose of crossline (y-axis) at field size 10cm × 10cm only. Two types of manufactured linacs: Elekta and Varian for energies range 6 MeV – 18 MeV and 6 MeV– 22 MeV respectively. They used the same of our software for Commissioning data were acquired in OmniPro Accept (IBA Dosimetry GmbH, Schwarzenbruck, Germany) with an IBA Electron Field Detector 3G. They found out that there were differences in measured and calculated doses but all of them in limits of the tolerances value (± 2 %). The separation values (PDD values close to the e-string ends) were very well observed by King R. P. and Anderson [20] as compared with the standard values of all electron energies in the 3D-water fiction, except for the 12 and 15 MeV beams (same as those in our study). With the 15 MeV electron ray and 2.42 mm for the 12 MeV electron beam the highest difference was 2.28 mm. They stated that for all electron energies in the fields 14 cm to 14 cm and 20 cm to 20cms, the difference in field size was outside the recommended limit.

5. Conclusion
In conclusion, the high electron beam energy analysis needs to be recalibrated before irradiating the patients to electron beam therapy at 12 MeV to better delivery of the output dose distribution for 1.5 cm depth at 6cm × 6cm and 10cm × 10cm additionally with 14cm ×14cm at 0.5 cm depth.

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