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REVIEW

Quality Assurance in Brachytherapy

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Introduction

Brachytherapy (BT) is a form of radiotherapy where a sealed radiation source is placed inside or next to the area requiring treatment, allowing a high-dose to the tumor while sparing the surrounding tissue.[1] Since this complex procedure is performed quickly, with high doses given in a short period, with minimal opportunity for correction, quality assurance (QA) is extremely important in BT. Therefore, BT quality control program for QA is essential for obtaining the best achievable tumor control, avoiding unnecessary side effects, and accurate patient treatments and radioprotection of the hospital staff and the public. The main goal of QA is the comparison of the current findings with a previously accepted system that is ready for clinical use.[2,3]

QA Program

In high-dose rate (HDR) BT applications, treatment dose is given in a short amount of time and fast. Fixing an inaccurate dose would be impossible. QA is essential for obtaining the best achievable tumor control, avoiding unnecessary side effects, and accurately and safely performing HDR BT. It is extremely important because HDR BT procedures are performed quickly, with high doses given in a short time, with minimal opportunity for correction.[2,4] Owing to the complexity of applications and the presence of radioactive sources, it is very important to implement BT quality control program for accurate patient treatments and radioprotection of the hospital staff and the public. For sustainability of the QA, a responsible medical physicist must identify and record the periods, processes, and results of the measurements in detail.[3,4] These tests may differ for machine types with specific options.[4] In case of frequent usage of these two BT applications, QA program is crucial.

Low-Dose Rate (LDR) BT Applications

LDR (0.4–2.0 Gy/h) is the application of the radioactive sources of Ir-192 and I-125 frequently at the dose rate. In quality control tests in LDR BT applications, in the vicinity of the protective container where the resources are stored with the survey meter, the area where the sources are prepared and the area around the Pb-shielded glass compartment should be measured. These measured values should be filled and documented for each patient.[1,2]

LDR Seed BT Form Must Include

- Patient information
- Application date
- Amount of the ordered seed
- Wanted resource activity
- Used resource amount
- Remaining resource amount (if remained)
- Area where resources were prepared and measurements in needles used
- Measurement of radiation in the application room
- Measurement of the resting room

These should be documented for all patients.

HDR BT Applications

10 Curie activity with doses of 12 Gy and dose defined at a dose of Ir-192 and Co-60 sources are often used. The initial step of the quality control program is to perform a welding leak measurement before the clinical application begins. This measurement is the level of radiation measured around the device in the armored protection of the welding device. Turkish Atomic Energy Authority measurements at distances determined

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by the company and the manufacturer should be followed (Fig. 1a, b). The values read in different directions at a distance of 30 cm from the welding position of the device should be <1 μSv/h. The recommended measurement time should be after each source change.[3]

The quality control program of BT consists of treatment procedure, imaging protocol, treatment planning system protocol, sterilization, and treatment room tests.[4]

Fig. 1. (a, b) Source leakage test.

1. Patient Treatment Procedure

- Insertion and fixing of applicators
- Check the applicator position (X-ray)
- Computed tomography (CT) or magnetic resonance (MR) transfer from the patient's application table

Check the applicators and fittings after application. All data required for treatment planning should be recorded and documented. The type and size of the applicator, the volume to be irradiated, the dose and number of fractions, the dose restriction for critical organs, and the position of the applicator according to the treatment volume should be defined.

2. Imaging Protocol

- CT and MR scan length of the planning images (including the target volume and applicator)
- Image cross-sectional range and thickness
- The position of critical organs (e.g., bladder and rectum full/empty)

3. Treatment Planning System (TPS)

- Transferring images to TPS
- Contouring of volumes (e.g., gtv and HRctv) and organs at risk
- Identification of applicators and sources
- Dose distribution and dose–volume–histogram evaluation
- Treatment plan and report to be sent to the device

The accuracy of dose point calculations should be compared with the values found by matching them with manual calculations or independent computer calculations.

4. Sterilization

Each applicator and transfer cables used at the end of the treatment must be sterilized according to the type and nature of the material. A sterilization request form should be created.

In the Document

- Applicator name and number
- Name and number of applicator fittings
- Transfer cable
- Specify the desired sterilization conditions

5. Treatment (Room) Unit Tests

The tests to be performed within the scope of the quality control program related to the treatment room and the device can be classified into two groups: mechanical and dosimetric tests. Mechanical tests are the control of physical parameters and security systems con-

nected to the device's properties. The dosimetric check is used to measure leakage test and source activity after periodic source change and to compare it with the source certificate.[2,3]

Mechanical Testing
Control of Security Systems
1. Hardware Control

- Patient communication system
- Patient monitoring system
- Radiation warning systems
- Door light warning
- Radiation warning on the control room and/or control console
- Door safety system
- Emergency stop button
- Beam break switch
- Device connection transfer cables of applicators
- Control panel locking system (interrupt button on the control console)
- Emergency source armor
- Source retraction mechanism (e.g., mechanical and compressor)
- Room radiation monitors
- Emergency plan

2. Control of Device Functions
Control of Device Pushbutton Functions
Buttons are controlled on the treatment console. The device is controlled with the aid of the plan output.

Control of Source Activity, Treatment Time, and Date Information on Plan Output
The source activity, treatment time, and date information on the plan output are compared with the device output and source certificate values.

Check the Battery System Connected to the Device
During treatments, the control of the battery system inside the device, which ensures the completion of the treatment against power failure and the safe withdrawal of the source, is performed. This test is done by simulating power failure during the irradiation of the test plan sent to the device. It is checked that the source is safely retracted.[2]

Check Whether the Source Continues From Where it Stays
This test is controlled by the indicator in the control console and by autoradiography. Transfer cables or applicator film (verification film) is placed on. Decisions on the film are determined by a 1 cm interval (according to the source activity). At a certain moment, the treatment is stopped and restarted. The irradiation of the irradiated film and the post-irradiation report is checked whether the irradiation continues from where it is left (Fig. 2a, b).

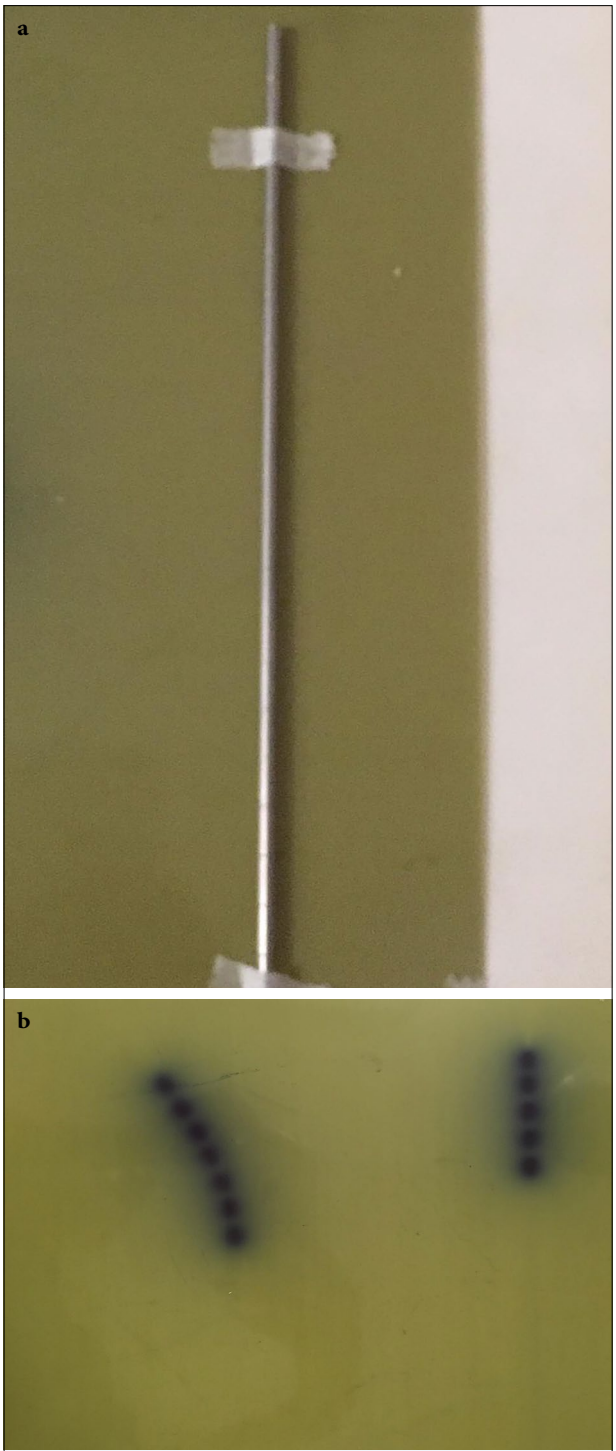

Fig. 2. (a, b) The resource to resume.

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Examination of Source, Applicator, and Transfer Cables

Depending on the use and sterilization, there may be deformation in the applicators and transfer cables. The length of the transfer cables and the connectors must be checked regularly, including the mechanical integrity of all applicators. The applicator and transfer cable combination can only be measured with a wire of suitable length (Fig. 3a, b).[2]

Control of the Locking Cable of the Transfer Cable to the Device

All aplicators should be connected to the transfer cables which are checked with colour and number codes. The locking mechanism of the device is controlled.

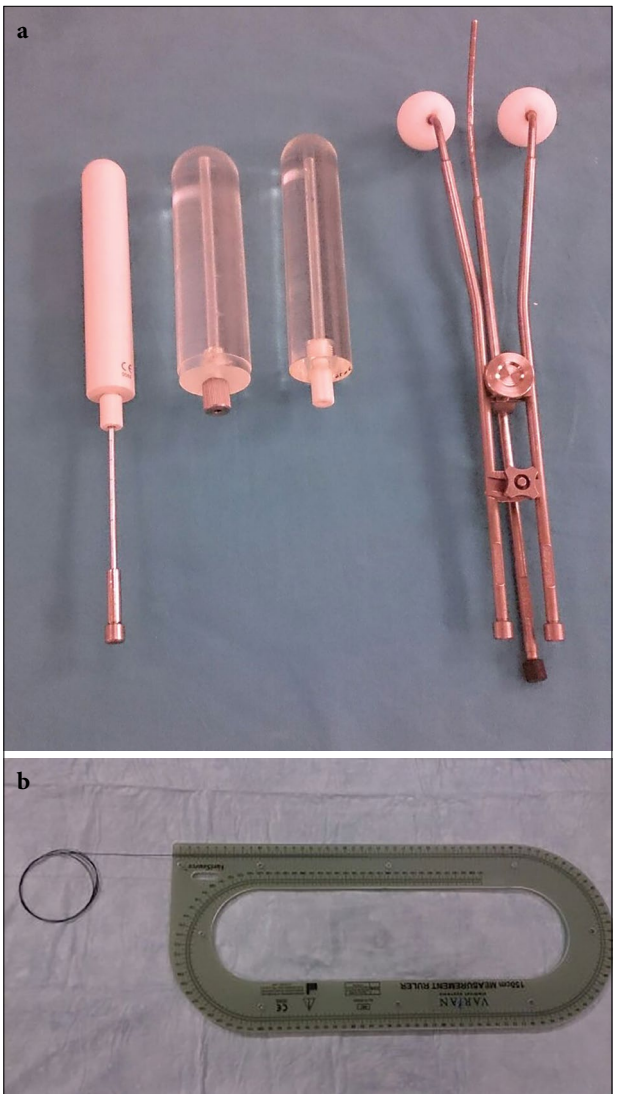

Fig. 3. (a, b) Measurement of applicator and transfer cable with wire and check ruler.

Control of Source Position

Tolerance for source position due to high-dose gradients and for dummy source is ±1 mm. The size and stopping distance of the source are important for a healthy evaluation of the test result. Because in some devices the stopping point is considered to be the center of the source, the stop at which the source is sent is considered to be the end point of the source.

Whether the source used is in the desired position in the applicator

- Mechanical methods
- Tested by dosimetric methods.

Mechanical methods, position verification tests (PVTs), and PVTs performed by the mechanical ruler with the mechanism in the device provided by the device manufacturer.[2,4]

PVT

In the system consisting of the mechanical ruler, fixed camera, connection is made with the connector specially designed for testing (Fig. 4a, b). The device is sent to the designated stop positions in the QA software by the source and dummy (Fig. 4c). Stand positions for source and dummy are displayed by the camera. At the end of the evaluation, the difference should be <1 mm (Fig. 4d).

Mechanical Ruler Method

The special ruler is connected to the device with the appropriate transfer cable. The demo plan is prepared by considering the transfer cable and the ruler end point, taking into account the known distance to the source. Verification film is placed into the mechanical ruler. The room camera focuses on the scale of the mechanical ruler and the distance from which the movement of the source can be observed. The demo plan is sent to the irradiation position and prepared. The irradiation point on the film and the image are checked visually by the camera to see whether the source is at the intended distance (Fig. 5a, b, c).

The disadvantage of these two tests using mechanical methods is the use of special hardware and software. However, since the applicator is not used, it does not show the source position accuracy in the treatment.

Dosimetric Methods

In the so-called autoradiography method, the verification film is fixed on the phantom. All applicators used in the clinic are fixed on the film, respectively. A special marker (marker) is placed into the applicators. If

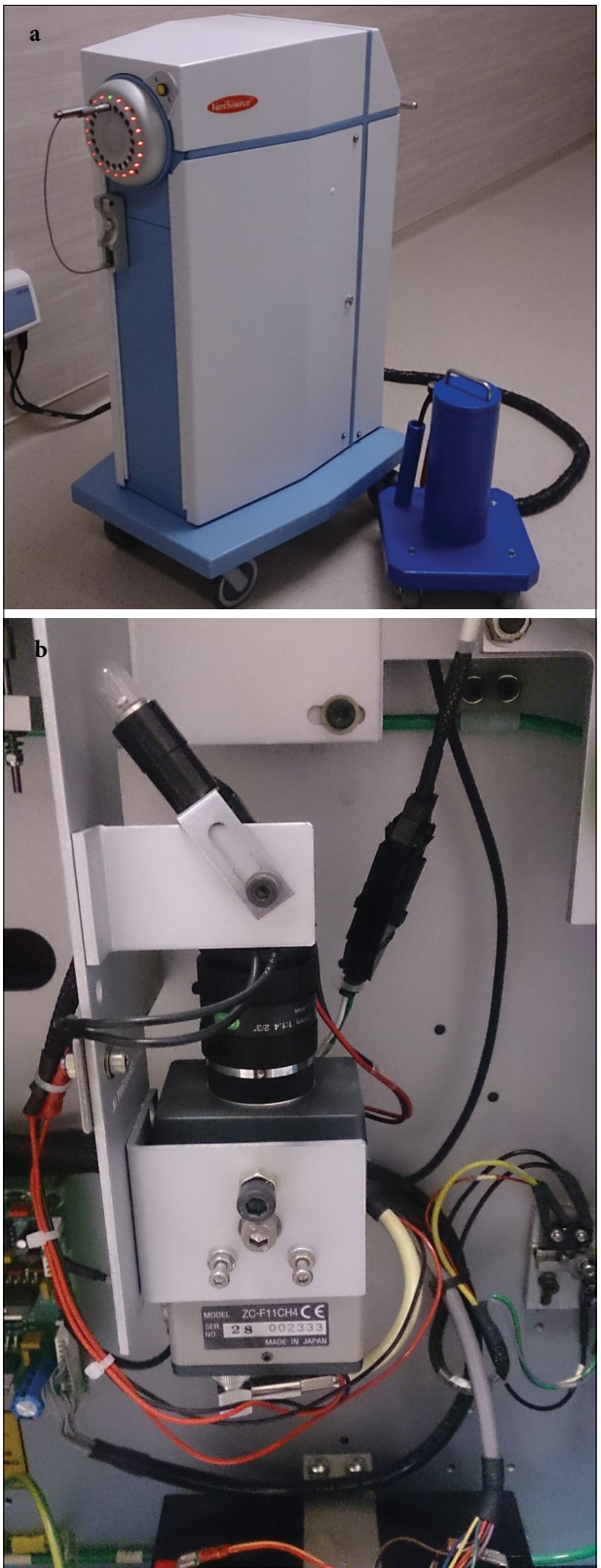

Fig. 4. (a) PVT test setup. (b) Camera system. (c, d) PVT test evaluation.

Fig. 4. (a) PVT test setup. (b) Camera system. (c, d) PVT test evaluation.

there are no markers, pins, and wires, and so on, it will correspond to the positions corresponding to the posture positions. Metal markers are placed. In a medium voltage generating device, the kV and mAs values determined according to the feature of the film are set. After the image has been obtained, carefully remove the markers inside the phantom without moving the film and applicator. The demo plan in the source position is sent to the device and beamed. The reference stop positions obtained in the first irradiation and the blackening obtained from the source irradiation are compared (Fig. 6a, b).

4. Source Calibration

The resource activity should be measured after each change of resource and entered into the treatment planning computer as compared with the source certificate value. However, since the activity value stated in the certificate may contain ±5% uncertainty, it should be measured and verified by applying the recommended calibration procedures. The two reference protocols for measurement of the activity of HDR BT sources are Tecdoc 1079 and 1274, published by the International Atomic Energy Agency.[5,6] Resource activity is measured using three different methods.

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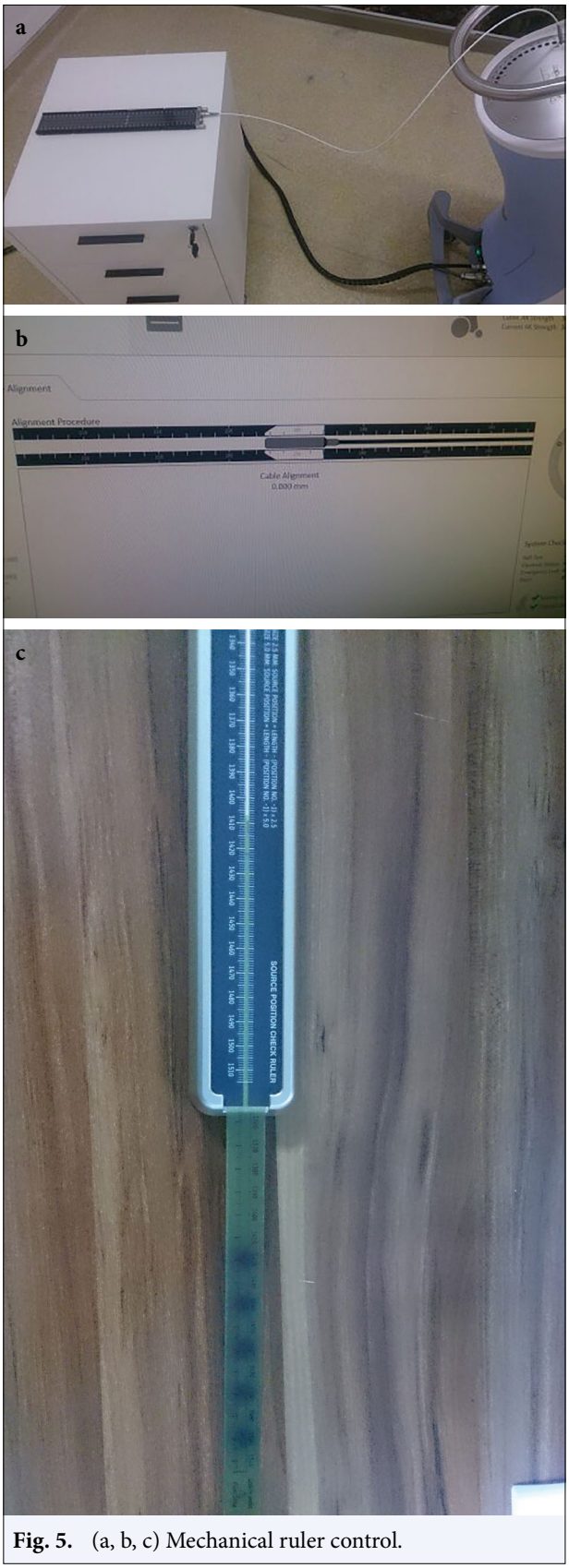

Fig. 5. (a, b, c) Mechanical ruler control.

Fig. 6. (a, b) Autoradiography method.

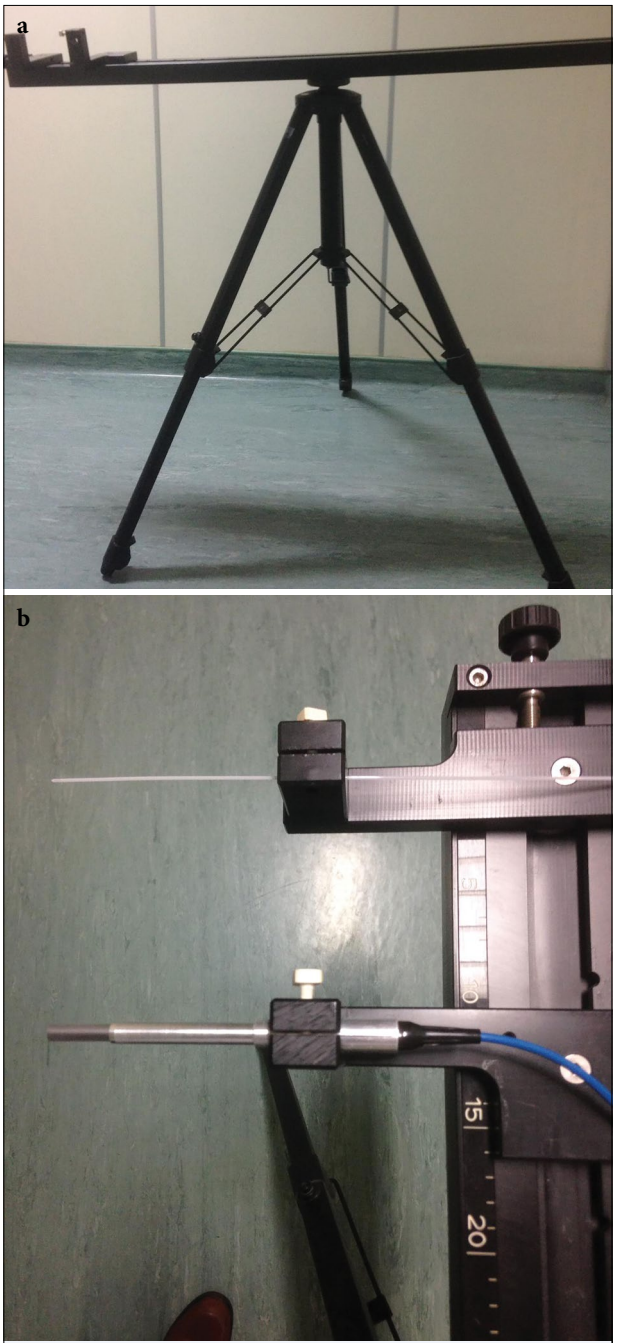

Fig. 7. (a, b) Calibration jig for airborne measurement.

Activity Measurement

- Measurement with ion chamber in air
- Measurement with well-type ion chamber
- Measurement with special phantoms

Measurement with ion Chamber in Air

The quantity of air used to express the source power is the power of the kerma. The air in unit time is expressed as the kerma speed. The unit used for HDR BT sources is μGy/h. For HDR BT sources, the value given in the source certificate by the manufacturer is the visible source activity (Aapp). The ion chambers that are recommended for use in the measurement with ion chamber in the air are ion type rooms with a volume of 0.6 cc. Calibration jig is produced specially for measurement. For measurement, a measurement device is installed above the ground by paying attention to the absence of metal around the ion chamber and scattering from the ground (Fig. 7a, b). To reduce positioning uncertainty and calibration jig scattering factor, the source is set to the geometric midpoint of the ion chamber, and the

Table 1 Linearity control table

Time adjustment	Reading (nC)	Net	Net time	1 s'lik net	Linearity
5s			0s		
6s			1s		
10s			5s		
15s			10s		=1
25s			20s		
35s			30s		

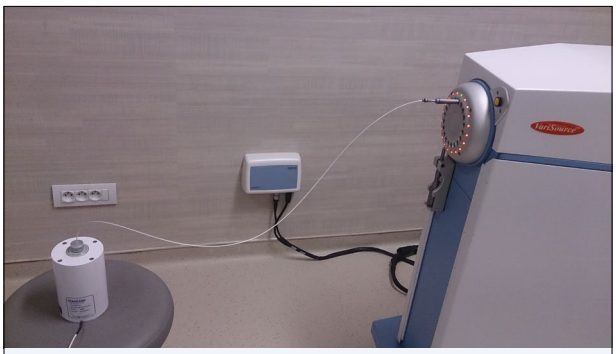

Fig. 8. Well-type ion chamber measuring device.

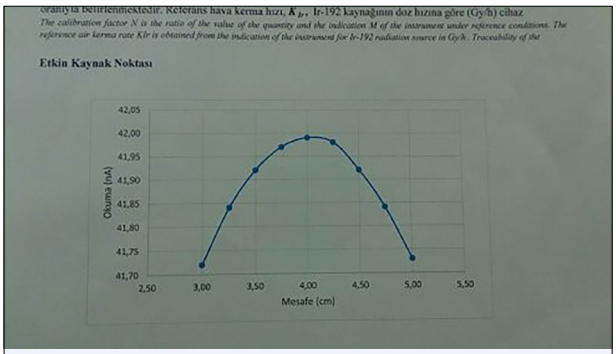

Fig. 9. Different stopping points maximum value.

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Table 2 Example of a multiple dose reading table with well-type ion chamber

Measurement of the distance cm	Reading	Measurement of the distance cm	Reading	Measurement of the distance cm	Reading
120	....	119	....	118.3	....
119	....	118.5	....	118.1	....
118	....	118	....	117.9	....
117	Max.	117.5	Max.	117.7	Max.
116	....	117	....	117.5	....
115	....	116.5	....	117.3	....
114	....	116	....	117.1	....
113	....	115.5	....	116.9	....
112	....	115	....	116.7	....
111	....	114.5	....	116.5	....

Table 3 Quality assurance program to be applied in the clinic

Control parameter	Test frequency	Intervention level
Emergency plan	Daily/quarterly tests*	-
Device user manuals	Daily/quarterly tests*	-
Radiation warning labels on the door and related areas	Daily/quarterly tests*	-
Camera system	Daily/quarterly tests*	-
Communication with patient	Daily/quarterly tests*	-
Control of UPS system	3 months	-
Illuminated warning and audible alarm system activated during irradiation	Daily/quarterly tests*	-
Door light warning	Daily/quarterly tests*	-
Emergency stop button on treatment console	Quarterly tests	-
Secondary emergency stop button in room	Quarterly tests	-
Control system that cuts the radiation when the door is open	Quarterly tests	-
Room radiation monitors	Daily/quarterly tests*	-
Portable survey meter	Daily/quarterly tests*	-
Emergency vehicles	Daily/quarterly tests*	-
Emergency movement mechanism on the device handle	Yearly	-
Power cut	Quarterly tests	-
Applicator and catheter connections	6 months	-
Damaged catheter	Quarterly tests	-
Leak test	Resource change	-
Timer control	Yearly	>%1
Source calibration	Resource change	>%5
Source position accuracy	Daily/quarterly tests*	>2 mm
Length of transfer cables	Yearly	>1 mm
Date, time, and activity accuracy in the treatment console	Daily	-
Transition time effect	Yearly	-

distance between the plastic catheter and the ion chamber is set to 10 cm^2. The barometer and thermometer should be placed in the measurement room 1 h before it can adapt to the environment. Electrometer and ion chamber connection are made, and the reading value obtained from the electrometer in 60 s.[5,6]

$K_R=N_K \quad (M_u/t)\cdot K_{air}\cdot k_{scatt}\cdot k_n \quad (d/d_{ref})^2$ Aktivite$=K_R/(\Gamma_\delta)\cdot(W/e)_{air}$

Timer Control

This test, which is the measurement of the linearity of the timer, is investigated with the effect of total irradiation depending on the motion and speed of the source. For this, irradiation is performed at different times in the same stop positions. The ratio of the reading values obtained using the airborne measurement device is compared (Table 1).

- Net=reading–5 s reading
- Reading 1 s=Net/Net time
- Linearity=1 s net normalized value corresponding to a 10 h net time

Calibration Using Well-Type Chambers

For measurement, well-type ion chamber and electrometer connection are made with the source transfer cable (Fig. 8). The barometer and thermometer must be placed in the measurement room 1 h before it can adapt to the environment. The point to note is the determination of the measurement distance at which the ion chamber gives the highest signal (Fig. 9). Multiple readings are used to obtain the maximum reading value and position. Ten readings are obtained with 1 cm stops. Ten readings are obtained with 0.5 cm stops in the range where the highest reading is read. The reading range is narrowed, and the highest reading value and position are determined precisely by obtaining 10 readings with a 0.2 cm stop interval (Table 2). Together with the pressure, temperature, and highest reading values, the activity is calculated and compared with the certificate value. The difference should be within 5%.[1,2]

Measurement with Special Phantoms

The source activity can be measured using ion chamber, electrometer, and cylindrical solid phantom. The geometry of the cylindrical phantom consists of four channels located at the center, with the catheter channel at which the source will go, and at right angles to each other around the channel (0°, 90°, 180°, and 270°). In the four channels around the catheter, place the ion chamber sequentially and read 60 s. The readings of all geometries are averaged, and the activity is calculated.[7]

To ensure safe and accurate treatment of patients, the clinical density and the applicable QA program should be established and carefully applied (Table 3).[2]

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