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COMMISSIONING OF HDR BRACHYTHERAPY: PROCEDURES, PROTOCOLS AND QUALITY ASSURANCE

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Abstract

***Purpose:** To assess the dose accurately administered to cancer patients as a component of HDR Brachytherapy, and address initial source installation tests acceptances test and quality assurance program.*

***Method:** Nucletron Micro Selectron HDR V3 (18 channel) 192Ir Brachytherapy After loader was used for the study, which was conducted at St. Gregorios Medical Mission Hospital, Kerala. Measurements of "sweet spots" (maximum dose distribution) were made with a well chamber (Standard Imaging HDR 1000 Plus) connected to an electrometer (Standard Imaging Max 4000 Electrometer). These observations provided the Air Kerma Strength of the source. Step size confirmation, nuclide radioactivity and machine safety measures were also evaluated. The surface radiation dose outside the brachytherapy facility was surveyed using a well-calibrated G.M. Detector based radiation Survey meter NUCLEONIX RADMON(MICRO).*

***Results:** The acceptance testing and commissioning of the HDR brachytherapy unit were successfully completed. The recently placed source showed minimal variation in air kerma strength, all within acceptable limits. The step size had a standard deviation of 0.05 relative to the intended value, indicating precise calibration. Radiation levels were confirmed to be within permissible limits as specified by the Atomic Energy Regulatory Board of India.*

***Conclusion:** The Concentra treatment planning system has been successfully commissioned for clinical use with the Nucletron Micros electron 192Ir HDR brachytherapy unit. Acceptance testing confirmed the unit's satisfactory performance, verifying that all components are functioning correctly to ensure accurate radiation dose delivery within the prescribed parameters for effective cancer patient treatment.*

***Keywords:** HDR Brachytherapy, Air Kerma Strength, Quality Assurance, Time Linearity, G.M. Detector, Acceptance Testing*

I. INTRODUCTION

High-dose radiation (HDR) brachytherapy is an advanced form of internal radiation therapy designed to treat many types of cancer by delivering a high-intensity radioactive source directly into or near the tumor for a short period of time. This technique ensures precise radiation delivery to the cancerous tissue while minimizing exposure to surrounding healthy tissues. The procedure involves inserting a small catheter or applicators into the tumor area, where a remote after-loader delivers a radioactive source. The source will remain in place for several minutes before being withdrawn.

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HDR brachytherapy has many advantages, such as high accuracy, which reduces damage to healthy tissue. The treatment is easy. Usually, short term and can often be done on an outpatient basis. It is also versatile, being used to treat a range of cancers such as prostate, cervical, and head and neck cancers. Brachytherapy can be permanent or temporary. This depends on each case. Temporary brachytherapy is typically performed using a catheter to deliver a radioactive source for a short period of time

HDR brachytherapy applications differ based on the type of lesion, with methods including intracavitary, interstitial, surface mold, and intraluminal brachytherapy. This technique is commonly used in treating various cancers, such as prostate, breast, cervical, and ocular cancers. In addition to its role in oncology, brachytherapy is applied in cardiology to treat coronary artery disease by helping prevent restenosis after angioplasty.

The benefits of brachytherapy are extensive and depend on the patient's needs, priorities, and preferences. As a minimally invasive treatment, it avoids the need for surgery, offering quicker recovery times, shorter hospital stays, and a reduced risk of postoperative infections.
In HDR brachytherapy, a small Iridium-192 source with a high air kerma rate, such as 4.6 $cGy.h^{-1}.m^2$ (10 Ci), is typically used. This source provides a high dose rate(≥12Gy/hr) and allows for superior dose distribution while maintaining radiation safety for healthcare staff.

II. MATERIALS AND METHODS

The present study was performed in the Department of Radiotherapy, St. Gregorios Medical Mission Hospital (SGMMH), Kerala, India. The main aim was to identify sweet spots - regions of maximum dose distribution – with a well chamber, Standard Imaging HDR 1000 Plus, and an electrometer, Standard Imaging Electrometer Max 4000 Plus. These observations allowed one to compute the Air Kerma Strength of the radiation source. Moreover, the exercise included checking step size, measuring the radioactivity of the nuclides used, and checking whether the rules of safety were followed in the brachytherapy department. A radiation survey has been done for the brachytherapy area by using a well - calibrated radiation survey meter.

III. RESULT

Initial Source Installation:

1. Room and Shielding Design

An optimized single - room setup for HDR brachytherapy should be carefully designed to ensure maximum safety for both patients and staff. The room must be thoughtfully arranged to minimize radiation exposure and position the control room for optimal operation and protection. Shielding is crucial, including 60 cm of solid concrete walls, lead - shielded doors, integrated safety interlocks, emergency shut – off systems, and radiation monitoring devices to monitor and maintain safety.

The layout should be tailored to site-specific requirements, prioritizing radiation protection, accessibility, and space. It should allow smooth access for patients, accommodate bed entry, and have sufficient space for after-loading equipment, ensuring rapid and secure access in emergencies. The design and construction of the facility adhere to IAEA standards for radiation

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protection, safety, and functionality, facilitating both effective treatment and the protection of all personnel.

2. Radiation Survey

A radiation survey was conducted using a well-calibrated G.M. Detector-based radiation survey meter, the NUCLEONIX RADMON (MICRO), which measures a wide range from 0 to 10 R/hr (0 to 100 mSv/hr). The highest recorded dose rate was 3.9 μSv/h at the control console wall, indicating a localized area of higher radiation. When the robotic arm was retracted, the maximum reading on the robot surface was 2.0 μSv/h for a source strength of 8.907 Ci ($mGy \cdot m^2 \cdot h^{-1}$). These measurements confirm that the radiation levels are within acceptable safety limits for an assured safe workplace.

Radiation Survey around HDR unit

Figure 1.A. Side View. Side View.

Figure 1. B. Top view

3. QC measures of HDR Machine

Given the variability in treatment equipment and room configurations, the specific safety checks should be tailored to the local context. The following outlines some common functions and components that typically require testing.

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Pre-Treatment Source Strength Verification Test: This source strength of the computer and console was compared to the source decay table. A well-calibrated Well Chamber-Standard Imaging HDR 1000 Plus-and an Electrometer-Standard Imaging Electrometer Max 4000 Plus-were used for source strength tests. The sweet spot using the well chamber and electrometer was identified following all the instructions given in the manuals. The biasing voltage during exposure was -300V for 20 seconds. A sweet spot was observed in the chamber at the 20th position. Having identified the sweet spot, a treatment reference distance of 1367 mm was programmed to this dwell position for 60 seconds.

Table 1

Source Strength Verification:				
Dwell Positions	**Current (nA)**			**Avg. Current (nA)**
	Trial 1	**Trial 2**	**Trial 3**	
24	60.358	60.335	60.303	60.332
23	60.519	60.491	60.456	60.489
22	60.651	60.595	60.569	60.605
21	60.718	60.641	60.619	60.659
20	60.736	60.662	60.625	60.674
19	60.714	60.605	60.578	60.632
18	60.637	60.516	60.484	60.546
17	60.506	60.368	60.349	60.408
16	60.336	60.176	60.15	60.221
15	60.124	59.936	59.915	59.992

The source strength recorded on different dates after calibration was compared with the manufacture's specified calibration strength. The deviation seen between the source strength observed and the manufacturer's calibration was -0.27%, which remained well within the acceptable tolerance limit.

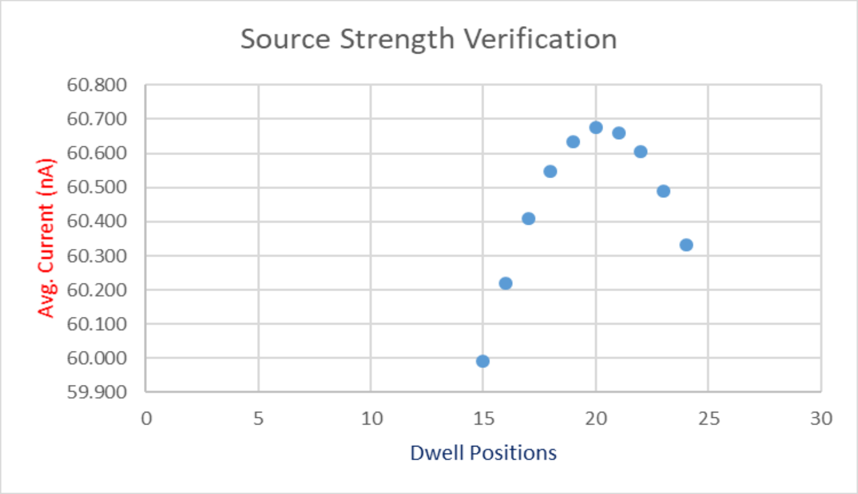

Figure 1 Source Strength Verification

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Table 2

Maximum current reading in one dwell position				
Max Position	Current (nA)			Avg. Current (nA)
	Trial 1	Trial 2	Trial 3	
20	60.587	60.578	60.566	60.577

Time Linearity and End Error: The measurement was conducted by setting the dosimeter to charge in micro coulomb mode and configuring the time to 300 seconds. The resulting graph demonstrated time linearity and end error, represented as a straight line.

Table 3

Charge accumulated in the electrometer for Different Dwell time in seconds.					
Time Set (sec)	Charge in nano Coloumb				Time Measured = Average Charge / Current
	Trial 1	Trial 2	Trial 3	Average charge	
60	3634.300	3632.300	3631.400	3632.667	**60.3**
120	7244.300	7241.500	7240.800	7242.200	**120.2**
180	10859.000	10855.000	10855.000	10856.333	**180.3**
240	14495.000	14493.000	14489.000	14492.333	**240.6**
300	18104.000	18103.000	18101.000	18102.667	**300.6**

Timer Linearity =	(1 - Slope) * 100	-0.1498044	%

End Error =	0.136152313	Sec

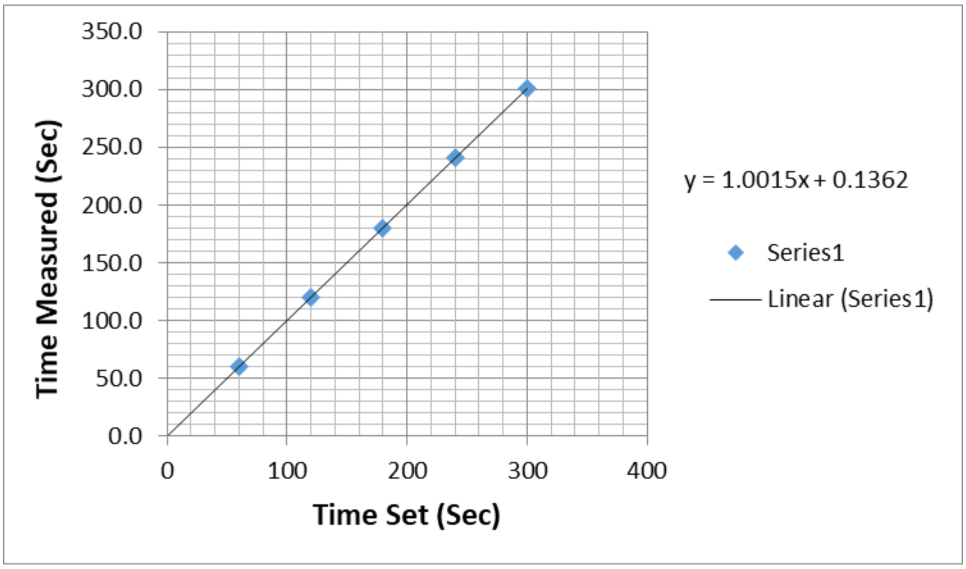

Figure 2 Time Linearity and End Error

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Time Error: The time taken to drive the source to the ON and OFF positions was found to be 4.85 seconds. The time error, measured in charge mode with and without interruption of treatment, was found to be 0.630 %, which is below the tolerance limit of 1%.

Table 4

Timer Error					**Setup Parameters**
Particulars	**Charge (nC)**				Chamber = Well Chamber HDR 1000 Plus
	Trial 1	**Trial 2**	**Trial 3**	**Average**	Electrometer= Max 4000 Plus
Without interruption (R1)	3650.20	3651.00	3649.70	3650.30	Mode = Current, Range = High
With interruption (R2) at 30 secs	3674.7	3671.8	3673	3673.17	Tolerance= ±1%

Timer error =	(R2-R1)t/(2R1-R2)	**0.378**	**Sec**

% Timer error =	(timer error in sec * 100)/60	**0.630**	%

Source Position Film Check: To assess source positioning accuracy, we employed GaF Chromic film. A reference distance was entered into channel 1, connected to the transfer tube, while the dwell time was set to 2 seconds. The source was then sent out. The exposed GaF Chromic film was aligned with a dummy X-ray marker, ensuring the dummy's source position corresponded to the programmed reference distance marked on the film. In a second film check, we verified the exposed active source position against the scale on the GaF Chromic film. The source positioning accuracy, specified at ±1 mm, was found to be within limits, The standard deviation obtained is 0.05mm.

Setup Parameters
Source Check Ruler
Gafchromic Film
Programmed Length = 1270 mm, 1280 and 1290mm
Dwell time = 2 sec
Tolerance= ±1mm

Figure 3 Source Position Film

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IV. DISCUSSION

In HDR brachytherapy, providing single-room accommodation is generally preferable. The room layout should consider factors such as wall thickness and door shielding. The maximum peak observed at the 20th position is due to the well chamber's most sensitive region being located at its center. This ensures accurate measurement of the source strength. The "action level" data presented represents the upper limit under clinical conditions, indicating the threshold at which corrective actions must be taken.

For an acceptance test, it is crucial to compare the design specifications with the actual performance of the system. System designs often allow for superior performance under reference conditions, such as positional checks using autoradiography, to ensure precise source placement and dose delivery.

It is the physicist's responsibility to continuously monitor the system's performance history to ensure it remains within acceptable limits. In this case, the observed deviation between the calibrated source strength and the manufacturer's calibration source strength was -0.27%, which is well below the tolerance limit, indicating the system is performing accurately and reliably. Regular monitoring and adherence to these protocols are essential to maintain the safety and effectiveness of HDR brachytherapy treatments.

V. CONCLUSION

This study highlights the critical role of medical physicists in the successful implementation of High Dose Rate (HDR) brachytherapy, a cutting-edge treatment for cancer. Through meticulous experimentation, essential parameters such as Air Kerma Strength and step size were precisely measured and validated, ensuring accurate radiation dose delivery to patients. Rigorous quality assurance protocols were adhered to, guaranteeing the reliable and safe operation of the brachytherapy system.

A comprehensive radiation survey was conducted, confirming that radiation levels within the facility were within the prescribed safety limits. This ensures the protection of hospital staff, patients, and visitors from unnecessary radiation exposure. The successful commissioning of the HDR brachytherapy unit, along with the implementation of effective safety and quality assurance measures, ensures that cancer treatments are delivered both safely and effectively.

The study underscores the importance of continuous monitoring and adherence to safety protocols to maintain the high standards required for HDR brachytherapy. The role of the medical physicist is pivotal in this process, as they are responsible for ensuring that all equipment functions correctly and that all safety measures are in place. This commitment to safety and precision contributes significantly to the ongoing improvement of cancer care, providing patients with the best possible outcomes.

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