Radioactive Cobalt-60 Teletherapy Machine – Estimates of Personnel Dose in Mock Emergency in Patient Release during “Source Stuck Situation”

Sir,

Radioactive cobalt-60 teletherapy machines still find a place in radiation therapy departments, in more populated and developing countries.[1-3] In the advent of crisis globally in the management of cancer care, cobalt teletherapy machines have an edge over the linear accelerators because of less maintenance costs, less infrastructure requirements, low power demands, and simple quality assurance of the beam parameters. An activity about 444 TBq (12,000 Ci) is loaded initially in these cobalt machines. The cobalt-60 source decays at a rate of about 1% per month. Therefore, the mean activity encountered in these machines at any point of time range between 185–333 TBq (5000–9000 Ci).

Linear accelerators generating megavoltage photons do not have radioactive sources, and there are no problems such as “source” in the “machine head” in “OFF” position or problems such as “source remaining stuck in ON position.” Everyone claims that linac should be the machine of choice because of no radiation hazards like “prevailing radiation levels during source “OFF” condition, and the fear associated with the high radiation levels if the teletherapy source stuck in “ON” position. In these circumstances, to overcome the concern associated with technologists and administrators about the optimal use of telecobalt machines, it is felt that thorough understanding of the functional aspects of the available model cobalt machines is necessary. A “true hazard evaluation” involves estimates of “annual personnel doses” received by the operators[4] as well as “the likelihood of personnel exposures” the operator might be exposed to, in the event of “source stuck in ON position” may be objectively discussed. Through this note, these aspects are highlighted.

“Theratron 780E, MDS Nordian” (Canadian model),[5] “Bhabhatron,” (Indian model),[6] cobalt machines house radioactivity in the form of a cylindrical source of 2 cm diameter, mounted on a steel cylinder. Other models such as ATC-9 (USA) make use of a rotating drum with a mounted “cylindrical source” held against an helical spring. “Source on” position is achieved by a DC motor against the spring tension. Both types of systems have fail safe mechanism to bring the source to “OFF position” in case of power failure. Bhabhatron[5] machine has safety facility for total closure of the diaphragms electrically (0 cm × 0 cm field size) during source stuck position using a safety interlock, which are not available in the existing old Canadian models.

National regulatory authority (in India, Atomic Energy Regulatory Board) requires (a) obtaining clearance for the concrete rooms, (b) obtaining license for the procurement and use of these equipments, (c) conducting periodic surveys and documenting radiation levels for telegamma installations as well as linear accelerators. For cobalt-60 machines and high dose rate brachytherapy machines, a need for “formulating procedures for managing emergency situations” is also stipulated. Working professionals are appraised about the incidents and mishap situations with high-intensity telegamma machines in a few reports.[7,8] The Radiological Safety Officer (RSO) of the institutions has the responsibility to display sufficient warning instructions and the actions to be followed in terms of emergency situations, such as “source drawer stuck ON position” or “not going fully back to OFF position.” Availability of a “mechanical source drawer pushing rod” at a visible position in the control console area is emphasized. There is need for keeping these procedures as part of “hospital disaster management document.” The radiation technologists should know the actual steps involved in the disaster management, depending on the situations encountered, and to understand the “standard guidelines of the hospital (SGH)” and the “radiation safety guidelines” in unusual situations encountered, shall be properly understood by the staff. During these situations, the radiation levels inside the room will be high due to “primary radiation + scattered radiations” from the patient on the table. The leakage levels also will be relatively high. The patient is a scatter medium with large volumes depending on the field opening.

“Source stuck” situations are understood by the following indications (a) source on indicator mechanical rod is outside the machine head, seen in the closed-circuit television monitor, (b) hooter sound of the zone monitor does not stop, (c) “warning red light” continues to glow on the collimator, (d) the control console continues give source on alarm/red light continues to glow, (e) door “red warning light” does not go off, (f) zone monitor displays “high reading” in the analogue/digital scales. The existing guidelines are (1) the staff should not be panic, they should get the patient “out” from the treatment room, do not perform any other action to complicate the existing situation, lock the room, keep the door key safely, inform the RSO, and wait for further action.

There is a need felt to really understand the actual operation, and a drill needs to be conducted by the RSO to show the actual scenario as a pseudo practice. There is also a need for the patient to respond to the instructions, during “source stuck.” There are no reports presently available as a “model” for this.
This report highlights “mock situations encountered” “the steps to be followed in response” and documentation of “personnel doses” which are likely to occur in these emergency operations.

The cobalt machine of our department (Theratron 780E) had a decayed source with activity 89 TBq (2400 Ci). The old models such as Theratron 780C have a manual lock for the longitudinal and lateral motions of the table top. If the locks are released, the table becomes freely floating and could be longitudinally pulled backward or translated laterally. However, our cobalt-60 machine (Theratron 780E) does not have such manual movements. All the movements of table top are motorized. As per the technical documentation, the patient has to be moved only with operation of motorized movements.

A human dummy model (Medical Mannequin) was kept on the treatment table for demonstration. A “mock trial” “source stuck” was simulated by keeping the machine is in OFF condition. Two radiation technologists carried out the above exercise to release the clamp on the “Orfit” Base Board, table top operations, and the actual duration is recorded with an electronic stop watch as a measure of two attempts. Movement of the technologists was restricted starting from the “maze wall exit into treatment room,” finish patient release operation, and return back to “maze wall passage.” Three actions were tried with different machine orientations in the “mock drill,” and timings are initiated by stop watch for recording the durations of action plan.

‘Thermoplastic’ cast present on his head and neck (lateral beam) treatment, was moved away from the table top, using longitudinal “table withdraw” method. Vertical treatments (carcinoma of esophagus and cervix) were removed using “sliding control of table top” to swing the table away from primary beam. For tangential breast treatment setup, “lowering of table top” brought the patient outside primary beam. The time taken during these operations are recorded.

To document the likelihood of exposures, two types of measurements were carried out. Leakage in “source ON” condition was estimated with primary beam blocked, using a 0.6 cc ionization chamber with buildup cap, and compact-disk electrometer (CD instruments, Bangalore). A condenser chamber type “calibrated pocket dosimeter” (Model 909, chamber 242952) (Arrow-Tech Inc., USA) was used to estimate the doses at known location inside the room. Cumulated doses were estimated at a position 1.45 m radially away from “source,” which corresponded to the location of a technologist standing and operating the hand control. The pocket dosimeter had a water can to provide back scatter. Stray doses at the pocket dosimeter were evaluated, with and without scatter water phantom in the path of the gamma beam, at 0°, 90°, and 270° positions of the gantry.

For lateral beam, the recorded dose rates were 72.4–37.2 µGy/min with and without water phantom. Same lateral beam with machine head on the opposite side had 35% increased exposure rate due to forward scatter, i.e., 98 µGy/min against previous value of 72.4 µGy/min. It reveals the presence of more forward scatter in the gamma beam. In this position, when the phantom is not there, the exposure rate at the radial location increases from 98 µGy/min to 114.0 µGy/min (increase of about 16%). This implies that unattenuated primary (with no phantom in the path) initiates increased scatter from the opposite concrete barrier wall, thereby increasing the stray radiation dose level at the pocket dosimeter. Effect in the vertical beam results in an exposure rate of 147.2 µGy/min with phantom present, which reduces to 86.8 µGy/min (a reduction of about 41%) when phantom is moved out.

From the above measurements, if we normalize the values for a nominal source activity of 333 TBq (9000 Ci) and 30 s duration (assumed as patient releasing time by technologist), the resultant personnel dose in these situations vary from 63 µGy to 267 µGy (6.3–26.7 mR). As part of the time in these estimations is for “presence of primary” and later only scatter, the actual exposures will be nearer to 63 µGy (6.3 mR). CD dosimeter estimated a leakage of 2.2 cGy/h at 89 TBq, which will correspond to 1.8 mGy/min if the collimator is totally closed (as in the case of Bhabhatron machine) when the technologist will be exposed to only leakage radiations as the primary is shut off.

In this present report, the true situation encountered in a cobalt-60 teletherapy installation is simulated, and a possible management strategy is arrived at. Radiation safety text books and protection safety guides of different nations give guidelines how to react at a situation, but so far, there are no reports how these are executed practically. There is no documented method, how a technologist will approach problems of this nature, when the patient wears an immobilization shell. Some approaches indicate moving of gantry; however, in reality, the primary beam will not come out of the patient’s contour, takes more time of operation, lead of excess irradiation of the patient, and sometimes frighten the patient also. We have come out with a SGH methodology, with only table top operation and also evaluated the risk involved. As the doses are based on original measurements at a known strength of the cobalt-60 source, the actual dose estimates could be arrived at for the maximum source loadings. These types of source stuck up could be possible when the teletherapy machine is very old and treated maximum number of patients. After making the drill, the technologists could foresee an event and know how to manage that event. Two detailed posters were left the control area, indicating likelihood of incidents, and the drill how to handle the incident. The posters sent to a couple of institutions gave a feedback that this kind of information is not available, and it obviates the apprehensions on the part of technologists. Linear accelerator manufacturers claim that cobalt machines will give rise to hazardous situations; but from this objective estimates, it is clear that with present facts, it becomes a planned operation, well explained in radiation safety literature. The radiation technologists are well aware of the basic concepts of radiation safety, namely, “least time spent in the vicinity,” “maintain longest possible distance from the patient emitting scatter radiation,” and “take advantage of
the head shielding of the machine” (time, distance, shielding), the optimal position of the technologist is taken for the mock drill. This report, therefore, gives the genuine simulation of exigent conditions.

In the light of permissible dose equivalent for occupational worker 20 mSv/year (20,000 µGy/year), i.e., 0.4 mSv/week (400 µGy/week), the estimated personnel dose of about 60 µGy to 270 µGy is less than the weekly permissible exposure. Therefore, the technologist’s work environment does not call for apprehension. This also implies that linac suppliers should not speculate that there is more hazard in cobalt room when the source is stuck. This work, therefore, shows some light into the area. A previous report\(^1\) brought out that for external beam radiotherapy machines, mean personnel “equivalent dose” for 5-year block period is 1.1 mSv (110 mR), and mainly, these estimates were for cobalt machines in that institution.

This brief communication brought out a methodology to be implemented as an SGH and brought out the efficacy to make the dose received as low as possible (ALAP). As one of the expressed disadvantages of cobalt-60 beam is possibility of “source stuck in ON position,” it became mandatory to calculate and express the “risk” encountered by personnel. As a few authors supported the continuation of cobalt-60 to be available in the armamentarium in the radiotherapy department,\(^1-5\) the above work assumes importance. In this paper, we have outlined the situation when the patient is ambulant. If the patient is not ambulant, the exposure received will be by two technologists, and both will receive the estimated doses because the “time taken or estimated by us” includes the duration “to bring out the patient away from the primary beam.”

As the international and national agencies on radiation safety such as International Atomic Energy Agency during their audits look for such written guidelines to manage radiation emergency, this document will compliment such information in the department. In this report, it is highlighted that “radiation technologist” does not push the source drawer unless he is authorized by the RSO. There is misconception that this operation is in the purview of the technologist, but this should be the responsibility of the RSO of the institution. In India, as we still have about 150 telecobalt machines operational, message from this report will be of immense application for the live demonstration of the hazard evaluation.

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