Clinical Implementation Experiences of Low kV Intraoperative Radiation Therapy (IORT) Intrabeam System for Low Risk Breast Cancer Patients

1. Introduction

IORT is a procedure designed to deliver a single high dose of boost radiation following immediately after tumor resection in the OR. It eliminates the possibility of irradiating the wrong site and delivers dose at the earliest possible time: right after surgery. Because of the sharp dose fall off, \( \sim 1/r^3 \) (the point source has the typical inverse square fall off \( 1/r^2 \) and attenuation in the tissue introduces an approximate inverse linear fall off \( 1/r \)), IORT delivers fewer doses to the contra lateral breast and OARs and it has relatively less side effects compared to EBRT. In this report, we present clinical implementation of a new IORT system for breast cancer patients using Intrabeam in terms of quality assurance and reproducibility in the OR. We also present our 1st year experience of treating low risk breast cancer patients using this device such as applicator sizes used, total treatment time, and measured ambient radiation exposure rate in the OR for each case during treatment.

2. Materials, methods and results

IORT procedure using Intrabeam system with 50kV, 40µA, is recently being implemented to treat low risk breast cancer patients in our clinic. Pretreatment daily QA of IORT is performed following step-by-step procedures: (1) Probe straightening – verification and correction (if needed) of the probe alignment, (2) dynamic offset measurement using photo diode array (PDA) – aligning the electron beam direction with the mechanical center of the probe, (3) PDA source check – verifying the isotropy of the X-ray beam emitted from the probe tip, and (4) X-ray tube output check – in-air output measurement using ion chamber and compared with the baseline data provided by Intrabeam were major steps followed before treating patient. Total treatment time for each applicator size was estimated by dividing prescription dose, \( D \) (Gy) by the dose rate, \( D_{\text{rate}} \) (Gy/min):

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D_{\text{rate}} = \frac{I_{\text{p}}(C/s) \times N_{\text{i}}(\text{Gy/C}) \times k_{\text{q}} \times (60\text{s/min})}{\text{ATF}}
\]

where, \( I_{\text{p}} \) (C/s), \( N_{\text{i}} \) (Gy/C), \( k_{\text{q}} \) and ATF = ratio between dose rates in the presence and in the absence of the applicator size (i.e., diameter). An intraoperative ultrasound images were acquired to estimate the distance of the applicator surface to the skin. Measurement of ambient radiation exposure rate was made at different locations in the OR for each patient during treatment.

Fig. 1 (a) Miniature x-ray tube providing a point source of 50kVp at the tip of a 3.2 mm diameter drift tube with a gold target at the tip emitting a nearly isotropic radiation field, (b) Sterilizable/reusable spherical applicators made of polyetherimide that range in size from 3 to 5 cm in diameter with 0.5 cm increment, (c) Pretreatment daily QA setup with ion chamber & electrometer, (d) An intraoperative US image performed in the OR: where the black arrow measuring the distance of the applicator surface to the skin distance: It must be >1 cm to avoid significant skin doses. After surgery, we had to cancel one IORT patient treatment because of the margin was <1cm, (e) beam delivery in the OR without soft lead shield on the treated breast, & (f) with ~1mm soft-lead shield on the treated breast in place to reduce the radiation exposure in the OR.

Fig. 2 Sampled pretreatment daily output in-air measurement for each month. The relative output variation of the IORT device for nearly over 4.5 min period was mostly within ± 2.0%, showing excellent output reproducibility.
Fig. 3 (a) Histogram of the spherical applicators used: 5 cm diameter size followed by 4 and 3.5 cm were mostly used, so far, 3 cm diameter size was used once, and (b) corresponding total treatment time for all applicator size, 3 and 4 cm diameter has similar treatment time because of the 3 cm applicator has larger inherent filtration to harden beam.

Fig. 4 Measured ambient dose equivalent rate at different locations in the OR with and without soft-lead shield on the treated breast in place. (a) Radiation room survey shows that, very high radiation exposure at different distances from the source position in the OR without lead shielding in place on the treated breast, whereas (b) shows it was reasonably low (< 2mR/hr) in sensitive areas such as behind anesthesiologist shield (portable lead screen shield & lead sys-glasses is provided for anesthesiologist). Behind the Intrabeam control console (one corner of the OR), the exposure rate was as high as 12mR/hr in some cases while not using soft-lead shield on the treated breast.

3. Summary and Discussion

IORT unit is feasible to deliver a single fraction of high boost dose for breast cancer patients, immediately after tumor resection in the OR. It is a relatively cheaper mobile unit and it requires minimal radiation shielding with no potential risk to the radiation workers. Radiation exposure in the OR was reduced nearly 12 fold when using a thin lead shield on the patient. Therefore we recommended using soft-sheet shield to lower the exposure limit in the OR. But, the back-scatter dose to the patient due to soft lead sheet on the treat breast is unknown. In future, we plan to physically measure surface dose to the patient skin (using either films or MOSFET) as well as back-scatter dose due to soft-lead shield to verify/estimate the delivered skin dose. Patients follow up and outcome studies in terms of late & early effects as well as tumor recurrence will be followed. Heterogeneities correction in dose distribution to better estimate the delivered dose using IORT is interest of future investigation.

References