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Using a thermoluminescent dosimeter to evaluate the location reliability of the highest–skin dose area detected by treatment planning in radiotherapy for breast cancer

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ABSTRACT

Acute skin reaction during adjuvant radiotherapy for breast cancer is an inevitable process, and its severity is related to the skin dose. A high–skin dose area can be speculated based on the isodose distribution shown on a treatment planning. To determine whether treatment planning can reflect high–skin dose location, 80 patients were collected and their skin doses in different areas were measured using a thermoluminescent dosimeter to locate the highest–skin dose area in each patient. We determined whether the skin dose is consistent with the highest-dose area estimated by the treatment planning of the same patient. The χ^2 and Fisher exact tests revealed that these 2 methods yielded more consistent results when the highest-dose spots were located in the axillary and breast areas but not in the inframammary area. We suggest that skin doses shown on the treatment planning might be a reliable and simple alternative method for estimating the highest skin doses in some areas.

Introduction

Breast cancer has been the most common type of cancer diagnosed among women in Taiwan since 1996. According to statistics of Department of Health, Executive Yuan, R.O.C., its incidence rate increased by 19.6% from 2008 to 2011.[1] The age-adjusted incidence rate has increased steadily, and in 2011, it reached 74.63 new cases per 100,000 people.[2] Because of the relative success of cancer screening programs, early detection and timely and appropriate treatment yield a more favorable prognosis for patients with breast cancer than for patients with most other types of cancer. Breast cancer is the fourth leading cause of deaths due to cancer in Taiwanese women, with a mortality rate of 11.45 per 100,000 people in 2011.[2]

Postoperative adjuvant radiotherapy (RT) plays a crucial part in the locoregional management of breast cancer. Nowadays, breast-conservation therapy is preferred for T1, T2, and selected T3 tumors[3,4] involving breast-conserving surgery, followed by 6 to 7 weeks of daily radiation treatments for the entire breast. RT is an essential component of breast-conservation therapy. However, it is inevitable that the skin receives a high radiation dose in the RT field. The skin is relatively radiosensitive and tends to exhibit various degrees of damage after certain radiation doses.[5] Therefore, the appearance of radiation dermatitis in the RT field of breast cancer is expected. Maintaining radiation-induced skin toxicities as low as possible, while providing the intended dose to the underlying breast, remains a challenge.[6] Accurately estimating skin doses provides a guide for predicting the location and severity of RT-induced skin reactions in patients with breast cancer.

Little information is available regarding accurate skin doses because of its uncertainty.[7,8] The skin irradiated dose is observable on the isodose curve distribution by using the RT treatment planning system (TPS), the results of which enable approximation of the location of the highest–skin dose area. Nevertheless, estimating a skin dose accurately is difficult because megavoltage x-ray beams exhibit the well-known phenomenon of dose buildup within the first few millimeters of the incident body surface,

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which is the skin. However, appropriately measuring a skin dose during radiation may overcome this problem, and thermoluminescent dosimeter (TLD) measurement has been reported to be a suitable method for providing reliable dose data.[9] In a previous study, we suggested that the location of the highest–skin dose area predicted using the TPS may adequately reflect the severe skin reaction area in some treatment areas.[10] We designed the current study to measure skin doses using the TLD and to locate the highest–skin dose area in each patient. We compared the results with the highest-dose area located using the TPS to ascertain the consistency between the 2 methods and to determine whether the skin dose shown using the TPS is an alternative, reliable approach for estimating the highest–skin dose area.

Methods and Materials

Patients

Between January 2013 and October 2013, 80 consecutive patients with breast cancer who had received breast-conserving surgery and were referred to our department for postoperative adjuvant RT were evaluated. The eligibility criteria were patients with pathologically proven primary breast carcinoma, curative intent for RT, and the ability of the patients to raise their arms steadily when immobilized during daily RT. There was no age limitation. This study was approved by the Institutional Review Board at Kaohsiung Armed Forces General Hospital and the patient's written consent had been obtained before the study process.

Treatment planning

The patients received computed tomography (CT) simulation by the Philips AcQSim CT simulator with a customized immobilization cast. Treatment planning was conducted by implementing the ADAC Pinnacle TPS. The clinical target volume included the ipsilateral breast and possible axillary lymph nodes (LNs). RT for internal mammary chain LNs or ipsilateral supraclavicular LNs (SCLNs) or both was reserved for cases with a high risk of tumor recurrence in those areas. The planning target volume was the clinical target volume with an extension of 0.5- to 1-cm margins. Opposed tangential fields on megavoltage linear accelerators with a 3-dimensional conformal RT technique were used to cover the breast, axillary LNs (except for Stage 0 cases), and possible ipsilateral internal mammary LNs. To spare as much of the larynx and upper esophagus as possible, an anterior-posterior field with a tilt of 10° to 15° was used to cover the supraclavicular fossa when targeting the ipsilateral SCLNs. The beam energy was 6 MV. Treatment plans were designed to deliver the prescribed dose to the target volumes with consideration of normal tissue constraints. A collapsed cone convolution algorithm was used for the calculation with the TPS. The prescribed dose for the planned target volume is 50.4 Gy in 28 fractions, and an additional breast surgical-scar boost of 10.8 Gy in 6 fractions using an electron beam is reserved for cases with high risk.[11] Electron energy was chosen to deliver 90% of the prescribed dose to the tumor bed.

The highest–skin dose area estimated using the TPS

For each patient, the isodose distribution was analyzed and the maximum dose location on the isodose curve of treatment planning in the ADAC Pinnacle TPS was observed (Fig. 1). The nearest overlying skin was assumed to be the location with the highest skin dose. The RT field was divided into 3 areas: the main breast area (B), inframammary area (I), and axillary area (A) (Fig. 2). It was then determined to which area the highest skin dose belonged (B, I, or A). In addition, the location of the maximum dose was defined as either close to the skin surface (depth is less than 1 cm from the skin surface) or deep seated (depth is 1 cm or more from the skin surface).

TLD measurement

Standard LiF TLD-100H chips (Harshaw/Thermo Fisher Scientific Inc., MA) of 3.2 mm × 3.2 mm × 0.9 mm were used in this study. The absolute dose of TLD chips was calibrated by applying Varian LINAC iX, using a 6-MV beam. A calibrated Farmer-type ionization chamber was used to confirm the output of LINAC and to ensure that the outputs were within 0.5%. The TLD chips used in this study were irradiated and screened 3 times until the uncertainties were within ± 3%. After screening, the qualified TLD chips were placed inside a Solid Water phantom at a depth of 5 cm, and the output from 46.25 to 212.75 cGy was applied to perform the calibration experiment. The calibration equation was created and the linear-square correction curve was found to be highly linear ($R^2 = 0.9845$; Fig. 3). All of the measurements were repeated at least 3 times to reduce the number of statistical errors. The readouts were obtained using a Harshaw TLD 5500 Automatic TLD reader (Bicron RMP), after which the chips were annealed at 240°C for 15 minutes and cooled at an ambient temperature. The chips were cooled to room temperature before irradiation.

Thereafter, 3 qualified TLD chips were positioned at each part (B, I, or A) of the patient's skin surface during a single RT treatment (Fig. 4). To ensure that the TLD chips placed were near the location where the maximum dose was estimated using the TPS, the highest-dose region shown in the TPS was recorded and the TLD chips were placed subsequently in correspondence of that area. Overall, 9 TLD chips were collected from each patient. The reading process consisted of a preheat at 100°C for 15 seconds, followed by the heating protocol with the temperature increasing linearly at 10°C per second to a maximal temperature of 260°C, which was then maintained constant. The photomultiplier signal was recorded during the linear-heating phase and at the maximal temperature for a total acquisition time of 30 seconds. The mean skin dose of each area was calculated to determine the highest–skin dose area.

Other patient and tumor characteristics

The demographics and lesion characteristics of each patient were documented, including age, body mass index (BMI), breast size (represented by bra cup size), lesion side and stage, and the treatment field coverage of SCLNs.

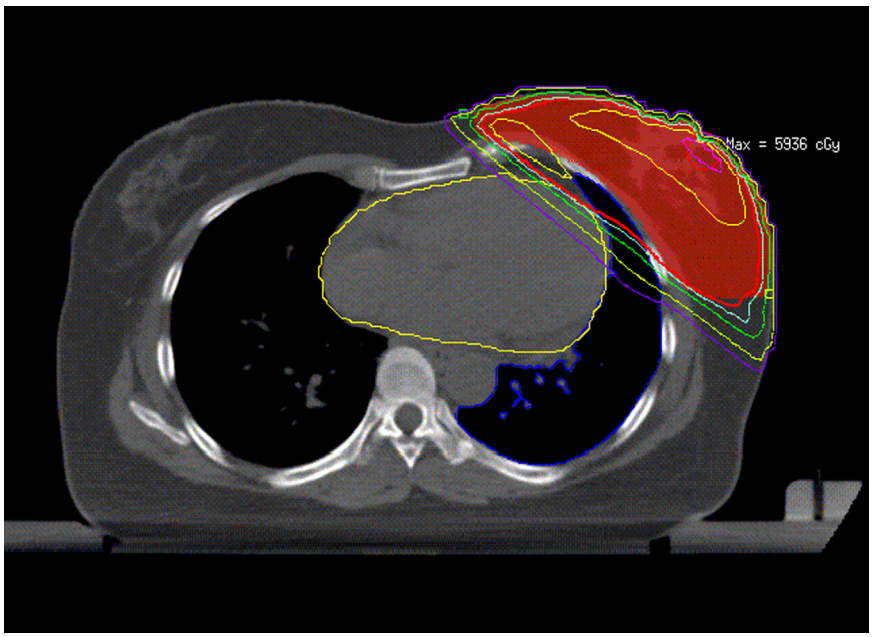

Fig. 1. One slice of CT scan illustrates the isodose distribution of a patient receiving left breast RT after BCS. It shows that the maximum dose (5936 cGy) is located in the breast and close to the skin surface. BCS = breast-conserving surgery. (Color version of figure is available online.)