Radiotherapy and Oncology 93 (2009) 87–93

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Breast cancer radiotherapy

The influence of the use of CT-planning on the irradiated boost volume in breast conserving treatment

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ARTICLE INFO

Article history:
Received 20 January 2009
Received in revised form 14 April 2009
Accepted 2 May 2009
Available online 8 June 2009

Keywords:
Breast cancer
Radiotherapy
Boost volume
Breast conserving therapy
Boost

ABSTRACT

Background and purpose: The purpose of this study was to investigate the effect of CT-based delineation and planning on the irradiated boost volume. For this specific purpose we used the data as derived from 2 prospective phase III randomised trials.

Patients and methods: Data from 1331 patients (⩽50 years) were analyzed with a reported boost volume from a simulation-based treatment plan (EORTC boost vs no boost trial, $n = 922$), and a CT-scan-based treatment plan (Young Boost Trial, $n = 409$) group. Tumour diameter, irradiation technique (photons vs electrons), lumpectomy size, and age were used as covariates.

Results: Median $V_{95\%}$ in the conventional simulation-based treatment plans was 99 cc (range 9–628) for photons and was 98 cc (13–651) for electrons, whereas in the CT-planned patients, these figures were 178 cc (37–2699) and 150 cc (43–1272), respectively. Multivariable analysis showed an association of the irradiated boost volume with tumour size ($p < 0.0067$), lumpectomy size ($p < 0.0002$), and boost technique ($p < 0.0004$). The use of a CT-scan for volume delineation and treatment planning remained significant ($p < 0.0001$).

Conclusions: The use of a CT-scan for delineation and treatment planning led to a significant increase of the irradiated boost volume by a factor of 1.5–1.8, compared to conventional simulator-based plans.

In the EORTC boost vs no boost trial (EORTC), a boost radiation dose of 16 Gy after whole breast irradiation in breast conserving therapy (BCT) reduced the local recurrence rate approximately by a factor 2 [1–8]. In this trial the radiation portals were conventionally set with a simulator [9].

Since the local recurrence rate was nevertheless quite high in young patients (8% at 5 years in the age group ⩽50 years), a prospective randomised multi-centre trial was started in the Netherlands, where the effect of a further increase of the boost dose (from 16 to 26 Gy) is being investigated in patients ⩽50 years (Young Boost Trial, YBT). In this trial, the use of CT-based volume delineation and treatment planning to define the radiation fields is strongly recommended. This procedure was gradually adopted by all participating centres within the first 2 years of patient accrual.

The inaccuracy of the surgical scar and palpable indurations as landmarks for defining the boost region and the importance of the use of surgical clips and a CT-scan for the definition of the tumour bed were reported already more than 15 years ago [10,11].

It was recently suggested that the use of CT-based volume delineation and treatment planning results in a larger irradiated boost volume [12,13]. This larger boost volume may however unnecessarily increase the risk of side effects especially with a higher boost dose [8,14,15]. Therefore, we studied the effect of the use of CT-based volume delineation and treatment planning on the irradiated boost volume using the data of both randomized trials.

Moreover, Bauduceau et al. reported on the importance of the use of CT data to reach an optimal coverage of the PTV in whole breast irradiation as well [16].

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doi:10.1016/j.radonc.2009.05.002

Patients and methods

From 1989 to 1996, the EORTC trial 22881/10882 accrued 5318 patients with stage I and II breast cancer patients, whose tumours had been microscopically completely excised (as judged by local pathology examination). These patients were randomised to receive 50 Gy whole breast irradiation with ($n = 2661$) or without ($n = 2657$) a boost dose of 16 Gy to the primary tumour bed. The patients were treated in 31 institutions from 9 countries [1]. From this group, patients $\leqslant$50 years old who received a boost dose to the primary tumour bed with a photon or electron beam technique and for whom the irradiated boost volume ($V_{50\%}$) was reported ($n = 944$), were selected for this study.

In the EORTC trial, the boost clinical target volume (CTV) was defined as a rim of tissue around the original tumour excision area (tumour bed). The tumour bed was defined using information from physical examination, mammography, the surgical report, the scar and, if present, surgical clips. The field margins of the boost fields were set with a safety margin of 1.5 cm around the tumour bed in the case of a microscopic complete excision and of 3 cm if an extensive intraductal component was present. For photons, the boost dose was specified at the centre of the tumour excision area. For electrons, the dose was specified at the depth of dose maximum with the 85% isodose encompassing the target volume. The boost volume irradiated to at least 50% of the prescribed dose ($V_{50\%}$), coinciding with the field borders, had to be reported. The formulae used to calculate the $V_{50\%}$ of the boost volume was boost technique dependent:

$$\text{For a direct electron field, } V_{50\%} = X * Y * \text{ depth } 85\% \text{ isodose} \quad (1)$$

$$\text{For 2 tangential photon fields, } V_{50\%} = (X * Y * Z)/2 \quad (2)$$

$$\text{For a wedged pair or } > 2 \text{ photon fields, } V_{50\%} = X * Y * Z, \quad (3)$$

where X is the field length in craniocaudal direction, Y is the field width, and Z is the diameter of the breast in the plane of the dorsal field edge (Fig. 1).

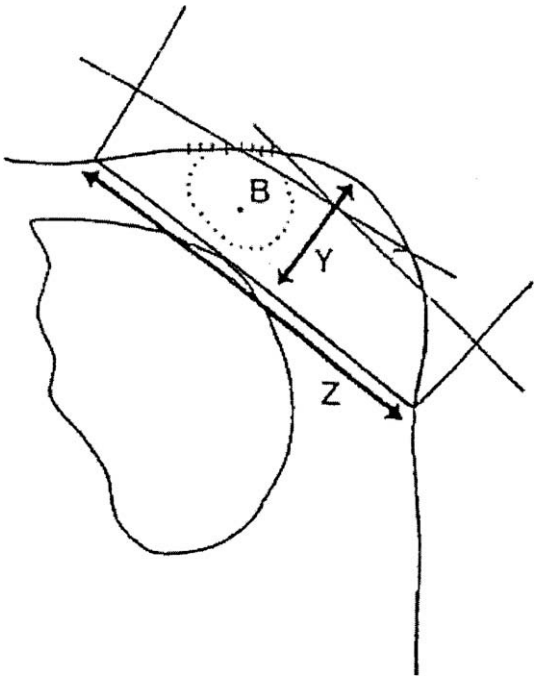

Fig. 1. Calculation of $V_{50\%}$ based on equation in protocol: tangential boost level: $(X * Y * Z)/2$ (X = cc direction).

The YBT trial started in 2004 and is ongoing. Patients with stage T1-2N0-2aM0 invasive breast cancer, age $\leqslant$50 year, and with a microscopically complete tumourectomy (focally involved margins are allowed) are eligible for participation. After whole breast irradiation of 50 Gy, patients are randomised to a boost dose of 16 or 26 Gy. The randomization is stratified for age, tumour size, lymph node involvement, oestrogen receptor status, interstitial/external boost, and participating institute. As of January 2008, 816 patients had been included and randomised. For the present analysis we selected only 409 patients receiving a CT-based planned boost dose to the primary tumour bed by a photon or electron beam technique for whom the irradiated boost volume ($V_{95\%}$) was reported.

The CTV of the boost area was also defined as the rim of tissue 1.5 cm around the original tumour. Attempt should be made to reconstruct this 1.5 cm rim of tissue using as much information as available, including clinical examination before and after surgery, preoperative mammography, surgical reports describing the tumour site, surgical marker clips if present, and the scar (including post-operative effects visible on CT-scan). The boost CTV was not to be extended beyond the palpable or visible breast tissue, neither into the skin (excluding 5 mm beneath the skin) nor into the underlying muscle or thoracic wall. In case of external beam irradiation an additional margin of 0.5 cm was added to take set-up errors into account (PTV).

In the YBT trial, the boost volume receiving at least 95% of the prescribed dose ($V_{95\%}$) has to be documented. If CT-based 3D-planning and volume calculation are not performed, the $V_{95\%}$ of the boost is calculated according to the same formulae as in the EORTC trial, but subtracting 1 cm from the field sizes, to estimate the $V_{95\%}$ instead of the $V_{50\%}$:

$$\text{For a direct electron field, } V_{95\%} = (X-1) * (Y-1) * \text{depth } 85\% \quad (4)$$

$$\text{For 2 tangential photon fields, } V_{95\%} = (X-1) * (Y-1) * (Z-1)/2 \quad (5)$$

$$\text{For a wedged pair or } > 2 \text{ photon fields, } V_{95\%} = (X-1) * (Y-1) * (Z-1) \quad (6)$$

where X is the field length in craniocaudal direction, Y is the field width, and Z is the diameter of the breast at the dorsal field edge (Fig. 1).

Recalculating of $V_{50\%}$–$V_{95\%}$

As the boost volumes were documented differently in the 2 trials ($V_{50\%}$ vs $V_{95\%}$), we developed and validated a recalculation model to convert the $V_{50\%}$ reported in the EORTC trial into the $V_{95\%}$ as reported in the YBT, enabling a comparison between the 2 groups:

In the case of an electron boost, we considered the field in the EORTC trial as being a square ($X = Y$). The 85% PDD depth was assumed to be equal to 1/3 of the nominal electron energy (E_{nominal}). Substituting this in Eq. 1, we get:

$$X = (V_{50\%} \times 3/E_{\text{nominal}})^{\frac{1}{2}}$$

From this, $V_{95\%}$ can be derived using Eq. 4.

In the case of 2 tangential photon fields or for the wedged pair or >2 field photon techniques, we considered the field in the EORTC trial as cubic (Fig. 4) ($X = Y = Z$). $V_{95\%}$ can then be calculated combining Eqs. 2 and 5 and Eqs. 3 and 6, respectively.

We validated these formulae using the 3D dose calculation data of 20 patients with known field sizes and volumes who received a boost using 2 tangential fields, and of whom $V_{50\%}$ was at most 200 cm^3, as almost no volumes above this level were reported in the EORTC trial (Table 2). This resulted in similar volumes. Therefore, in our final analysis the good linear fit ($R^2 = 0.90$) of the $V_{95\%}$ as a function of the $V_{50\%}$ based on the data from these 20 patients was used (Fig. 2).