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Original article

Effects of online cone-beam computed tomography with active breath control in determining planning target volume during accelerated partial breast irradiation

Effet de la tomographie conique avec contrôle actif de la respiration sur la planification du volume cible prévisionnel durant la radiothérapie accélérée partielle du sein

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ABSTRACT

Purpose. – To test if active breath control during cone-beam computed tomography (CBCT) could improve planning target volume during accelerated partial breast radiotherapy for breast cancer.
Methods. – Patients who were more than 40 years old, underwent breast-conserving dissection and planned for accelerated partial breast irradiation, and with postoperative staging limited to T1-2 N0 M0, or postoperative staging T2 lesion no larger than 3 cm with a negative surgical margin greater than 2 mm were enrolled. Patients with lobular carcinoma or extensive ductal carcinoma in situ were excluded. CBCT images were obtained pre-correction, post-correction and post-treatment. Set-up errors were recorded at left-right, anterior-posterior and superior-inferior directions. The differences between these CBCT images, as well as calculated radiation doses, were compared between patients with active breath control or free breathing.
Results. – Forty patients were enrolled, among them 25 had active breath control. A total of 836 CBCT images were obtained for analysis. CBCT significantly reduced planning target volume. However, active breath control did not show significant benefit in decreasing planning target volume margin and the doses of organ-at-risk when compared to free breathing.
Conclusion. – CBCT, but not active breath control, could reduce planning target volume during accelerated partial breast irradiation.

Mots clés :
Volume cible prévisionnel
Tomographie conique
Contrôle actif de la respiration
Irradiation partielle accélérée du sein
Chirurgie conservatrice du sein
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RÉSUMÉ

Objectif de l'étude. – Étudier si le contrôle actif de la respiration lors de la tomographie par faisceau conique (CBCT) pourrait améliorer la planification du volume cible prévisionnel au cours du traitement du cancer du sein par irradiation partielle accélérée.
Matériel et méthodes. – Les patientes enrôlées dans cette étude étaient âgées de plus de 40 ans. Une irradiation partielle accélérée du sein était prévue après une chirurgie conservatrice pour un cancer pT1-2 pN0 M0 d'au plus 3 cm et une marge chirurgicale saine de plus de 2 mm. Les patientes atteintes d'un carcinome lobulaire ou d'un carcinome canalaire in situ de grande taille ont été exclues de l'étude.

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Les tomographies coniques ont été obtenues avant correction, après correction et après le traitement. Les erreurs engendrées ont été enregistrées dans les directions gauche–droite, antéropostérieure et tête–pieds. Les différences entre les tomographies coniques ainsi que les doses de radiation calculées ont été comparées entre les patientes avec contrôle actif de la respiration et celles avec respiration libre.
Résultats. – Quarante patientes ont été inscrites dans le protocole, dont 25 avec contrôle actif de la respiration. Un total de 836 tomographies coniques a été obtenu pour l'analyse. La tomographie conique a conduit à une réduction significative du volume cible prévisionnel tandis que le contrôle actif de la respiration n'a pas montré un avantage important dans la diminution de la marge du volume cible prévisionnel et les doses délivrées aux organes à risque comparativement au groupe de patientes avec respiration libre.
Conclusion. – La tomographie conique, mais pas le contrôle actif de la respiration, pourrait réduire le volume cible prévisionnel au cours d'un traitement du cancer du sein par irradiation partielle accélérée.

1. Introduction

Breast cancer is the most common invasive cancer in women worldwide [1]. Radiation therapy is an essential component of comprehensive breast cancer treatments. Traditionally, after breast-conserving dissection for patients with early breast cancer, whole breast irradiation with tumor bed boost radiotherapy was the widely accepted standard radiation approach [2]. However, this irradiation approach requires long treatment duration and high health care cost, with more frequent side effects, unsatisfactory cosmetic results and poor patient compliance [3]. Several other radiation approaches have been proposed and studied.

One of these radiation approaches is accelerated partial breast irradiation, which focuses the irradiation to the tumor bed and adjacent tissues. With accelerated partial breast irradiation, a higher dose of radiation is delivered to the small area of tumor bed in a relatively short period of time. Prospective studies have demonstrated that patients who received accelerated partial breast irradiation had similar 10-year survival and distant metastatic risk, with fewer side effects, when compared to those received traditional whole breast irradiation with tumor bed boost radiotherapy [4,5]. Therefore, accelerated partial breast irradiation has become an important irradiation strategy in the breast cancer treatment. However, accelerated partial breast irradiation is usually targeted to a small tumor bed. This requires accurate localization and determination of tumor target volume in the breast [6].

Difficulty in localizing tumor tissue has been related to several factors, including patients' respiratory motion, movements during and between treatments, set-up errors and the position of the surgical clips [7,8]. Traditional imaging methods could provide limited solutions to overcome these difficulties. Recently, a new imaging technique, cone beam-computed tomography (CBCT), has been developed and can provide real time accurate positioning of targeted tissue. Several studies have been published and showed promising application of CBCT in breast cancer irradiation therapy [9,10]. However, more studies are needed.

The position of breast tissue may shift with the respiration movements [11]. During whole breast irradiation therapy, active breath control has been successfully applied to reduce the planning target volume (PTV) margins [12]. However, active breath control has not been well studied in the setting of accelerated partial breast irradiation.

In the current study, we investigated the PTV margins during accelerated partial breast irradiation by CBCT scans. We compared the PTV between active breath control and free breath and reported our results here.

2. Methods and materials

2.1. Study design and patient population

The study was a prospective observational study performed at the Sichuan University West China Hospital from August 2012 to September 2013. The study protocol was approved by the hospital ethics committee and all the study participants signed the informed consent. Inclusion criteria included:

- age over 40 years old;
- received breast-conserving dissection and planned for accelerated partial breast irradiation;
- postoperative staging limited to T1-2 N0 M0;
- for postoperative staging T2, a lesion no larger than 3 cm with a negative surgical margin greater than 2 mm was required.

Exclusion criteria included:

- lobular carcinoma;
- extensive ductal carcinoma in situ;
- refusal to sign the informed consent.

2.2. Study protocol

Every patient received intensity-modulated radiation therapy (IMRT). Clinical target volume (CTV) 1 was defined as the area expanding 1 cm circumferentially out from the area labelled by the clips and CTV2 was defined as the area expanding 1 cm out from CTV1. Based on the protocol from tumor bed boost irradiation, the total dose to CTV1 was 48 Gy/12 fractions/16 days (i.e. a dose per fraction is 4 Gy) [13]. The total dose to CTV2 was 41.6 Gy/12 fractions/16 days (i.e. a dose per fraction is 3.47 Gy). PTV was generated to account for set-up uncertainties and organ motion by 10 mm automatic expansion of the CTV [14]. The treatment planning for accelerated partial breast irradiation was evaluated according to RTOG-0319 [15].

Patients were positioned on the Aktina Axion 1^{tm}shelf in the supine position. The first (pre-correction) CBCT was acquired after patient positioning and aligned to the planning CT. A second CBCT (post-correction) was acquired to verify the confidence of correction. A third CBCT (post-treatment) was obtained to assess the intrafraction error. The CBCT images were obtained with 120 kV, 647 mAs, 3.18°/s, 5.5 frames/s and at least 200 frames were acquired. The gross tumor volume (GTV) contour on the planning CT was matched to the clips in the breast on CBCT. Then,